Essays on Risk Management in Times of Deepening Economic Inequality

Von der Wirtschaftswissenschaftlichen Fakultät der
Gottfried Wilhelm Leibniz Universität Hannover
zur Erlangung des akademischen Grades

Doktor der Wirtschaftswissenschaften
– Doctor rerum politicarum –

genehmigte Dissertation
von

M.Sc. Miguel Angel Rodriguez Gonzalez

geboren am 19. September 1986 in Peine

2021

Referent: Professor Dr. J.-Matthias Graf von der Schulenburg
Ko-Referent: Professor Dr. Jens Robert Schöndube

Tag der Promotion: 27. April 2021

Für meine Eltern

Table of Contents

Zusammenfassung

Die vorliegende Arbeit untersucht unterschiedlichste finanzielle Risiken im Rahmen der empirischen Wirtschaftsforschung und diskutiert die mögliche Wechselbeziehung zwischen diesen Risiken und verschiedenen Aspekten sozialer bzw. ökonomischer Ungleichheit. Dabei wird insbesondere die Notwendigkeit angemessener Risikomanagementmaßnahmen betont, um negative Effekte der einen Größe auf die Andere zu verhindern oder zu minimieren. Beispielhaft werden hierzu wichtige Übertragungskanäle zwischen Risiko und Ungleichheit – sowohl auf mikro- als auch auf makroökonomischer Ebene – vorgestellt und positive Effekte durch Risikomanagementmaßnahmen auf individueller, institutioneller und staatlicher Ebene diskutiert.

Insgesamt umfasst die kumulative Dissertation elf Forschungsarbeiten – zehn empirische Aufsätze und eine Literaturübersicht. Der geographische Fokus liegt dabei vorwiegend auf hochentwickelten Industrieländern. Aus diesem Grund werden Teilanalysen für einige der weltweit führenden Volkswirtschaften durchgeführt: die USA, Deutschland, das Vereinigte Königreich und ausgewählte Mitgliedsländer der Europäischen Währungsunion, eingeteilt in Kern- und Peripheriestaaten. Ausgehend von unterschiedlichen finanziellen Risiken auf der Mikro- und Makroebene sind die elf Module in vier Forschungscluster untergliedert:

- Der erste Cluster zeigt Zusammenhänge von Risiko und Ungleichheit innerhalb des deutschen Rentensystems auf. In diesem Kontext werden insbesondere das Invaliditätsrisiko und die bevorstehenden Finanzierungsprobleme innerhalb der gesetzlichen Rentenversicherung näher betrachtet. (Module 1-2)
- Der zweite Cluster hebt Ungleichheit als einen wesentlichen Treiber der Globalen Finanzkrise hervor und betont insbesondere die Bedeutung eines vorausschauenden Risikomanagements im Immobiliensektor. (Module 3-6)
- Der Dritte Cluster diskutiert Aspekte der Ungleichheit in der Europäischen Witschaftsunion, bedingt durch unterschiedliche Kreditrisiken der Mitgliedsländer bei einer gleichzeitig einheitlichen Geldpolitik, und betrachtet dabei die Zeit um die Europäische Staatsschuldenkrise. (Module 7-9)
- Der vierte Cluster präsentiert einige Gedanken zum Zusammenhang zwischen privater Versicherungsaktivität und Ungleichheit. (Module 10-11)

Zusammenfassend veranschaulicht diese Arbeit die Notwendigkeit eines angemessenen Risikomanagements, um den Effekt zunehmender Ungleichheit aufgrund steigender finanzieller Risiken (oder vice versa) zu beeinflussen. Da diese dynamischen Entwicklungen von Politik und Regulierungsbehörden allein nur schwer zu kontrollieren sind, gewinnt weitere Forschung in diesem Bereich – insbesondere in Zeiten einer ansteigenden wirtschaftlichen Ungleichheit – zunehmend an Bedeutung.

Schlagwörter: Angewandte Ökonometrie, Finanzmärkte, Risikomanagement.

Abstract

This thesis examines various types of financial risk in the context of empirical economic research and discusses the potential interrelationship between these risks and various aspects of social or economic inequality. In particular, the need for appropriate risk management measures is emphasized to prevent or minimize negative effects of the two variables on each other. Exemplarily, important transmission channels between risk and inequality at micro- and macroeconomic levels are presented and positive effects through risk management measures at the individual, institutional, and governmental level are discussed.

This cumulative dissertation contributes a total of eleven research papers on risk management issues – ten empirical essays and a literature review. The geographical scope of this thesis is predominantly on highly developed industrialized countries. For this reason, sub-analyses are conducted for some of the world's leading economies: the United States, Germany, the United Kingdom, and selected European Monetary Union 'core' and 'non-core' member countries. Basically, the eleven modules are organized into four research clusters, based on different financial risks at micro- and macroeconomic levels:

- The first cluster shows linkages of risk and inequality within the German pension system. In particular, the invalidity risk and impending funding problems within the statutory pension system will be examined. (Module 1-2)
- The second cluster highlights inequality as a major driver of the Global Financial Crisis and emphasizes, in particular, the importance of a forward-looking risk management in the real estate sector. (Module 3-6)
- The third cluster discusses aspects of inequality in the European Economic Union, caused by different credit risks of the member countries in a simultaneous single monetary policy, focusing mainly on the period around the European Sovereign Debt Crisis. (Module 7-9)
- The fourth cluster presents some thoughts on the linkage between private insurance activity and inequality. (Module 10-11)

In summary, this thesis illustrates the need for appropriate risk management to prevent inequality from rising due to higher financial risks (or vice versa). Since those dynamic developments are difficult to control by politics and regulatory authorities alone, the importance of research on risk management issues further increases – in particular in times of deepening economic inequality.

Keywords: Applied Econometrics, Financial Markets, Risk Management.

Outline of Modules

Cluster	Module
I. German Pension System	1: Rodriguez Gonzalez, M. / Lohse, R. / Schröder, M. / Krohn, S. / Zuchandke, A. (2015). Sozioökonomische Analyse des Erwerbsminderungsrisikos – Eine Untersuchung anhand von BASiD-Daten, published in: *Zeitschrift für die gesamte Versicherungswissenschaft, Vol. 104, No. 2, pp. 151-178. DOI: https://doi.org/10.1007/s12297-015-0300-3.* 2: Vanella, P. / Rodriguez Gonzalez, M. / Wilke, C. (2021). The Impact of Population Aging on the German Statutory Pension System – A Probabilistic Approach, published in: *Hannover Economic Papers (HEP), No. 688.*
II. Global Financial Crisis	3: Meier, S. / Rodriguez Gonzalez, M. / Kunze, F. (2021). The Global Financial Crisis, the EMU Sovereign Debt Crisis and International Financial Regulation: Lessons from a Systematic Literature Review, published in: *International Review of Law and Economics, Vol. 65. DOI: https://doi.org/10.1016/j.irle.2020.105945.* 4: Rodriguez Gonzalez, M. / Basse, T. / Kunze, F. / Vornholz, G. (2018). Early Warning Indicator Systems for Real Estate Investments: Empirical Evidence and some Thoughts from the Perspective of Financial Risk Management, published in: *Zeitschrift für die gesamte Versicherungswissenschaft, Vol. 107, No. 4, pp. 387–403. DOI: https://doi.org/10.1007/s12297-018-0426-1.* 5: Kunze, F. / Basse, T. / Rodriguez Gonzalez, M. / Vornholz, G. (2020). Forward-Looking Financial Risk Management and the Housing Market in the United Kingdom: Is there a Role for Sentiment Indicators?, published in: *The Journal of Risk Finance, Vol. 21, No. 5, pp. 659–678. DOI: https://doi.org/10.1108/JRF-10-2019-0191.* 6: Rodriguez Gonzalez, M. / Basse, T. / Saft, D. / Kunze, F. (2021). Leading Indicators for US House Prices: New Evidence and Implications for EU Financial Risk Managers, published in: *European Financial Management. DOI: https://doi.org/10.1111/eufm.12325.*

Outline of Modules (cont'd)

Cluster	Module
III. European Sovereign Debt Crisis	7: Rodriguez Gonzalez, M. / Kunze, F. / Schwarzbach, C. / Dieng, C. (2017). Asset Liability Management and the Euro Crisis – Sovereign Credit Risk as a Challenge for the German Life Insurance Industry, published in: *The Journal of Risk Finance, Vol. 18, No. 4, pp. 466–483. DOI: https://doi.org/10.1108/JRF-01-2017-0016.* 8: Tholl, J. / Basse, T. / Meier, S. / Rodriguez Gonzalez, M. (2021). Risk Premia and the European Government Bond Market: New Empirical Evidence and some Thoughts from the Perspective of the Life Insurance Industry, published in: *Zeitschrift für die gesamte Versicherungswissenschaft. DOI: https://doi.org/10.1007/s12297-021-00503-2.* 9: Rodriguez Gonzalez, M. / Basse, T. / Tholl, J. (2019). Interest Rate Differentials and Monetary Policy in the European Monetary Union: The Case of 10 and 30 Year Bonds, published in: *Zeitschrift für die gesamte Versicherungswissenschaft, Vol. 108, No. 1, pp. 19–42. DOI: https://doi.org/10.1007/s12297-019-00434-z.*
IV. Insurance	10. Rodriguez Gonzalez, M. / Wegener, C. / Basse, T. (2021). Re-Investigating the Insurance-Growth Nexus Using Common Factors, published in: *Finance Research Letters. DOI: https://doi.org/10.1016/j.frl.2021.102231.* 11. Wrede, D. / Linderkamp, T. / Rodriguez Gonzalez, M. (2017). Risks of the German Power Supply System Difference between Risk Assessments from the Insurance Industry and Energy Technicians, published in: *Zeitschrift für Energiewirtschaft, Vol. 41, No. 2, pp. 105–117. DOI: https://doi.org/10.1007/s12398-016-0191-6.*

Essays on Risk Management in Times of Deepening Economic Inequality

> "Financial theory is about risk management. And risk management ought to reduce inequality. That's the idea, right? If you effectively pool the risks, then the random shocks that affect people differently will go down."
> — Robert J. Shiller, Sterling Professor of Economics, Yale University, 2011.

From Engels to COVID-19: What about Risk and Inequality?

Friedrich Engels, born in 1820 into a time of fundamental economic transition, would recently have celebrated his 200th birthday. Despite being a very successful entrepreneur during the First Industrial Revolution, Engels (together with Karl Marx) simultaneously became a leading critic of the classical political economy. Basically, in Marxian dogma the economic liberalism may be reduced to two main arguments: The problem of a recurring risk of systemic breakdowns and social inequality due to economic exploitation of low-skilled labor force. Even though Marxism has clearly not proven to be the 'cure', its intellectual dogma on inequality, however, still becomes the focus of academic and political debates. For example due to the consequences of major financial crises since the beginning of this millennium – such as the bursting of the Internet bubble in 2000, the Global Financial Crisis (GFC) in 2007, or the European Sovereign Debt Crisis (ESDC) in 2010 – and, more recently, because of the consequences of the COVID-19 pandemic. Especially since the financial crash of 2008, leading economists have increasingly focused on the correlation between social inequality and the emergence of negative economic and financial shocks. The book 'Capital in the 21st Century' by the economist Thomas Piketty became an international bestseller and focused attention on the issue of rising inequality in industrialized countries (Piketty, 2013). According to his research, today's inequality stems from ideology and politics, and not technology, as the Marxist school of thought mainly argues. Nevertheless, both conclude, that increasing disproportionality of capital and labor leads to financial crashes. As the introductory quote of Robert J. Shiller suggests, in order to prevent further increasing effects on social inequality, appropriate risk management tools are needed.

This work focuses on the relationship between inequality and different types of risk in the context of the current scientific debate, and provides preliminary anecdotal evidence of how risk management measures can potentially influence this relationship. For this purpose, after outlining some current

trends in global income and wealth distributions, this work discusses how the author's research fits into the context of economic and social inequality. While highlighting the possibilities of risk management to mitigate negative economic or social shocks at individual, institutional and governmental level, the findings of eleven research papers are presented in this context. The topics in this dissertation are tackling issues on risk, as well as financial risk management, but might be also connected to increasing inequality in income and wealth distributions in countries like the United States (U.S.), United Kingdom (UK) and Germany. Čihák and Sahay (2020), for instance, describe the link of inequality and the risk of a financial crisis as some kind of 'vicious circle', since inequality can lead to a crisis, and its economic effects reinforce inequality. Accordingly, a mutual relationship of these aspects (as presented in Figure 1) is assumed. This 'inequality-risk nexus' serves as conceptual framework to organize the eleven modules of this work and highlights some major transmission channels on both, micro- and macroeconomic levels. Furthermore, since those dynamic developments are difficult to control by politics and regulatory authorities, it is argued that the importance of research on risk management issues increases – in particular in times of deepening economic inequality.

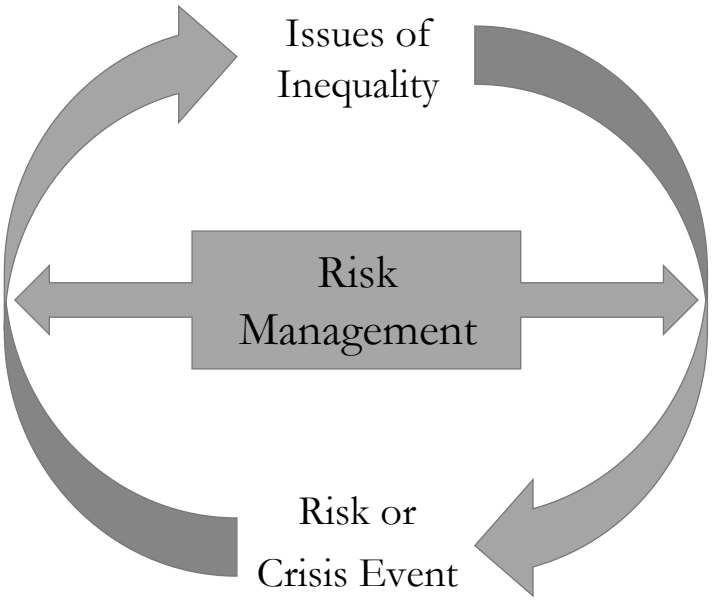


Figure 1. Schematic representation of the relationship between inequality and risks. Source: Own representation.

Undoubtedly, the debate on inequality has lately focused to the widening effects in income and wealth distributions in the light of the global SARS-CoV-2 pandemic. Even if it is not rooted in economic disproportionality of capital, this health crisis unambiguously illustrates the fundamental link between risks, issues of risk management, and economic or social inequality.[1] The outbreak of the Coronavirus Disease 2019 (COVID-19) and the massive political interventions into economic and private activity, revealed the enormous unequally distributed financial and social impacts on individual, institutional, and governmental level. In case of the U.S., due to the national lockdown

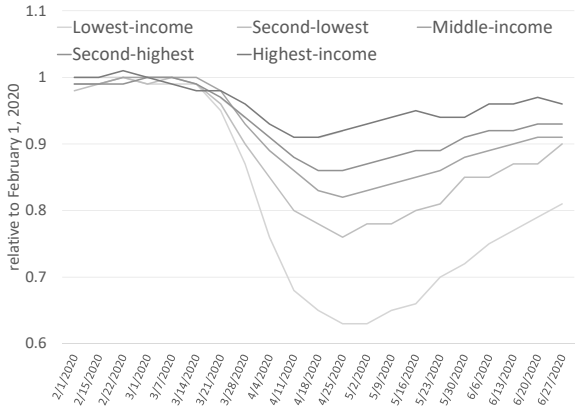


Figure 2. Relative change in U.S. employment.

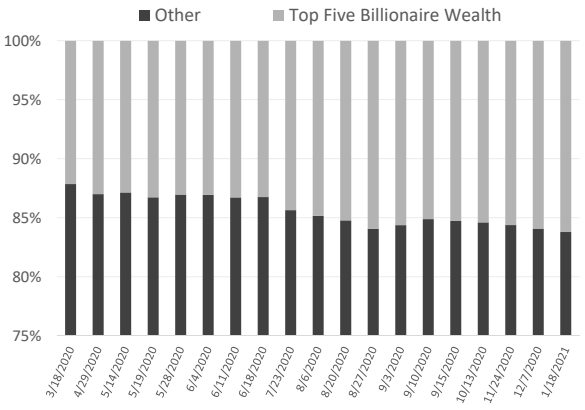


Figure 3. Top 5 billionaire wealth.

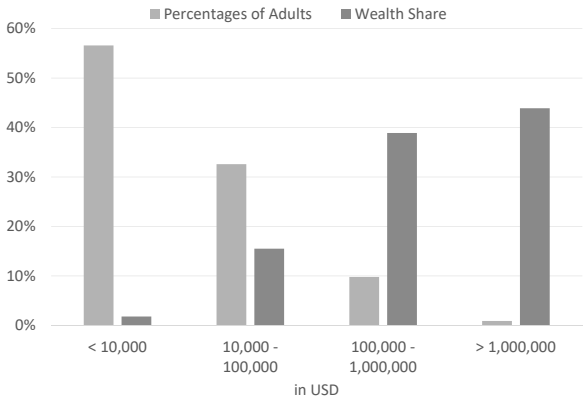


Figure 4. Global wealth inequality.

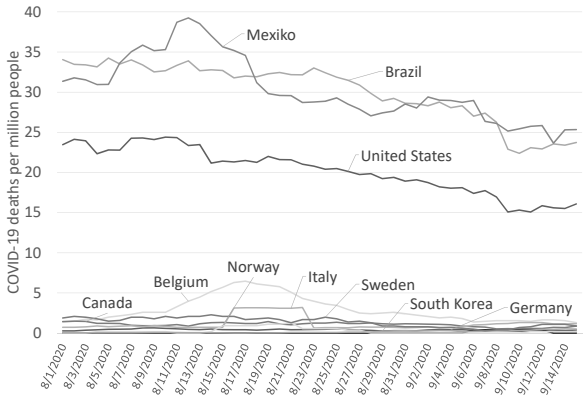


Figure 5. COVID-19 deaths and inequality.

Source: Own representations based on: `https://inequality.org/facts/`.

measures, especially low-wage industries are at risk of significant job cuts and income losses, while the five most affluent people on earth have experienced a tremendous increase in wealth (see Figures 2 and 3). Thus, not only various risks are unequally distributed among income classes, but the resulting shifts in wealth also foster increasing inequality in the global wealth distribution. Figure 4 shows the status quo of global wealth and population shares for a set of income groups indicating a high social inequality, since the wealthiest percent of the world population owns 44 % of total capital. On a personal level, these financial impacts are accompanied by other risks, such as higher health risks for socially disadvantaged ethnicities or higher risk of infection in low-income classes due to limited possibilities of self-isolation (see, for example, Abedi, Olulana, Avula, Chaudhary, Khan, Shahjouei, Li, and Zand, 2020). Fundamentally, while the effects of inequality are mostly individual risks, there is also evidence for more unequal societies being rather associated with social crises and other negative externalities that reduce, in particular, the available human and physical capital.[2] In case of the pandemic, Figure 5 shows the relationship between the proportion of deaths from COVID-19 in

relation to inequality measured per country. The graph indicates that especially more equal societies have implemented superior risk management measures to contain the pandemic in order to keep the health risk among the population low. According to this line of reasoning, reducing economic inequality should be an overall societal Pareto improvement. Therefore, inequality might be an issue being important from both, a micro- and a macroeconomic perspective, but also with respect to appropriate risk management measures.

While the liberal rationale of modern political economy legitimizes a certain degree of economic or social inequality by guaranteeing legal equality, increasing economic inequality also leads to more social conflicts. The rise of right-wing populist movements and intense political debates, in the UK, the European Union (EU) and the U.S., is often attributed to a growing public sentiment of social inequality. It is also not surprising that many protest movements on issues of inequality have been particularly prevalent in the U.S., where national income and wealth inequality has risen sharply since the 1980s (see also Figure 7). The most prominent movement opposing economic inequality in the last decade is probably the Occupy Wall Street movement in response to the GFC of 2007. While most banks were rescued through government bailouts, the American middle class suffered hard economic consequences following the collapse of the U.S. housing market, and thus, a widespread image of an unfair distribution of risk and financial losses emerged. Further, there is evidence that the unequal distribution of income and wealth was one of the key preconditions for the emergence of the U.S. housing bubble. Moreover, the globalization of finance raises the risk of financial and economic crises due to high contagion effects, which again implies the need for improving financial risk management and data science techniques to identify, assess, and manage future economic shocks and other possible negative effects resulting in, or from, unequal societies.

As illustrated above, there seems to be a need for proper risk management tools to control the interrelationship between economic shocks and inequality. A risk management measure, such as prevention or insurance, is able to reduce both, potential losses and loss probability. Therefore, risk management might be generally a tool to prevent or weaken the effects of social relegation, for instance by covering the risk of an income-reducing disability. This illustrates the usefulness of research on risk management practices that are directly and indirectly related to the 'vicious cycle' between past and potential crises and issues of economic or social inequality, both on a micro- and macroeconomic basis. Within this conceptual framework, the dissertation contributes a total of eleven scientific publications on risk management issues – ten empirical essays and a literature review. The modules focus on certain risks in the context of inequality or financial risk management. The geographical scope of this thesis is predominantly on highly developed industrialized countries. For this reason, sub-analyses are conducted mostly for some of the world's economically most important economies: the U.S., Germany, the UK, and some selected European Monetary Union 'core' and 'non-core' member countries. Basically, the eleven modules are organized into four research clusters, based on different financial risks at micro-

and macroeconomic levels:

- The first cluster shows linkages of risk and inequality within the German pension system. In particular, the invalidity risk and impending funding problems within the statutory pension system will be examined. (Module 1-2)
- The second cluster highlights inequality as a major driver of the Global Financial Crisis and emphasizes, in particular, the importance of a forward-looking risk management in the real estate sector. (Module 3-6)
- The third cluster discusses aspects of inequality in the European Economic Union, caused by different credit risks of the member countries in a simultaneous single monetary policy, focusing mainly on the period around the European Sovereign Debt Crisis. (Module 7-9)
- The fourth cluster presents some thoughts on the linkage between private insurance activity and inequality. (Module 10-11)

Challenges in the German Social Insurance System

Some of the biggest economies in the world, e.g. the U.S. and the UK, pursue the concept of a liberal market economy, in which fair prices, as kind of 'self-regulation' in the markets, are supposed to lead to growing prosperity for all market participants. Whereas in other industrialized countries, or specifically in case of the European Union, the adoption of a social market economy, is even established as a common goal of all member states in the EU Treaty of Lisbon:

> "The Union shall establish an internal market. It shall work for the sustainable development of Europe based on balanced economic growth and price stability, a highly competitive social market economy, aiming at full employment and social progress, and a high level of protection and improvement of the quality of the environment." (EU, 2016, Title I, Art. 3, § 3)

Germany, for instance, was the first country ever to introduce elements of a social welfare state under Otto von Bismarck as Reich Chancellor, albeit under enormous social and political pressure from the labor movements of the 19th century. The implementation of health and accident insurance in 1884 was followed by an old-age and disability insurance in 1891. Ultimately, after many reforms and crises during the Weimar Republic and National Socialism, the concept of the present German social market economy was finally introduced in the post-World War II era. The idea of a social market economy was inspired by the 'Frankfurt School', a group of intellectuals who took the basic idea of Marx and Engels' critique of capitalism and expanded the theory on how to create social progress. However, looking at the ratio of wealth to income (as presented for instance in Figure 7) the data shows a widening gap, even in an economy with a strong social security system like Germany, making

this country particularly interesting for studies on issues of risk and inequality.

Measured in social expenditures, the statutory pension insurance is the largest branch of the five social insurance schemes in Germany, and aims to provide coverage for household income losses due to a reduction in earning capacity, retirement, or an individual's death. Basically, this form of insurance is based on two major principles: actuarial equivalence and solidarity. Thus, even though longer contributions, or higher payments basically result in higher pension entitlements, aspects of social equalization are implemented to prevent income inequalities from being reinforced into retirement age or periods of disability. Therefore, social protection can help to improve long-term planning security by consumption smoothing, and mitigating the effects of inequality. The conversion to a so-called 'Generation Contract' in 1957 is based on this solidarity principle, as an instrument to reduce social and economic inequality.[3] In addition, especially low-income groups have a higher average mortality rate than higher-income earners, causing the unequal duration of pension benefits to further exacerbate the inequality effects on a life-time scale. However, the question about fairness, characterized by a balanced design of solidarity in the pension system, has always played a major role in political debates. In Germany, just recently, a law on more solidarity in basic state pension was passed on July 2, 2020, which is primarily intended to create greater social compensation through fairer benefit payments for low-income earners.

The first Module of this dissertation examines a micro aspect of inequality in the German pension system that has been rather neglected in research: social inequality in the context of the governmental disability pension system in Germany. For this purpose, Rodriguez Gonzalez, Lohse, Schröder, Krohn, and Zuchandke (2015) examine a panel dataset combined via record linkage from the research data centers of the German Pension Insurance (German: Deutsche Rentenversicherung) and the Federal Employment Agency (German: Bundesagentur für Arbeit) to explore the link of socio-economic determinants to work-restrictive health risks. This panel dataset consists of complete individual employment records of people subject to mandatory pension schemes, and is examined for the risk of disability across different groups of education, occupation, and income level. Accordingly, monthly data from a 25 % sample of all insured persons born between 1940 and 1977 is analyzed for the interrelationship between social and health inequalities in the German pension system. The results confirm the negative correlation between an individual's socioeconomic status and the risk of disability in the examined educational and occupational groups. Moreover, the results reveal inequalities even when viewed from a gender-differentiated perspective. Although the disability risk is generally higher for men, women in the high educational and professional groups are exposed to a higher early retirement risk than the average better-paid group of males. Based on our analysis, the biggest issue regarding the ability to effectively manage these risks, through private insurance coverage for instance, is summarized as:

> "The professional groups with the highest risk of a reduced earning capacity, and thus the

> highest need for coverage, have relatively low incomes, and their working lives are more severely interrupted by unemployment. As a result, the level of coverage provided by social security is relatively low, and the financial resources available for private risk coverage are more limited." (Loose translation of the original quote in Rodriguez Gonzalez, Lohse, Schröder, Krohn, and Zuchandke, 2015, p. 174)[4]

We find similar results regarding the relationship between income-reducing risk situations in Lohse, Rodriguez Gonzalez, Schröder, Morgenroth, and Himmelreicher (2016). In addition to the risk of disability, two more income-reducing situations, here unemployment and illness, are included in the analysis of the pension data on working lives. Moreover, the statistical analysis addresses a key limitation mentioned in Rodriguez Gonzalez, Lohse, Schröder, Krohn, and Zuchandke (2015), which is caused by the omission of deceased individuals within the sample. By merging two pension datasets on mortality rates, we estimate more robust ratios in the socio-economic risk groups by offsetting the downward bias in the data. The results confirm previous findings and show substantial periods of unemployment or sickness before the onset of disability, which further exacerbates the social inequality effect in groups with lower social status. Our findings suggest that these processes seem to cause a gradual social decline by lowering working capabilities (respectively income), as may be suggested by the exemplary results shown in Figure 6. Thus, according to our results, longer periods of unemployment and/or sickness indicate a higher risk of disability, so that they may be suitable early indicators for determining the risk of an individual's disability. In addition, the results show that people from higher qualification groups tend to be reintegrated faster, and more often, into the labor market, than from less qualified groups. Moreover, differentiated by gender, men have a higher return-to-work rate than highly qualified women. Hence, additional negative effects on the distribution of income and wealth are expected, since highly qualified men, i.e. the top earners in society, are thus enabled to accumulate more capital, than their female equivalents.

Overall, Grossmann and Strulik (2019) however argue that the German health and pension system – compared to a theoretical model – is close to an optimal social security system, even behind a Rawlsian 'veil of ignorance'. However, as indicated by Rodriguez Gonzalez, Lohse, Schröder, Krohn, and Zuchandke (2015) the pay-as-you-go pension system is facing increasing financial distress. In the case of Germany, and many other industrialized countries, this is due to the unfavorable demographic change which creates an increasing imbalance between contributors and pension recipients. In order to address this unfavourable trend with proper reform measures, it is important to make precise projections of the population's development. Apart from their relevance for long-term financial planning, demographic shifts are also linked to inequality issues like income distributions effects (e.g. due to labor market effects) and is summarized by Dolls, Doorley, Paulus, Schneider, and Sommer (2019) as follows:

> "Given their tremendous impact on society, demographic changes are among the most important policy challenges in the European Union. Population projections suggest that

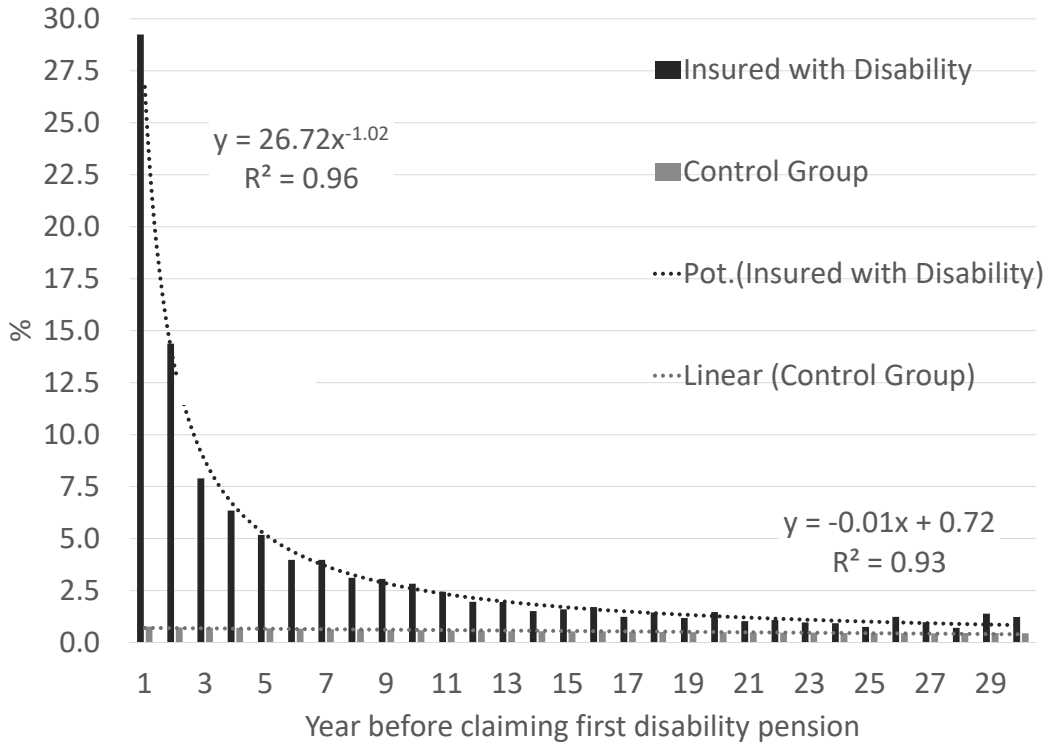


Figure 6. Shares in illness before the onset of a disability in working life. Source: Own calculations (as reported in Lohse, Rodriguez Gonzalez, Schröder, Morgenroth, and Himmelreicher, 2016).

> ageing and shrinking labor forces will have important implications, not only for fiscal revenue and social security systems, but also for the income distribution." (Dolls, Doorley, Paulus, Schneider, and Sommer, 2019, p. 210)

Therefore, in the second module of this dissertation, Vanella, Rodriguez Gonzalez, and Wilke (2021) present such a projection, in the form of a stochastic forecast model for the population in Germany until 2040, and discuss the possible implications for the pension system. In addition, disability pensions are forecasted as well. Our results suggest the necessity of further reform measures, that need to be implemented to prevent a financial collapse. This might be also to prevent rising inequality through the externalities on social redistribution, since the model predicts an increasing imbalance between contributors and beneficiaries, which increases either the risk of a financial collapse of the social security system (macro level), or the risk of an individual's old-age poverty (micro level).

Modules 1 and 2 of this paper show some micro- and macroeconomic impacts of inequality in Germany, indicated for example by the risk assessment of disability rates and income losses in various socioeconomic groups, or the demographic development towards a financial collapse of the German pension system. Furthermore, there is evidence for a close connection between the effects of economic and financial crises, inequality of income and personal health (see, for instance,)Pressman2011. Accordingly, the relationship between inequality, the GFC and the ESDC, and risk management measures

to influence the effects within this interrelationship will be considered in more detail below.

The Global Financial Crisis and the Role of Housing Prices

Since the prominent critique of Engels and Marx, the link between inequality and financial crises is a recurrent aspect of scientific and scholarly debate. Basically, there is a consensus, that in particular the imbalance between labor and capital income played an important role in the emergence of the GFC (see, for instance, Mah-Hui and Ee, 2011). In the public perception, however, the origin of the GFC is often associated with a speculative bubble, triggered by deregulation and greedy bankers. Therefore, it is particularly interesting to take a closer look at the academic debate to shed further light on this issue. Given that, the first module in this cluster highlights a possible disregard of some important inequality aspects in the finance literature. Similarly, to the comments of Mah-Hui and Ee (2011), for instance, stating that:

> "Among the macro-economic imbalances that have been put forward to explain the [...] GFC, [...] other structural imbalances that are equally important are less discussed; these are the imbalance between the financial sector and the real economy, and the imbalance in income and wealth between the rich and poor." (Mah-Hui and Ee, 2011, p. 210)

In the years leading up to the bursting of the price bubble in the U.S. mortgage market, income and wealth inequality in particular rose sharply in countries with deregulated financial markets, like the U.S. and UK, but also in countries with strong social systems, like Germany (see again Figure 7). Kirschenmann, Malinen, and Nyberg (2016), for example, provide empirical evidence for inequality being the most significant crisis predictor in a dataset of developed countries (including the U.S., the UK, and Germany) in the period from 1870 to 2008, while emphasizing that the correlation increases with rising inequality. According to economic theory, there are three dynamics of wealth inequality that could trigger a crisis (Wisman and Baker, 2011, p. 64): First, inequality causes individuals to increase their consumption spendings to maintain their relative standard of living ("Thorstein Veblen's theory of consumer behavior"). Second, credit is cheap and financial innovation is encouraged, since marginal income and wealth increases in the top income groups flow mostly into financial markets instead of additional consumption ("Keynesian/Kaleckian underconsumptionist school"). Third, growing economic strength implies greater political influence in the form of lobbying for more liberal capital market regulation ("Karl Marx's theory of ideology formation"). In case of the GFC, the link between inequality and the emergence of the crisis is described for example by Lysandrou (2011):

> "[...] the toxic assets were created largely in response to external pressures, a principle source of which was global inequality: while income inequality was an important factor behind the supply of those assets, wealth concentration was a major factor behind the demand for them." (Lysandrou, 2011, p. 323)

Figure 7. Net national wealth as percentage of national income in the U.S., the UK, and Germany. Source: Own representation based on `https://wir2018.wid.world/`.

However, the outbreak of a financial crisis is not limited to inequality exclusively. Therefore, in order to better understand the causes of recent crisis events, as well as the regulatory shortcomings contributing to it, in Module 3 Meier, Rodriguez Gonzalez, and Kunze (2021) provide a systematic literature review on the effects and consequences of financial regulation before and after the onset of the GFC and the ESDC. For this purpose, 455 academic papers from the period after the 2007 events are evaluated and systematically organized. Based on this data, we examine some of the potential causes for both crisis events. We also investigate the policy and regulatory responses, particularly in the EMU countries, and identify, as well as summarize, policy recommendations to strengthen the current regulatory regime. In total, six clusters are identified as key crisis drivers in this systematic review, which all could be scholarly linked to the topic of inequality.[5] To clarify, an extended version of the categorical overview from the review is provided in Figure 8. As already stated above, the identified crisis drivers determined by Meier, Rodriguez Gonzalez, and Kunze (2021) are not only linked to issues of inequality, but likewise to the need for appropriate (risk management) measures to prevent future crashes. In a similar manner, Mah-Hui and Ee (2011) highlight inequality as a major crisis driver and the need for addressing these issues:

> "We do not propose that inequality is the only or direct cause of economic and financial

crisis. We propose that it is an important factor contributing to financial imbalance in the economy which, combined with a highly leveraged financial sector that chruns out new financial products to increase overall lending, increases the vulnerability of the financial system to systemic break-down. Hence the rising income inequality issue must be addressed in order to resolve economic and financial instability." (Mah-Hui and Ee, 2011, p. 225)

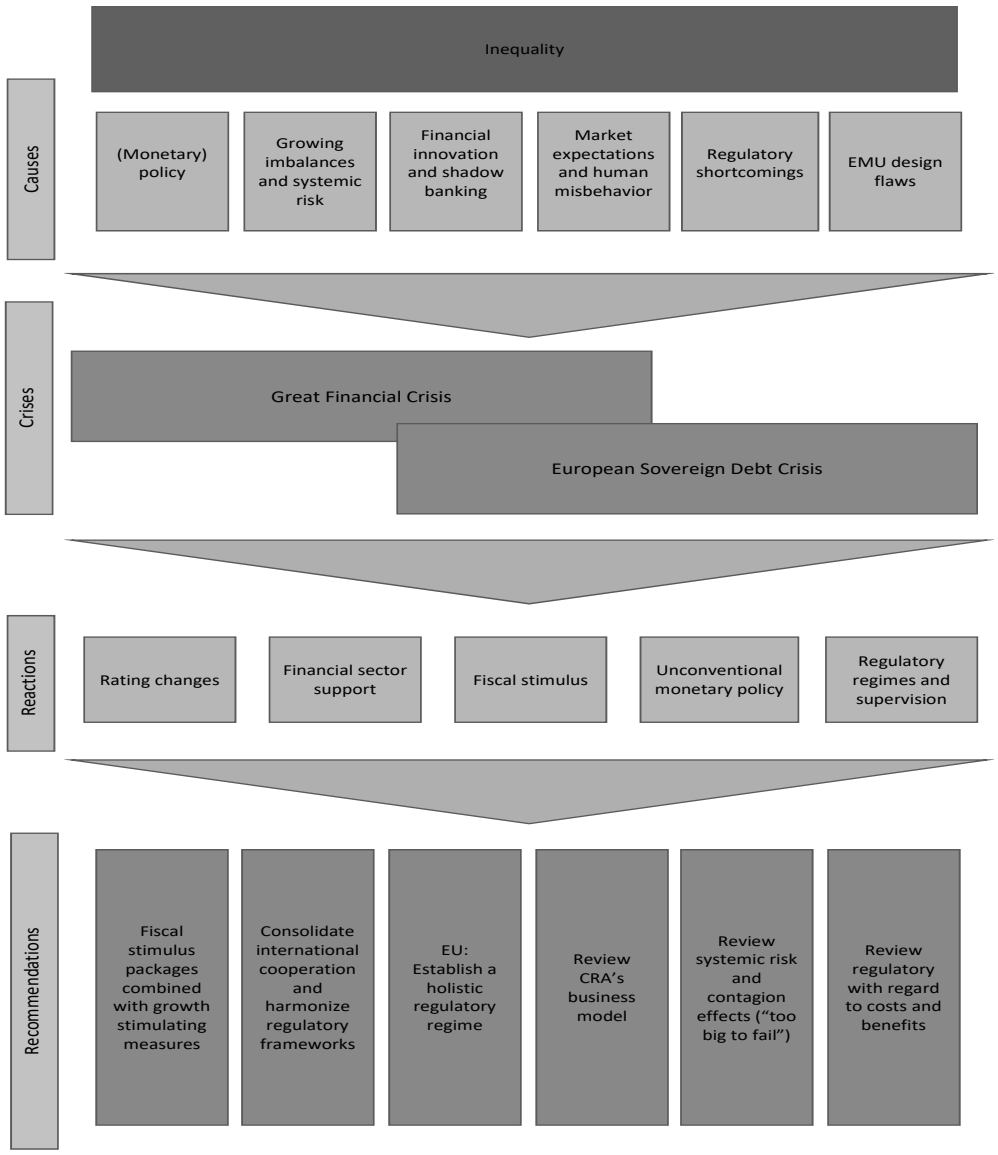


Figure 8. Inequality as a potential root cause of the GFC and the ESDC. Source: Own representation based on Meier, Rodriguez Gonzalez, and Kunze (2021).

Following the reasoning of Thomas Piketty, inequality is fostered primarily by ideological and political influence. Likewise, a recent study argues that politics (and leverage) could be the main

transmission channel(s) leading from income inequality to the emergence of financial crises (see Čihák and Sahay, 2020). In this context, the leverage effect is often explained by a policy-induced rise of credit bubbles (see, for example, Rajan, 2010), even though, there is also literature that criticizes this connection (see Bordo and Meissner, 2012). According to this line of thought, policy and regulatory frameworks could significantly affect the riskiness of economic systems. Therefore, Meier, Rodriguez Gonzalez, and Kunze (2021) also give recommendations for regulatory action to potentially prevent, or at least weaken, the effects of future crisis events that could further exacerbate inequality. Overall, as presented in Figure 8, six root causes (possibly all linked to inequality), and seven recommendations are drawn from the literature.

To summarize, the exact transmission channels between inequality and financial crises are not sufficiently described yet, which is probably due to the complexity and interdependence of the multitude of influencing factors. In general, there are indications that there may be a bidirectional relationship between crises and inequality. As an example, it is striking that there is a high increase in inequality before two major U.S. crises, the Great Depression and the GFC. Before both crashes, there was a sharp increase in social pressure due to an over-concentration of capital at the top of the income distribution and stagnating labor prices for the low- and middle-classes, as well as an increasing debt among the middle class. One plausible argument would be, that a saturation of consumption in the real sector results in asset price inflation on financial markets (like stocks in the 1930s, or real estate in 2007). Thus, assuming this correlation, inequality in the wealth distribution ultimately manifested itself in a worldwide banking crisis. In the case of the housing bubble, the purpose of financial regulation would have been to create incentives and frameworks for an effective risk management to improve the monitoring of real estate asset prices (e.g. to reveal the existence of a bubble) and prevent future crashes. Instead, lending to 'NINJA households' (no income, no job, no assets) was even promoted by the political agenda (see, for instance, De Michelis, 2009) and concerns about overpriced housing were therefore ignored. As a result, the bursting of the bubble originated from increasing loan defaults in the subprime segment, causing many families to lose their homes. Accordingly, in addition to the economic loss, that further increased the indebtedness of low-income classes, there is also a social aspect in the loss of housing, highlighting the special importance of the housing market, as argued for instance by Wisman and Baker (2011):

> "What distinguishes the crises of 1929 and 2008 is that the speculative mania preceding them occurred not only in stock markets, but in real estate markets as well. Real estate markets are more democratic than stock markets in that a larger share of the population participates in ownership, and thus a collapse of a speculative bubble in real estate has consequences that are far greater and potentially far longer lasting. Real estate ownership also possesses a social characteristic that is special: for most households it constitutes not only the most important store of wealth, but also the most important symbol of social status." (Wisman and Baker, 2011, p. 65)

Likewise, forecasting real estate prices might also help addressing other issues of inequality, for example with respect to the social phenomena of 'superstar cities'. This term, as described for instance by Gyourko, Mayer, and Sinai (2013), is related to empirical evidence that rising prices (and respectively rents) crowd out lower income groups from metropolitan areas. This trend directly affects the social coexistence, and thus also aspects of inequality. Moreover, if house prices rise faster than incomes, this leads to an additional impoverishment of the population strata without financial reserves. Politically, this problem could then be confronted by redistribution or market-regulatory interventions, such as the introduction of a rent brake – a development currently to be seen in Berlin in Germany. Therefore, the investigation of rising prices in the housing market, is of particular importance, not only because possibly being a predictor of an inequality-enhancing crisis, but also because being apparently triggered by wealth inequality itself.[6] Hence, Modules 4 to 6 deal with risk management issues in the real estate sector. By applying variations of Granger causality tests to datasets of different industrialized countries (here the UK and the US), the relationship between market sentiment data and price indices of real estate markets is investigated.

First, in Module 4 of this thesis Rodriguez Gonzalez, Basse, Kunze, and Vornholz (2018) examine the statistical long-run relationship between the National Association of Home Builders (NAHB) housing market index as a sentiment indicator and, as a price index, the S&P/Case-Shiller 20 city home price index in the U.S. using the concept of Granger causality to data from January 2000 to March 2018 in monthly periodicity. Since Granger causality is a statistical concept stating that one variable contains information that helps to predict another variable, we test for Granger causality of both indices to test for empirical evidence on the bidirectional relationship. In the first paper, we find a unidirectional relationship running from the NAHB index to the S&P/Case-Shiller price index. Thus, we find evidence for the U.S. market, that sentiment data could be helpful in predicting price movements in the more illiquid real estate market. Subsequently, in Module 5 Kunze, Basse, Rodriguez Gonzalez, and Vornholz (2020) also test for Granger causality between the sentiment indicator and house prices for the UK housing market by investigating monthly data from January 2000 to December 2018 in a follow-up study. In addition, Granger causality is tested for stability over time, to control to some extent for structural breaks in the time series. In doing so, the results of our empirical examination, similar to the results from Rodriguez Gonzalez, Basse, Kunze, and Vornholz (2018), reveal that there is evidence of a stable unidirectional Granger causality running from the sentiment data to the price index. As a result, Kunze, Basse, Rodriguez Gonzalez, and Vornholz (2020) discuss different possibilities to use these findings for early warning systems in risk management. In Module 6, Rodriguez Gonzalez, Basse, Saft, and Kunze (2021a) investigate causal inference between sentiment and price data in the U.S. housing market with a more sophisticated approach using machine learning algorithms in the context of new data science trends. For this purpose, the index of NAHB, and the S&P CoreLogic Case-Shiller 20 City Composite Home Price Index, are examined for the period from January 1995 to April 2018. Using advanced techniques of data science, we are able to confirm

additional empirical evidence of a unidirectional relationship between sentiment and price data in the U.S. housing market, as already examined by Rodriguez Gonzalez, Basse, Kunze, and Vornholz (2018). By implementing a high-sophisticated machine learning approach on a larger dataset, the results can be considered to be much more robust than traditional tests for Granger causality.

Most importantly, real estate is a high-demand asset class for institutional investors, and more wealthier individuals, especially in the post-crisis low-interest environments in the U.S. and Europe. As argued above, there is evidence for the existence of an interrelationship among market risks in the real estate sector and social (resp. economic) inequality. Early warning indicators are supposed to forecast systemic developments in markets in order to minimize market-related risks. Therefore, in a total of three papers, we empirically analyze long-run relationships between price developments and market sentiment data, either in the U.S., or the UK housing market. As a result, unidirectional Granger causality running from sentiment data to the price index is confirmed in all three cases. This information might be helpful for improving risk management models by implementing indicator-based forecasts for price movements in modern risk management systems, which also might be helpful to indicate increasing wealth inequality in financial systems.

Sovereign Credit Risk in EMU Countries

The bursting of the U.S. real estate bubble in 2007 unleashed a chain reaction that finally resulted in a global financial crisis.[7] As Tomz and Wright (2007) argue, a sovereign default is also often caused by a macroeconomic shock. Because of the distressed banking sector, many government bail-outs throughout the industrialized world became inevitable, and thus, the severe impact of the banking crisis placed a particularly heavy burden on many government budgets. In the case of the EMU, especially in some Southern European countries, like Portugal, Italy, Greece and Spain, as well as Ireland (PIIGS), the impact of the GFC has been particularly severe, probably because of existing structural problems. Therefore, these countries were hit relatively hard, and as a result the inequality between European core and periphery countries widened even more in 2010. To some extent, this widening inequality was also reinforced by a common monetary policy within the EMU. As a result, in the wake of the ESDC, concerns about sovereign credit risks and redenomination risks in financially depressed EMU member states increasingly emerged. Since both are important determinants for the risk premium of government bonds, they also determine the cost of refinancing government debt when new fixed-income securities are issued. Thus, since rising risk premiums in periphery countries lead to rising country-level inequality in the EMU, this represents another macroeconomic transmission channel between risk and inequality. Likewise, Aizenman and Jinjarak (2012) conclude that reducing income inequality also reduces sovereign risk, indicating that there might be a bidirectional relationship. Otherwise, the literature on the relationship between inequality and sovereign risk is very limited (see, for example, Jeon and Kabukcuoglu, 2018). Accordingly,

some empirical evidence on the interrelationship of sovereign risk spreads in the context of the ESDC could be helpful in the context of financial risk management and is discussed in more detail below.

In Module 7, Rodriguez Gonzalez, Kunze, Schwarzbach, and Dieng (2017) examine the long-run relationship between yields of 10-year European government bonds, divided into richer 'core' and poorer 'non-core' (or peripheral) countries. Using the St. Louis Fed database (FRED), we examine the monthly government bond yield spreads to their German equivalents of two core countries (Austria and the Netherlands) and two non-core countries (Italy and Spain) for the period from January 1999 to February 2015.[8] The time series are examined using statistical unit root and cointegration tests. The unit root tests allow us to examine time series with unknown structural breaks. As a result, we confirm a structural break in the cointegration relationships of yield spreads in some countries at the time of the ESDC. This suggests that the risk premiums have been increased by higher probabilities of sovereign default or currency redenomination. This also shows an effect that c.p. increases the inequality between the financially stronger core countries and the structurally weaker peripheral countries, because of higher risk premiums in the more distressed countries. This made refinancing even more difficult for these countries, and a large number of aid packages and ECB measures had to follow in order to counteract these developments. In a follow-up study, Tholl, Basse, Meier, and Rodriguez Gonzalez (2021) further examine yield spreads of EMU member states in Module 8 of this dissertation. In this case, medium- and long-term bond spreads (of 5-, 10-, and 30-year bonds) are examined, to test the interest rate differentials in the EMU countries Austria, Belgium, France, Italy and Ireland for Granger causality, based on a weekly dataset from March 29, 2019 to July 03, 2020. Thus, we investigate information flows and the question of whether risk premiums in some countries can help to forecast risk premiums of other countries. In the case of 30-year bonds, no relationship can be confirmed in our dataset. Further, for 10-year government bonds, no clear conclusion can be drawn from the statistical analysis. Interestingly, we find Granger causality in the case of the 5-year bond spreads running from all four countries to Austria. This suggests that the Austrian yield spreads may be better explained by liquidity, rather than sovereign credit risk, as the risk premiums of government bonds are mainly determined by those two types of risk.

Moreover, the FED in the U.S., but in particular the ECB in the EMU, adopted conventional and unconventional monetary policy measures to contain the consequences of the GFC and, in the case of the EU, to counteract the threat of a break-up due to the ESDC. While Furceri, Loungani, and Zdzienicka (2018) highlight the difficulties to analyze such unconventional measures, they still conclude, that conventional liquidity expansion (contraction) reduces (increases) inequality. Likewise, Amaral (2017) explains some theoretical channels through which monetary policy affects inequality, even though he concludes, that the effect on individual inequality might be modest. Moreover, Samarina and Nguyen (2019) emphasize a particularly large effect for the periphery countries, meaning that actual developments could further widen the European North-South inequality gap.

Conversely, in case of quantitative easing programmes, Mumtaz and Theophilopoulou (2017) for example, find a negative relationship to inequality in the UK. Nevertheless, measures like quantitative easing resulted in a low-interest rate environment, and respectively, low costs of capital and inflating asset prices. When thinking about the GFC, the high liquidity resulted also in redistributive effects on income and wealth. Therefore, interest rate decisions by the central bank might be another channel between risk and inequality, and thus, the next module sheds further light on this issue and presents useful information on the relationship of sovereign credit risk and monetary policy for institutional risk managers like for example insurers, but also national and international policy makers.

In Module 9, Rodriguez Gonzalez, Basse, and Tholl (2019) examine the statistical long-term relationship of 10-, respectively 30-year, government bond yield spreads of the EMU countries France, Italy, and Spain (relative to Germany), and interest rate increases for the ECB's main refinancing operations. Therefore we analyze the spreads' long-term relationship to key interest rate changes of the European Central Bank. Monthly data from January 1999 to August 2018 is examined to determine the effects of potential interest rate hikes in the current low interest rate environment to the government bond yield spreads in some key EMU member states. In order to analyze the cointegration relationships, in a first step, the unit root tests are performed to test the statistical prerequisites for applying this methodology to our dataset. However, the results of our cointegration tests show no cointegrating relationship between government bond spreads and changes in the interest rate on the main refinancing operations.

Since the results show that there is no evidence of a long-term statistical relationship between the ECB's interest rate policy and the risk of sovereign default, the long-term effect of monetary policy as an explanatory parameter to the credit risk may be neglected. Likewise, O'Farrell and Rawdanowicz (2017) argue, that the overall indications in research are too insignificant to assume a strong nexus between inequality and monetary policy. Hence, central bank responses do not seem to be an appropriate parameter for addressing inequality. However, other research stresses this conclusion with empirical evidence, that there might be a linkage for 'normal' times, but also concludes that inequality increases during long periods of low interest rates, as seen in some EU countries (see, for instance, Coibion, Gorodnichenko, Kueng, and Silvia, 2017; Guerello, 2018). Similarly, Domanski, Scatigna, and Zabai (2016) conclude:

> "The exercise provides tentative evidence of the relative importance of the channels through which monetary policy actions may have affected wealth inequality since the crisis. Taken at face value, our results suggest that the impact of low interest rates and rising bond prices on wealth inequality may have been small, while rising equity prices may have added to wealth inequality. A recovery of house prices appears to have only partly offset this effect." (Domanski, Scatigna, and Zabai, 2016, p. 60)

But, even if low interest rate policies lead to rising prices on the stock markets that possibly exacerbate

inequality, other externalities are in turn prevented, such as firm closures or rising unemployment. Thus, the net effect seems to be unclear. Similarly, Amaral (2017) also highlights the complexity of the linkage between monetary policy and inequality:

> "The complexity of the mechanisms linking monetary policy and inequality stems from the fact that they depend not only on economic variables that constantly change for reasons other than monetary policy, but importantly, also on the distributions of income and wealth themselves, which are in turn heavily influenced by demographics. Theoretically, it is cumbersome to develop models that can reflect all the relevant heterogeneity, and empirically, it is hard to control for all the endogeneity. Nonetheless, an examination of the literature and the evidence seems to point to a modest influence at best." (Amaral, 2017, p. 5)

To conclude, former Federal Reserve Chairman Ben Bernanke argues that inequality should not be a central goal of monetary policy in particular, but policy in general, because he suggests the effects of central bank actions also to be neutral in the long-run, and the positive outcomes of effective monetary policy on the real sector to outweigh the negative ones on financial markets (Bernanke, 2015). Thus, the long-term net effect of monetary policy on economic inequality still seems to be questionable.

Can Insurance Markets Help to Mitigate Inequality?

The contracting of insurance policies is a traditional measure of risk transfer within the classical risk management process. In fact, insurance companies are experts in underwriting new risks, but also in managing capital market risks in their asset-liability management. Therefore, in accordance to the opening quotation on risk management and inequality by Robert J. Shiller, insurance activity could also have a mitigating effect on inequality. Such a link is explained for instance by The Geneva Association (2020) as follows:

> "From a 'micro' resilience angle, inequality influences the ability of individuals, households and businesses to withstand shock events, based on unequal access to (insurance) protection or an insufficient awareness of it (e.g. as a result of financial illiteracy)." (The Geneva Association, 2020, p. 6)

On a personal level, income smoothing occurs by covering income-reducing natural risks, such as health issues, longevity risk, or death, by a health, pension, or life insurance, respectively. As stated earlier, in social insurance, inequality is reduced by the redistribution from less risk-exposed, but high income groups to poorer, and riskier ones. However, especially in high-industrialized markets, private insurance products are mostly priced at risk-adequate premiums, which can also help to increase inequality (see Lehtonen and Liukko, 2015). Due to the positive correlation between income and individual health risks, the inequality-reducing effect in commercial insurance is less obvious, since

insurance products are mostly held by middle- and high-income groups (see Enz, 2000). According to Cabral (2019), the lower middle income groups are sometimes even forced to sell insurance policies, when suffering times of financial distress. Likewise, a recent survey from the German Federal Statistical Office shows a higher trend of insurance density across wealthier income groups (see Table 1). The data confirm that the lowest income groups lack elementary risk coverage, with just 50 % of the lowest income groups having liability insurance, for example, while the highest income group has coverage to nearly 100 %. However, the insurance density in low-income groups could be rising, when technological and financial progress lead to reduced prices of insurance policies. Innovative approaches in insurance technology, such as the concept of inclusive insurance (micro-insurances), for instance, might help to offer financial protection at more affordable prices (see Cabral, 2019). This could reduce inequality, especially in countries where the supply of governmental and commercial insurance solutions is limited – like mostly in developing countries.

	Share in Household Net Income Groups in %*				
Insurance Type	Lowest	Low	Mean	High	Highest
Disability	5.5	8.4	25.6	44.9	55.5
Term Life	2.3	4.3	17.2	33.6	44.0
Endowment Life	10.1	17.7	31.9	46.8	56.0
Private Pension	5.9	9.1	22.7	36.9	45.2
Private Liability	50.0	67.9	82.8	95.1	95.3
Home Contents	44.6	62.3	75.7	86.5	89.5
Legal Protection	12.1	25.5	46.3	63.0	65.2

*(Lowest: < 900€; Low: $900 - 1,300$€; High: $3,600 - 5,000$€; Highest: $5,000 - 18,000$€)

Table 1: Insurance density for monthly net household income groups in Germany. Source: Own representation based on German Federal Statistical Office (2018, p. 68)

From a macroeconomic point of view, insurance markets in particular fulfill a stabilizing function in the growth of national economies. The possibilities of risk transfer to insurers and reinsurers promote business and investment activity. In addition, life insurers and pension funds are important financial market and price stabilizers, for example due to their long-term investment horizon, or by investing countercyclically (see also Tholl, Basse, Meier, and Rodriguez Gonzalez, 2021). According to Milanovic, Lindert, and Williamson (2010), promoting growth in the context of income inequality is also relevant in terms of social stability. However, even since there is empirical evidence that overall financial market development correlates negatively with measures of social inequality (see, for instance, Zhang and Ben Naceur, 2019), the relationship of risk and inequality, in the context of life and non-life insurance market activity, is a scarcely explored research issue.[9] Nevertheless, the results of Asongu

and Odhiambo (2019) indicate, that there might be a relationship between insurance activity and inequality. They quantify threshold values for some countries in sub-Saharan Africa, separately for life and non-life insurances. Likewise, Madsen, Islam, and Doucouliagos (2018) argue that the effect of inequality on growth, on the other hand, is dependent on a country's income level. The authors argue, that inequality might be negatively affecting growth in poorer countries, while the relationship is less strong in financially more developed systems. To conclude, the relationship between general market activity and insurance activity, as well as inequality, is summarized by The Geneva Association (2020) as follows:

> "For insurers, one of the most relevant aspects of social inequality is its impact on the stability and resilience of economies and societies. From a macro-level perspective, inequality affects an economy's capacity to develop smoothly across its path of potential growth and to minimise income and asset losses resulting from shock events. These effects are transmitted through less stable and dynamic economic growth, a higher vulnerability to financial crises and the risk of social unrest and political violence. Hence, it is in the insurance industry's enlightened self-interest to consider products and solutions which contribute to mitigating widening income and wealth parities." (The Geneva Association, 2020, p. 6)

To shed further light on the relationship of insurance activity and economic growth, the next Module first addresses the question of whether there are country-specific long-run relationships between insurance activity and economic growth as being the most prominent crisis indicator of the real economy. Accordingly, in Module 10, Rodriguez Gonzalez, Wegener, and Basse (2021b) examine the long-run relationship between insurance market activity, measured in real gross premiums aggregated at country level, and general economic activity, measured in real GDP. Thus, we investigate whether insurance activity might be an important driver for growth, or vice versa. Methodologically, a panel time series technique is applied accounting for cross-sectional dependence within the panels. Data on global real gross premiums from Swiss Re and real GDP from the World Bank is analyzed. The data for 90 countries is processed according to data availability and clustered into nine different risk-based panels, using the OECD country risk classification. As a result, we find evidence for panel cointegration between real insurance market activity and real economic growth. Therefore, insurance activity might be a way to mitigate the impact of negative economic shocks – for example by generally promoting the economic development. However, the causal relationship between insurance market activity and inequality remains ambiguous.

As already argued above by The Geneva Association (2020), financial literacy is another way to address inequality issues, for example, by increasing the awareness of unknown risk exposure through expertise of the insurance sector in the underwriting of risks, or the probabilities of rare disasters. The COVID-19 pandemic highlighted the importance of identifying and assessing potential extreme

events with small probabilities of occurrence, but large magnitudes in severity. Emergency plans for a pandemic would likely have limited the spread of the virus and thus decreased above mentioned inequality effects within some economies. In addition, underwriting emerging risks promote innovation and investment. Another prominent example is the coverage of cyber risks that also could be of growth-promoting importance within the Fourth Industrial Revolution. The experience in risk modelling and the quantification of risks can certainly create more planning security for entrepreneurs, which is expected to have a positive effect on business activity. Therefore, we discuss how the insurers' risk expertise could be instrumentalized to improve macroeconomic resilience. As an example, risks in the German power supply system are quantified within the risk management processes of risk identification and risk assessment.

Accordingly, in Module 11 of this dissertation, Wrede, Linderkamp, and Rodriguez Gonzalez (2017) provide a catalog for specific risks in the German power supply system, based on an empirical survey of insurance experts and technicians. Not only the energy infrastructure is an important growth driver in general, also the academic literature suggests that energy infrastructure has the potential to reduce income inequalities (see, for example, Medeiros and Ribeiro, 2020). Thus, the energy system belongs to the group of critical infrastructures and is of particular importance for increasing prosperity and also aspects of inequality. In order to assess the risks of the German power supply system, Wrede, Linderkamp, and Rodriguez Gonzalez (2017) develop an own risk classification mechanism. After identifying the potential risks, like terrorism or cyber attacks, an evaluation is carried out by empirically surveying experts from the insurance industry and the energy sector. In this context, both the probability of occurrence and the expected loss are rated. In general, economic risks such as increasing competition, falling market prices, or raw material shortages were identified as the most likely risks, while cyber attacks represent the highest damage potential. We then test for statistical differences in the risk assessments between the two expert groups. According to our results, especially the risk potential for natural hazards, such as storms and floods, but also risks from wars and terrorism, for example, are assessed higher by the insurance experts. This could be due to the market experience of insurers, and especially reinsurers, in assessing natural hazards.[10]

Overall, this last module demonstrates the insurance industry's expertise in identifying and assessing risks in the context of critical infrastructures in the German power supply system. The effects of a blackout, for example, have received increased attention in recent years, also due to the dramatic presentation of the societal consequences by Marc Elsberg in his book 'Blackout' (Elsberg, 2012). In this novel terrorist attacks on the European and U.S. energy grid occur to provoke an anarchic political order and to balance inequality and injustice within the society. Even though this is a purely fictional work, actual assessments of energy experts confirm that both, the described course of social degeneration, but also the risk of such terrorism, are assessed in a similar way – like for instance by Bruch, Münch, Aichinger, Kuhn, Weymann, and Schmid (2011). Likewise, the authors emphasize the

increasing risks of power outages in Europe and the U.S. with high potential losses in economic and social terms in the event of a long-term blackout. Nevertheless, they also emphasize the possibilities of insurers' risk management to counter these risks, as they state:

> "When risk management is done well and risks can be reliably quantified, insurance is an important mechanism for risk transfer. All parties, insurers, electricity industry and consumers should engage in risk dialogues to proactively address and manage related power blackout risks with the aim to maintain one of the most important goods in a civilized society, a reliable supply of electricity." (Bruch, Münch, Aichinger, Kuhn, Weymann, and Schmid, 2011, p. 25)

To conclude, the above results have shown that insurance might help to increase growth (and thus income) levels – as indicated in Module 10. If the additional income is transferred to low- and middle-income classes in the real sector (through more progressive taxation or alternative forms of redistribution), c.p. income and wealth inequality might be slowed down or even reduced. Furthermore, insurers are able to assess and manage risks with appropriate risk management measures due to their risk expertise – as shown in Module 11. In summary, however, given the complexity of the interrelationships, the net effect and causal links of insurance activity as possible risk management measure to reduce inequality remain vague.

Trickle-Down vs. Piketty: What to Do about Inequality?

The COVID-19 pandemic has clearly widened the gap between rich and poor, and the final extent of the economic devastation is far from clear at the time of writing. Jeff Bezos, for example, increased his wealth by about 75 bn USD from the outbreak of the pandemic until his resignation as CEO (see Bloomberg, 2021), while Amazon's corporate structure is regularly criticized for poor working conditions, especially among low-income earners.[11] Apart from this acute health crisis, we are currently experiencing a period of unprecedented change similar to Friedrich Engels' lifetime. According to the World Economic Forum "[...] inequality represents the greatest societal concern associated with the Fourth Industrial Revolution" (World Economic Forum, 2016). Already, the largest U.S. companies are located in the technology sector.[12] However, accusations of unfair tax and regulatory issues, use of monopolistic power, influence on political voting, or economic utilization of a cheap labor force are also major concerns regarding these companies. Through the digitization and automation of business processes and the implementation of smart technologies, despite increasing productivity, labor market disruptions could further exacerbate the disproportionality of capital and labor (like already argued during the First Industrial Revolution).[13] Apart from this, Pastor and Veronesi (2018) describe a close link between inequality and emerging populism in highly industrialized countries with elevated inequality – often resulting in a fight against the 'elite'.[14] Recent events, like the storming of the U.S. Capitol on January 06, 2021, highlight the dangerous nature of populism and anti-'establishment'

politics, which may be described as "[...] fragility of globalization in a democratic society that values equality" (Pastor and Veronesi, 2018, p. 33).

Given the above, the long-term trend of technological progress, but also the immense impact of the COVID-19 pandemic in particular, are only some recent illustrative examples for the need of more research on issues of inequality and how to address them by regulatory and political measures. Earlier approaches, that explain inequality with a rising skill-premium in the technological progress (see Krusell, Ohanian, Ríos-Rull, and Violante, 2000), or ideas of reducing inequality by a strict supply-side economic policy ('trickle-down theory') seem more or less outdated.[15] A more contemporary theory by Thomas Piketty focus on a fundamental relationship between the growth rates of the return on capital (r) and the real economy (g), that cause inequality when the capital income grows faster than the working income ($r > g$). Nonetheless, some economists argue against this simplified approach and criticize in particular Piketty's database, but also the statement, top income earners would steadily continue to accumulate wealth (see, for a detailed review of the literature, King, 2017).[16] However, the great research interest in inequality and the predominant evidence in top economic journals might be resulting from the fact, that this topic has gained great public attention in the course of the GFC, which may also have resulted in a publication bias, as described in a meta-analysis on the inequality-growth-nexus:

> "We find traces of publication bias in this literature, as authors and journals are more willing to report and publish statistically significant findings, and the results tend to follow a predictable time pattern over time according to which negative and positive effects are cyclically reported. After correcting for these two forms of publication bias, we conclude that the high degree of heterogeneity of the reported effect sizes is explained by study conditions, namely the structure of the data, the type of countries included in the sample, the inclusion of regional dummies, the concept of inequality and the definition of income." (Neves, Afonso, and Silva, 2016, p. 1)

Similarly, Van Treeck (2014) argues that the ambivalent results in the literature arise due to the fact of opposing perspectives (supply- vs. demand-oriented). Moreover, Gu and Huang (2014), conclude that the link between crisis and inequality might not be a universally valid relationship, but also dismiss the sustainability of a financial economy under rising inequality. Correspondingly, economist Paul Krugman stresses the connection between rising economic inequality and the emergence of financial crises by highlighting the unknown interrelation, which could be: "[...] Coincidence; [...] a common causation, like e.g. neoliberalism; or [...] actual causation, like inequality" (Krugman, 2011, p. 5). Nonetheless, regardless of the determination of precise linkages that might be too complex to be put into causal relationships, the fact of increasing inequality in many industrialized countries still persists. Therefore, this work contributes some examples and insights on how risk management could influence the potential link between crises and inequality.

Overall, this thesis emphasizes the relationship between inequality and different types of risk in the context of the current scientific debate, and provides preliminary anecdotal evidence of how risk management measures can potentially influence this relationship. In the above remarks, some important transmission channels between economic risks and social inequality have been discussed, highlighting the possibilities of risk management to mitigate negative economic or social shocks at individual, institutional and governmental level. The research in this dissertation tackles topics on risks, as well as micro- and macroeconomic risk management issues, and has been linked to various phenomena of inequality – for example in income and wealth distributions in the U.S., UK and Germany, but also some EMU member countries. To summarize, issues in the social security system in Germany, the GFC and the U.S. housing bubble, but also the sovereign credit risk of core and periphery EMU member states before and after the ESDC, and the emerging risk of sovereign credit risk in EMU countries, as well as questions on the possibilities of private insurance coverage to reduce inequality and crisis events, have been discussed. Fundamentally, this work demonstrates the vast research potential in the relationship between risk management measures and effects on inequality. As described above, long-term trends in digitization and automation, economic shocks such as the COVID-19 pandemic, recurring financial crises, or demographic change, as well as rising public debt, also in the context of public pension systems, point all to a worsening of inequalities. Since those dynamic developments are difficult to control by politics and regulatory authorities alone, the importance of research on risk management issues will likely increase in the future. Accordingly, further research on the topic seems to be reasonable, e.g. to identify effective regulatory or political recommendations.

Meanwhile, current developments in global and national income as well as wealth inequality, in particular due to massive state interventions with respect to private, public, and economic freedoms to counteract COVID-19, are regularly linked to questions on justice in the social debate. Undoubtedly, inequality and justice are two closely related concepts: While inequality mainly refers to the distribution of (im)material goods, justice is a concept based on normative values. Therefore, a comprehensive discussion about the right level of inequality based on different spiritual, social, or political values is difficult to realize and thus regularly leads to heated debates. A remedy for this imponderability is offered by the well-known thought experiment of U.S. philosopher John Rawls (Rawls, 1971). Within this theoretical construct, Rawls convincingly argues how inequality can be fair from a societal point of view. Therefore, he determines an individual's choice of a democratic society out of an initial state of social equality by assuming a 'veil of ignorance'. According to this intellectual game, people would neither choose a utilitarian, nor a libertarian system, because both forms imply risks of social discrimination. Accordingly, if the people act from an 'original position' (unknowing the future social status at the time of implementing the democratic society), a system would emerge that reduces inequality to a marginally desirable level. This philosophy could also be used to reflect on the optimal position of risk management and economic actors, as insurances, in our society.

Notes

[1] A review on the link of economic and social inequality is provided for instance by Thorbecke and Charumilind (2002).

[2] See, for instance Wilkinson and Pickett (2006) for a review of the link between inequality and population health, UN Office on Drugs and Crime (2020) for evidence of higher drug use in lower social strata, or Choe (2008) for a strong linkage of inequality and different income-generating crimes (like burglary or robbery).

[3] Not only income shocks will be compensated, but also gender and other socioeconomic inequalities are addressed in the German pension system, for instance by the crediting of substitute periods, such as in the case of taking care of a dependent family member, or times of child education, etc.

[4] Original quote: "Gerade die Berufsgruppen mit den höchsten EM-Risiken und damit dem höchsten Absicherungsbedarf sind zum einen mit einem relativ geringen Einkommen ausgestattet und zum anderen sind die Erwerbsbiografien stärker durch Arbeitslosigkeit unterbrochen. Demzufolge fällt auf der einen Seite die Höhe der gesetzlichen Absicherung relativ gering aus, auf der anderen Seite sind die finanziellen Möglichkeiten einer privaten Risikoabsicherung eingeschränkter."

[5] Notable examples include monetary policy (see Coibion, Gorodnichenko, Kueng, and Silvia, 2017), growing imbalances (see Stockhammer, 2015), shadow banking (see Helgadóttir, 2016), or regulation (see Vogel, 2021), just to name a few.

[6] Holt and Greenwood (2012), for instance, argue that four different channels of inequality affect the housing prices, which they designate as 'negative trickle-down-effect'.

[7] Moreover, Agnello and Sousa (2012) report evidence for a rising trend of inequality before a banking crisis, and a sharp declining trend afterwards.

[8] It is a common approach to consider Germany as reference value of a risk-free interest rate. This is because Germany is the largest economy in the European Union and has the best credit risk according to the 'Big Three' credit rating agencies.

[9] Most research analyze the inequality-insurance-nexus in the context of health insurance (see, for example, Burkhauser and Simon, 2010; Kaestner and Lubotsky, 2016).

[10] However, the academic literature also discusses whether individuals over- or underweight low-probability events. According to the widespread opinion, people overweight probabilities within a fixed decision-making framework, but underweight when assessing risks from experience (see, for instance, Barberis, 2013).

[11] To illustrate, Bezos could pay each of his Amazon employees about 105,000 USD and would still be as rich as before the pandemic (see Reich, 2020).

[12] The top five U.S. companies by market capitalization (in USD) as of March 31, 2020 are: 1. Microsoft; 1,200; 2. Apple: 1,113; 3. Amazon 971; 4. Alphabet: 799; 5. Facebook 475 (see PwC, 2020).

[13] In academia, there are also theories that productivity growth, despite technological change, can nevertheless be declining – also known as the 'productivity paradoxon' (see, for instance, Dewan and Kraemer, 1998).

[14] See also Burgoon, van Noort, Rooduijn, and Underhill (2018) for more evidence on European countries, like the UK or Germany.

[15] According to this theory a certain degree of inequality is necessary to promote economic growth at the top, which then 'trickles down' to the poorer social strata.

[16] See, for a detailed argumentation of the two mentioned counterarguments, the book 'Anti-Piketty: Capital for the 21st Century' published by the Cato Institute (Delsol, Lecaussin, and Martin, 2017).

Bibliography

Abedi, V., Olulana, O., Avula, V., Chaudhary, D., Khan, A., Shahjouei, S., Li, J., Zand, R., 2020. Racial, Economic, and Health Inequality and COVID-19 Infection in the United States. Journal of Racial and Ethnic Health Disparities 8:3, 732–742.

Agnello, L., Sousa, R. M., 2012. How do Banking Crises Impact on Income Inequality? Applied Economics Letters 19:15, 1425–1429.

Aizenman, J., Jinjarak, Y., 2012. Income Inequality, Tax Base and Sovereign Spreads. National Bureau of Economic Research Working Paper Series 18176.

Amaral, P., 2017. Monetary Policy and Inequality. Federal Reserve Bank of Cleveland Economic Commentary 2017-01.

Asongu, S. A., Odhiambo, N. M., 2019. Insurance and Inequality in Sub-Saharan Africa: Policy Thresholds. International Social Science Journal 69:233-234, 185–197.

Barberis, N., 2013. The Psychology of Tail Events: Progress and Challenges. American Economic Review 103:3, 611–616.

Bazillier, R., Hericourt, J., 2017. The Circular Relationship between Inequality, Leverage, and Financial Crises. Journal of Economic Surveys 31:2, 463–496.

Bernanke, B. S., 2015. Monetary Policy and Inequality. `https://www.brookings.edu/blog/ben-bernanke/2015/06/01/monetary-policy-and-inequality/`, Accessed: January 20, 2021.

Bloomberg, 2021. Bloomberg's Billionaire Index. `https://www.bloomberg.com/billionaires/profiles/jeffrey-p-bezos/?sref=p7zS9UoY`. Accessed: February 5, 2021.

Bordo, M. D., Meissner, C. M., 2012. Does Inequality Lead to a Financial Crisis? Journal of International Money and Finance 31:8, 2147–2161.

Bruch, M., Münch, V., Aichinger, M., Kuhn, M., Weymann, M., Schmid, G., 2011. Power Blackout Risks: Risk Management Options. CRO Forum Emerging Risk Initiative – Position Paper.

Burgoon, B., van Noort, S., Rooduijn, M., Underhill, G. R. D., 2018. Radical right populism and the role of positional deprivation and inequality. LIS Working Paper Series.

Burkhauser, R. V., Simon, K. I., 2010. Measuring the Impact of Health Insurance on Levels and Trends in Inequality. National Bureau of Economic Research Working Paper Series 15811.

Cabral, C., 2019. Income Inequality: An Underlying Threat to Sustainable Growth. Swiss Re Institute Economic Insights 18/2019.

Chancel, L., 2019. Ten Facts about Inequality in Advanced Economies. WID.World Working Paper 2019/15.

Choe, J., 2008. Income Inequality and Crime in the United States. Economics Letters 101:1, 31–33.

Čihák, M., Sahay, R., 2020. Finance and inequality. IMF Staff Discussion Notes SDN/20/01.

Coibion, O., Gorodnichenko, Y., Kueng, L., Silvia, J., 2017. Innocent Bystanders? Monetary Policy and Inequality. Journal of Monetary Economics 88, 70–89.

De Haan, J., Sturm, J.-E., 2017. Finance and Income Inequality: A Review and New Evidence. European Journal of Political Economy 50, 171–195.

De Michelis, A., 2009. Overcoming The Financial Crisis In The United States. OECD Economics Department Working Papers No. 669.

Delsol, J.-P., Lecaussin, N., Martin, E., 2017. Anti-Piketty: Capital for the 21st Century. Cato Institute, Washington, D.C.

Dewan, S., Kraemer, K. L., 1998. International Dimensions of the Productivity Paradox. Communications of the ACM 41:8, 56–62.

Dolls, M., Doorley, K., Paulus, A., Schneider, H., Sommer, E., 2019. Demographic Change and the European Income Distribution. The Journal of Economic Inequality 17:3, 337–357.

Domanski, D., Scatigna, M., Zabai, A., 2016. Wealth inequality and monetary policy. BIS Quarterly Review March 2016 .

Elsberg, M., 2012. Blackout – Morgen ist es zu spät. Blanvalet Verlag, München.

Enz, R., 2000. The S-Curve Relation between Per-Capita Income and Insurance Penetration. The Geneva Papers on Risk and Insurance – Issues and Practice 25:3, 396–406.

EU, 2016. Consolidated Versions of the Treaty on European Union and the Treaty on the Functioning of the European Union (2016/C 202/01). Title I: Common Provisions, Article 3 (ex Article 2 TEU).

Ferreira Dias Dos Santos, A. P., 2014. The impact of the income inequality on the sovereign credit risk: A panel approach for 26 european countries during 2005-2010. University Institute of Lisbon, IUL School of Social Sciences, Department of Political Economy.

Financial Times, 2016. Europe's Drive to Save Jobs Risks Fuelling North-South Inequality. `https://www.ft.com/content/ff31b665-22e7-4439-817f-75477bc77082`, Accessed: January 16, 2021.

Furceri, D., Loungani, P., Zdzienicka, A., 2018. The Effects of Monetary Policy Shocks on Inequality. Journal of International Money and Finance 85, 168–186.

German Federal Statistical Office, 2018. Wirtschaftsrechnungen: Einkommens- und Verbrauchsstichprobe. Fachserie 15. Heft 1.

Grossmann, V., Strulik, H., 2019. Optimal Social Insurance and Health Inequality. German Economic Review 20:4, 913–948.

Gu, X., Huang, B., 2014. Does Inequality Lead to a Financial Crisis? Revisited. Review of Development Economics 18:3, 502–516.

Guerello, C., 2018. Conventional and Unconventional Monetary Policy vs. Households Income Distribution: An Empirical Analysis for the Euro Area. Journal of International Money and Finance 85, 187–214.

Gyourko, J., Mayer, C., Sinai, T., 2013. Superstar Cities. American Economic Journal: Economic Policy 5:4, 167–199.

Hacker, J. S., Rehm, P., 2020. Reducing Risk as well as Inequality: Assessing the Welfare State's Insurance Effects. British Journal of Political Science.

Helgadóttir, O., 2016. Banking Upside Down: The Implicit Politics of Shadow Banking Expertise. Review of International Political Economy 23, 915–940.

Holt, R. P., Greenwood, D. T., 2012. Negative Trickle-Down and the Financial Crisis of 2008. Journal of Economic Issues 46, 363–370.

Jeon, K., Kabukcuoglu, Z., 2018. Income Inequality and Sovereign Default. Journal of Economic Dynamics and Control 95, 211–232.

Kaestner, R., Lubotsky, D., 2016. Health Insurance and Income Inequality. Journal of Economic Perspectives 30:2, 53–78.

Kim, D.-H., Lin, S.-C., 2011. Nonlinearity in the Financial Development–Income Inequality Nexus. Journal of Comparative Economics 39:3, 310–325.

Kim, Y. K., 2017. Inequality and Sovereign Default under Democracy. Journal of Economics and Financial Analysis 1:1, 81–115.

King, A. D., Harrington, L. J., 2018. The Inequality of Climate Change From 1.5 to 2°C of Global Warming. Geophysical Research Letters 45:10, 5030–5033.

King, J., 2017. The Literature on Piketty. Review of Political Economy 29:1, 1–17.

Kirschenmann, K., Malinen, T., Nyberg, H., 2016. The Risk of Financial Crises: Is there a Role for Income Inequality? Journal of International Money and Finance 68, 161–180.

Krugman, P., 2011. Inequality and Crises: Coincidence or Causation? Presented at The Politics of the Economic Crisis Conference Princeton University, March 5–6.

Krusell, P., Ohanian, L. E., Ríos-Rull, J.-V., Violante, G. L., 2000. Capital-skill Complementarity and Inequality: A Macroeconomic Analysis. Econometrica 68:5, 1029–1053.

Kunze, F., Basse, T., Rodriguez Gonzalez, M., Vornholz, G., 2020. Forward-Looking Financial Risk Management and the Housing Market in the United Kingdom: Is there a Role for Sentiment Indicators? The Journal of Risk Finance 21:5, 659–678.

Lehtonen, T.-K., Liukko, J., 2015. Producing Solidarity, Inequality and Exclusion Through Insurance. Res Publica 21:2, 155–169.

Lohse, R., Rodriguez Gonzalez, M., Schröder, M., Morgenroth, H., Himmelreicher, R., 2016. Erwerbsminderung, Arbeitslosigkeit und Krankheit im Kontext der Erwerbsbiografien sozialversicherungspflichtig Beschäftigter. Zeitschrift für Versicherungswesen 8, 252–258.

Lysandrou, P., 2011. Global Inequality as one of the Root Causes of the Financial Crisis: A Suggested Explanation. Economy and Society 40:3, 323–344.

Madsen, J. B., Islam, M. R., Doucouliagos, H., 2018. Inequality, Financial Development and Economic Growth in the OECD, 1870–2011. European Economic Review 101, 605–624.

Mah-Hui, M. L., Ee, K. H., 2011. From Marx to Morgan Stanley: Inequality and Financial Crisis. Development and Change 42:1, 209–227.

Medeiros, V., Ribeiro, R. S. M., 2020. Power Infrastructure and Income Inequality: Evidence from Brazilian State-Level Data Using Dynamic Panel Data Models. Energy Policy 146, DOI: `https://doi.org/10.1016/j.enpol.2020.111734`.

Meier, S., Rodriguez Gonzalez, M., Kunze, F., 2021. The Global Financial Crisis, the EMU Sovereign Debt Crisis and International Financial Regulation: Lessons from a Systematic Literature Review. International Review of Law and Economics 65, DOI: https://doi.org/10.1016/j.irle.2020.105945.

Milanovic, B., Lindert, P. H., Williamson, J. G., 2010. Pre-Industrial Inequality. The Economic Journal 121:551, 255–272.

Mumtaz, H., Theophilopoulou, A., 2017. The Impact of Monetary Policy on Inequality in the UK. An Empirical Analysis. European Economic Review 98, 410–423.

Neves, P. C., Afonso, O., Silva, S. T., 2016. A Meta-Analytic Reassessment of the Effects of Inequality on Growth. World Development 78, 386–400.

O'Farrell, R., Rawdanowicz, L., 2017. Monetary Policy and Inequality: Financial Channels. International Finance 20:2, 174–188.

Pastor, L., Veronesi, P., 2018. Inequality Aversion, Populism, and the Backlash Against Globalization. National Bureau of Economic Research Working Paper Series 24900.

Pickett, K. E., Wilkinson, R. G., 2010. Inequality: An Underacknowledged Source of Mental Illness and Distress. British Journal of Psychiatry 197:6, 426—-428.

Piketty, T., 2013. Capital in the 21st Century. Harvard University Press, Cambridge.

Pressman, S., 2011. Consequences of Economic Downturn: Beyond the Usual Economics, in: Inequality and Its Discontents: The Real Causes and Consequences of the Crisis (Editor: Starr, M. A.). Palgrave Macmillan, Basingstoke, 83–101.

PwC, 2020. Global Top 100 Companies by Market Capitalisation. https://www.pwc.de/de/kapitalmarktorientierte-unternehmen/ranking-der-100-wertvollsten-unternehmen-der-welt-2020.html. Accessed: January 5, 2021.

Rajan, R. G., 2010. Fault Lines: How Hidden Fractures still Threaten the World Economy. Princeton University Press.

Rawls, J., 1971. A Theory of Justice. Belknap Press, Cambridge.

Reich, R., 2020. Jeff Bezos Became even Richer thanks to COVID-19. But he still won't Protect Amazon Workers. The Guardian. https://www.theguardian.com/commentisfree/2020/dec/12/jeff-bezos-amazon-workers-covid-19-scrooge-capitalism. Accessed: February 5, 2021.

Rodriguez Gonzalez, M., Basse, T., Kunze, F., Vornholz, G., 2018. Early Warning Indicator Systems for Real Estate Investments: Empirical Evidence and some Thoughts from the Perspective of Financial Risk Management. Zeitschrift für die gesamte Versicherungswissenschaft 107:4, 387–403.

Rodriguez Gonzalez, M., Basse, T., Saft, D., Kunze, F., 2021a. Leading Indicators for US House Prices: New Empirical Evidence and some Thoughts from the Perspective of Financial Risk Management. European Financial Management. DOI: https://doi.org/10.1111/eufm.12325.

Rodriguez Gonzalez, M., Basse, T., Tholl, J., 2019. Interest Rate Differentials and Monetary Policy in the European Monetary Union: The Case of 10 and 30 Year Bonds. Zeitschrift für die gesamte Versicherungswissenschaft 108:1, 19–42.

Rodriguez Gonzalez, M., Kunze, F., Schwarzbach, C., Dieng, C., 2017. Asset Liability Management and the Euro Crisis: Sovereign Credit Risk as a Challenge for the German Life Insurance Industry. The Journal of Risk Finance 18:4, 466–483.

Rodriguez Gonzalez, M., Lohse, R., Schröder, M., Krohn, S., Zuchandke, A., 2015. Sozioökonomische Analyse des Erwerbsminderungsrisikos – Eine Untersuchung anhand von BASiD-Daten. Zeitschrift für die gesamte Versicherungswissenschaft 104:2, 151–178.

Rodriguez Gonzalez, M., Wegener, C., Basse, T., 2021b. Re-Investigating the Insurance-Growth Nexus Using Common Factors. Finance Research Letters. DOI: https://doi.org/10.1016/j.frl.2021.102231.

Samarina, A., Nguyen, A. D. M., 2019. Does monetary policy affect income inequality in the euro area? De Nederlandsche Bank Working Paper No. 626.

Stockhammer, E., 2015. Rising Inequality as a Cause of the Present Crisis. Cambridge Journal of Economics 39, 935–958.

The Geneva Association, 2020. The Role of Insurance in Mitigating Social Inequality. https://www.genevaassociation.org/research-topics/socio-economic-resilience/insurance-mitigating-social-inequality. Accessed: January 15, 2021.

Tholl, J., Basse, T., Meier, S., Rodriguez Gonzalez, M., 2021. Risk Premia and the European Government Bond Market: New Empirical Evidence and some Thoughts from the Perspective of the Life Insurance Industry. Zeitschrift für die gesamte Versicherungswissenschaft. DOI: https://doi.org/10.1007/s12297-021-00503-2.

Thorbecke, E., Charumilind, C., 2002. Economic Inequality and its Socioeconomic Impact. World Development 30:9, 1477–1495.

Tomz, M., Wright, M. L. J., 2007. Do Countries Default in "Bad Times"? Journal of the European Economic Association 5:2–3, 352–360.

UN Office on Drugs and Crime, 2020. Socioeconomic Characteristics and Drug Use Disorders. https://wdr.unodc.org/wdr2020/en/socioeconomic.html. Accessed: January 19, 2021.

Van Treeck, T., 2014. Did Inequality Cause the U.S. Financial Crisis? Journal of Economic Surveys 28:3, 421–448.

Vanella, P., Rodriguez Gonzalez, M., Wilke, C., 2021. The Impact of Population Aging on the German Statutory Pension System — A Probabilistic Approach. Hannover Economic Papers (HEP), No. 688.

Vogel, S. K., 2021. The Regulatory Roots of Inequality in America. Journal of Law and Political Economy 1:2, 272–300.

Wilkinson, R. G., Pickett, K. E., 2006. Income Inequality and Population Health: A Review and Explanation of the Evidence. Social Science & Medicine 62:7, 1768–1784.

Wisman, J. D., Baker, B., 2011. Rising Inequality and the Financial Crises of 1929 and 2008, in: Inequality and Its Discontents: The Real Causes and Consequences of the Crisis (Editor: Starr, M. A.). Palgrave Macmillan, Basingstoke, 63–82.

World Economic Forum, 2016. The Fourth Industrial Revolution: What it Means, How to Respond. https://www.weforum.org/agenda/2016/01/the-fourth-industrial-revolution-what-it-means-and-how-to-respond/. Accessed: January 10, 2021.

Wrede, D., Linderkamp, T., Rodriguez Gonzalez, M., 2017. Risks of the German Power Supply System. Zeitschrift für Energiewirtschaft 41:2, 105–117.

Zhang, R., Ben Naceur, S., 2019. Financial Development, Inequality, and Poverty: Some International Evidence. International Review of Economics & Finance 61, 1–16.

Module 1

Sozioökonomische Analyse des Erwerbsminderungsrisikos — Eine Untersuchung anhand von BASiD-Daten

Rodriguez Gonzalez, M. / Lohse, R. / Schröder, M. / Krohn, S. / Zuchandke, A. (2015)

Published in:
Zeitschrift für die gesamte Versicherungswissenschaft, Vol. 104, No. 2, pp. 151-178. DOI: https://doi.org/10.1007/s12297-015-0300-3.

ZVersWiss (2015) 104:151–178
DOI 10.1007/s12297-015-0300-3

ABHANDLUNG

Sozioökonomische Analyse des Erwerbsminderungsrisikos – Eine Untersuchung anhand von BASiD-Daten

Miguel Rodriguez Gonzalez · Ralf Lohse · Mathias Schröder · Sabrina Krohn · Andy Zuchandke

Online publiziert: 21. Mai 2015

Zusammenfassung Ziel dieser Arbeit ist ein Vergleich von Erwerbsminderungsrisiken unterschiedlicher sozioökonomischer Untersuchungsgruppen. Dabei soll der Forschungsfrage nachgegangen werden, wie stark sich die Erwerbsminderungsrisiken einzelner Bildungs-, Berufs- und Einkommensgruppen unterscheiden und welche Schlussfolgerungen sich aus der Erwerbshistorie ergeben. Die Ergebnisse sind sowohl für die Versicherungswirtschaft als auch -wissenschaft von Relevanz. In der Versicherungsmathematik können Rückschlüsse innerhalb der sekundären Prämiendifferenzierung getroffen werden und in der Sozialpolitik sind Implikationen durch die Analyse sozioökonomischer Faktoren möglich. Dabei werden evidenzbasierte Berechnungen der Erwerbsminderungsrisiken auf der Grundlage von bevölkerungsrepräsentativen personenbezogenen Längsschnittdaten des BASiD-Themenfiles durchgeführt werden. Die Verwendung der BASiD-Daten ermöglicht darüber hinaus die Berücksichtigung von Erwerbsbiografien mit mehreren Beschäftigungs- oder Arbeitslosigkeitszeiten. Auf der Datengrundlage der Längsschnittdaten von

Die in dieser Veröffentlichung geäußerten Inhalte und Ansichten sind allein die des Autors A. Zuchandke. Der Autor A. Zuchandke ist Mitarbeiter bei der VHV Allgemeine Versicherung AG. Der Beitrag gibt ausschließlich seine persönliche Meinung wieder.

M. Rodriguez Gonzalez (✉)
Institut für Versicherungsbetriebslehre, Leibniz Universität Hannover,
Königsworther Platz 1,
30167 Hannover, Deutschland
E-Mail: mr@ivbl.uni-hannover.de

Dr. rer. pol. R. Lohse · M. Schröder · S. Krohn
E+S Rückversicherung AG,
Karl-Wiechert-Allee 50,
30625 Hannover, Deutschland

Dr. rer. pol. A. Zuchandke
VHV Allgemeine Versicherung AG,
VHV-Platz 1,
30177 Hannover, Deutschland

sozialversicherungspflichtig Beschäftigten werden die relativen Häufigkeiten der Rentenzugänge wegen Erwerbsminderung für diverse sozioökonomische Statusgruppen berechnet. Dabei wird eine getrennte Untersuchung von männlichen und weiblichen in Deutschland lebenden Versicherten zwischen 30 und 59 Jahren vorgenommen, die in ihrer Erwerbsphase in einem westdeutschen Betrieb gearbeitet haben. Zur weiteren Analyse wird eine Cox Regression durchgeführt, um den gemeinsamen Einfluss der untersuchten Faktoren auf die Übergangsraten untersuchen zu können.

Abstract The aim of this work is a comparison of disability risks of different socio-economic study groups. It will be examined how much the disability risks of certain educational, occupational, and income groups differ. Additionally the employment history of the individuals will be analyzed. The results are relevant for both, insurance industry and science. From the actuarial perspective conclusions can be drawn with regard to the secondary premium differentiation. Implications for the social policy can be drawn from the analysis of the socio-economic factors. Evidence-based calculations of individual disability risks are carried out on the basis of population-representative longitudinal data from the BASiD theme files. Using BASiD data also allows the integration of careers with several periods of employment or unemployment. Based on the longitudinal data of employees paying mandatory social security contributions, the relative frequencies of new benefits due to disability for various socio-economic status groups are calculated. The analysis focuses on insured persons living in Germany, aged between 30 and 59 years, and working in a West German company during their employment phase while distinguishing between males and females. For further analysis, a Cox regression is performed in order to investigate the collective influence of the investigated factors on the transition rates.

1 Einleitung

Knapp 53 Mio. Versicherte ohne Rentenbezug führen ein Konto in der gesetzlichen Rentenversicherung (GRV) als Teil des deutschen Sozialsystems.[1] Neben einem Anspruch auf eine Rente wegen Alters sieht diese Versicherung sowohl einen Hinterbliebenenschutz sowie eine Erwerbsunfähigkeitsabsicherung vor. Eine verminderte Erwerbsfähigkeit bzw. eine Erwerbsminderung (EM) ist definiert als die Einschränkung oder der Verlust von Fähigkeiten den eigenen Lebensunterhalt durch eine Erwerbstätigkeit zu bestreiten und kann im internationalen Sprachgebrauch synonym mit dem Begriff der Invalidität verwendet werden.[2]

Das Invaliditätsrisiko wurde nach Implementierung der deutschen Sozialversicherung erstmals durch die Alters- und Hinterbliebenenrente versichert. Diese wurde zum 01. Januar 1891 unter Otto von Bismarck eingeführt, sodass eine Absicherung

[1] Stand: 31.12.2014. Vgl. DRV (2014), S. 17.

[2] Vgl. Rehfeld (2006), S. 7.

des Risikos einer Erwerbsminderung bereits seit mehr als 120 Jahren ein wesentlicher Bestandteil der Rentenversicherung in Deutschland ist.

Der durch Geburtenrückgang und Anstieg der Lebenserwartung bedingte demografische Wandel hat eine Reduzierung des Verhältnisses von Erwerbsminderungsrente zu Altersrente bewirkt. Nichtsdestotrotz erhalten heute etwa noch ein Fünftel aller Leistungsempfänger der GRV eine EM-Rente, sodass wissenschaftlichen Betrachtungen und daraus folgenden aktuariellen und sozioökonomischen bzw. -politischen Implikationen weiterhin ein hoher Stellenwert zugeschrieben werden kann. In der privatwirtschaftlichen Versicherungsmathematik können Rückschlüsse durch sekundäre Prämiendifferenzierung in der Berufsunfähigkeitsversicherung getroffen werden. In der Sozialpolitik der GRV sind Implikationen durch die Analyse sozioökonomischer Faktoren möglich. Durch die Relevanz dieser Fragestellungen ist es notwendig, eine ausreichende Erkenntnistiefe bezüglich der Determinanten des Invaliditätsrisikos zu generieren.

Deskriptive und induktive statistische Analysen zu Invalidisierungsraten sozioökonomischer Untersuchungsgruppen innerhalb der deutschen Erwerbsminderungsrente finden sich in der sozial- bzw. versicherungsökonomischen Forschung bislang relativ selten. Eine Vielzahl der Literatur basiert dabei auf Querschnitts- oder Längsschnittdatenerhebungen, sodass eine empirisch fundierte Deckung des Forschungsbedarfs auf Paneldatenniveau förderlich ist. Ein Vorteil von Paneldaten im Vergleich zu einer getrennten Querschnitts- bzw. Trendanalyse ist die genauere Bearbeitung kausaler Untersuchungen. Entwicklungen über die Zeit können an der gleichen Untersuchungsperson auf Basis von Individualdaten dargestellt werden.

Das Panel BASiD, der prozessproduzierte Forschungsdatensatz der Rentenversicherung (RV) und der Bundesagentur für Arbeit im Institut für Arbeitsmarkt- und Berufsforschung (BA/IAB), bietet eine große Datenbasis, um Untersuchungen verschiedener Bevölkerungsgruppen durchzuführen.[3] Klassifizierungen innerhalb des Datensatzes werden durch die sogenannte Blossfeld-Berufsklassifikation vorgenommen. Dabei wird der Forschungsfrage nachgegangen, wie stark sich das Erwerbsminderungsrisiko einzelner Bildungs-, Einkommens- und Berufsgruppen unterscheidet und welche Implikationen aus der Erwerbshistorie, sowie der tatsächlich ausgeübten Tätigkeit geschlossen werden können. Hierbei werden evidenzbasierte Berechnungen der Erwerbsminderungsrisiken auf Grundlage von bevölkerungsrepräsentativen personenbezogenen Längsschnittdaten des BASiD-Themenfiles durchgeführt. Wissenschaftliche Publikationen mit ähnlichen Fragestellungen und derselben Datengrundlage sind nicht bekannt. Neben der Analyse dieser Biografiedaten in Bezug auf EM-Zugangsraten einzelner Bevölkerungsgruppen, wird der vorhandene Datensatz somit erstmals mit Hilfe einer Überlebenszeitanalyse basierend auf dem Cox Regressionsmodell untersucht, um den gemeinsamen Einfluss sozioökonomischer Risikofaktoren einer Erwerbsminderung zu modellieren.[4]

Im nachfolgenden Kapitel wird vorerst ein Überblick über die nationale und internationale Literatur zum Thema Erwerbsminderung gegeben. In Kap. 3 findet eine ausführliche Beschreibung des BASiD-Datensatzes und der angewandten Methodik

[3] BASiD steht für „Biografiedaten ausgewählter Sozialversicherungsträger in Deutschland".

[4] Vgl. Cox (1972), S. 187 ff.

statt, um eine Nachvollziehbarkeit der Ergebnisse zu gewährleisten. Im vierten Kapitel dieser Arbeit werden die Auswertungen der deskriptiven und induktiven Analysen präsentiert und anschließend diskutiert und rezensiert.

2 Stand der Forschung

In Bezug auf das deutsche Rentensystem befasst sich eine Vielzahl an Publikationen mit der Entwicklung elementarer Kennzahlen der GRV, wie der absoluten oder relativen Anzahl an EM-Rentenzugängen, dem durchschnittlichen EM-Rentenzugangsalter oder der durchschnittlichen Höhe von EM-Renten. Dabei werden verschiedene Kriterien im Zusammenhang mit einer EM-Rente untersucht. Einige Studien differenzieren primär nach medizinischen Diagnosegruppen[5] oder nach Geschlecht.[6] Andere Arbeiten dagegen beziehen sich additional zu soziodemografischen Faktoren auch auf sozioökonomische Determinanten des Invaliditätsrisikos. Einige Ergebnisse sehen vor allem Männer gegenüber Frauen und Ostdeutsche gegenüber Westdeutschen einem höheren Risiko einer EM ausgesetzt. Des Weiteren gehen sie davon aus, dass das EM-Risiko mit zunehmender beruflicher Qualifikation -auch bei geschlechtsspezifischer Betrachtung- sinkt.[7] Dieser Zusammenhang gilt auch, wenn die Ergebnisse bezüglich der individuellen Arbeitsbedingungen und anderen Risikofaktoren angepasst werden.[8] Weitere Literatur analysiert zusätzlich zum Berufsstand den Bildungsabschluss als weitere sozioökonomische Variable.[9] Laut einer norwegischen Studie sind ein niedriger Bildungsstand sowie beschäftigungsrelevante Faktoren neben einer niedrigen subjektiven Gesundheitswahrnehmung und langanhaltenden Gesundheitsproblemen die stärksten unabhängigen Determinanten einer EM.[10] Andere Autoren kommen zu ähnlichen Ergebnissen, bezogen auf die sozioökonomischen Faktoren Bildung und Beruf.[11] Dabei scheint der Zusammenhang zwischen der sozialen Position und dem Gesundheitszustand stark mit der jeweiligen sozioökonomischen Klassifikation zu variieren.[12] Dennoch wird in der Literatur ein starker Zusammenhang zwischen ausgeübter Erwerbstätigkeit und der Entstehung chronischer Erkrankungen bzw. gesundheitlicher Belastung sowie statusniedrigeren Berufen und einer vermehrten Gesundheitsbelastung vermutet.[13] Bezüglich des Einkommens sehen einige Studien einen negativen Zusammenhang zur mittleren Lebenserwartung, wodurch

[5] Vgl. Bäcker et al. (2013), S. 51 ff.

[6] Vgl. Kaldybajewa und Kruse (2012), S. 206 ff.

[7] Vgl. Hagen et al. (2010), S. 1 ff.

[8] Vgl. Månsson et al. (1998), S. 1019 ff.

[9] Vgl. Arbeitnehmerkammer Bremen (2013), S. 1 ff.

[10] Vgl. Krokstad et al. (2002), S. 1183 ff.

[11] Vgl. Gravseth et al. (2007), S. 533 ff.; Samuelsson et al. (2012), S. 1999 ff. und Karlsson et al. (2008), S. 224 ff.

[12] Vgl. Macintyre et al. (2003), S. 288 ff.

[13] Vgl. Wurm und Tesch-Römer (2008), S. 131 ff.; Naegele und Sporket (2010), S. 449 ff. und Mika (2013), S. 391 ff.

die Wahrscheinlichkeit einer vorherigen EM erhöht wird.[14] Weitere Analysen ermitteln die Faktoren Alter, Gesundheit und Lohn vor Eintritt der Invalidität als stärkere Prädiktoren einer EM wie die erwarteten Unterstützungsleistungen des Rentenversicherungsträgers.[15] Andere Autoren schlussfolgern, dass ein niedriges Bildungsniveau das Risiko einer chronischen Erkrankung und damit einer EM erhöht.[16] In Zusammenfassend gibt es Hinweise darauf, dass Personen, die in Bezug auf Qualifikation, Berufsstatus und Einkommen als benachteiligt angesehen werden, vermehrt chronische Krankheiten und andere gesundheitliche Beschwerden auftreten.[17] Andere Autoren wiederum sehen vor allem die Arbeitsmarktsituation als erklärende Variable einer Inanspruchnahme der EM-Rente. So wird ein Zusammenhang vor allem für junge Versicherte,[18] bzw. zwischen Langzeitarbeitslosigkeit und einer schlechteren Gesundheit vermutet.[19] Antagonistisch zu den obigen Ausführungen kommen andere Studien zu dem Ergebnis, dass vor allem Anreizeffekte durch erwartete Sozialversicherungszahlungen das Arbeitsangebot bzw. die Inanspruchnahme einer EM-Rente beeinflussen.[20] Weitere Studien kommen zu ähnlichen Ergebnissen bezogen auf das deutsche Rentensystem.[21]

3 Datenbasis und Methodik

3.1 BASiD-Datensatz

Der BASiD-Datensatz ist ein Biografiedatensatz, erstellt vom Forschungsdatenzentrum der Rentenversicherung (FDZ-RV) und dem Forschungsdatenzentrum der Bundesagentur für Arbeit im Institut für Arbeitsmarkt- und Berufsforschung (FDZ-BA/IAB). Der Datensatz stellt selektierte prozessproduzierte Daten zur Verfügung, die sich aufgrund ihres großen Umfanges für sozioökonomische Analysen eignen, da die gesamte Rentenversicherungsbiografie und somit das vollständige Versichertenleben abgebildet wird.[22] Dabei wird dem aus den Routinedaten der Sozialversicherungsträger gewonnenen Datensatz hinsichtlich der „[…] Analyse des sozial ungleich verteilten Krankheits- und Sterberisikos[…]“[23] eine ansteigende Relevanz zugesprochen. BASiD ist das erste Projekt mit dem Ziel einen gemeinsamen Datensatz aus den Daten der RV und der BA bzw. IAB zu erstellen und der Wissenschaft anzubieten.

[14] Vgl. SVR (2006), S. 1 ff.; Lampert et al. (2007), S. 11 und Himmelreicher et al. (2008), S. 274 ff.

[15] Vgl. Riphahn (1999), S. 628.

[16] Vgl. Märtin und Zollmann (2013), S. 1 ff.

[17] Vgl. Mielck (2000), S. 1 ff. und Mielck (2005), S. 1 ff.

[18] Vgl. Brussig (2012), S. 1 ff.

[19] Vgl. Hollederer (2011), S. 1 ff.

[20] Vgl. Gruber und Wise (1999), S. ff.

[21] Vgl. Börsch-Supan (1992), S. 533 ff. und Börsch-Supan (2000), S. 25 ff.

[22] Ab 1975 ergänzt um Angaben zu Beschäftigung bzw. Leistungsbezug der BA und ab 2000 um Maßnahmen der BA.

[23] Hagen et al. (2010), S. 86.

Die Basisdaten der Versicherungskontenstichprobe (VSKT) der Rentenversicherung wurden durch Daten der Bundesagentur für Arbeit (BA) via Datenmatching erweitert.[24] Dabei wird auf die Integrierten Erwerbsbiografien (IEB) und das Betriebs-Historik-Panel (BHP) der BA/IAB zurückgegriffen. Die IEB enthalten Daten zu den sozialversicherungspflichtig Beschäftigten (ab 1975) und zu Personen mit Leistungsbezug sowie Zeiten der Arbeitssuche und Maßnahmenteilnahmen (ab 1990). Das BHP beinhaltet alle Betriebe seit 1975 in Deutschland, die jeweils zum 30. Juni mindestens einen sozialversicherungspflichtig Beschäftigten bzw. ab 1999 mindestens einen geringfügig Beschäftigten aufweisen.[25] Somit wurden Angaben zu personenbezogenen Daten aus dem Meldeverfahren zur Sozialversicherung und Daten aus dem Verwaltungsverfahren beider Institutionen abgeglichen und zusammengeführt.

Die VSKT der RV enthält biografiebezogene Daten über versicherungsrechtlich relevante Zeiten der betrachteten Versicherten. Hierzu zählen datentechnische und soziodemografische Merkmale (z. B. Versichertennummer, Geschlecht, Alter, Wohnort, Anzahl und Alter der Kinder, Versicherungsstatus, Ausbildung und Beruf, etc.), sowie Merkmale aus der Gesamtleistungsbewertung (z. B. durchschnittliche Entgeltpunkte, belegungsfähige Zeiten, Anteil der Entgeltpunkte (Ost/West), Berücksichtigungszeiten, berücksichtigte Entgeltpunkte, etc.) und der Rentenberechnung (z. B. Versorgungsausgleich, vollwertige bzw. geminderte Beitragszeiten, An- bzw. Zurechnungs- oder Ersatzzeiten, Pflichtbeiträge, zusätzliche Mindestentgeltpunkte, etc.). Diese meist fixen Angaben werden durch monatsbezogene Angaben zur sozialen Erwerbssituation, wie Krankheit, Arbeitslosigkeit, Kindererziehungszeit bzw. Berücksichtigungszeit, sowie detaillierten Entgeltpunktinformationen ergänzt. Somit stellt BASiD einen Datensatz aus zeitabhängigen personenbezogenen Sozialdaten (Längsschnittdaten) dar. Die VSKT dient als Operationsbasis für interne und legislative Planungsaufgaben sowie der Konsultation der Politik. Der generierte monatsbezogene Sequenzdatensatz wird als Scientific Use File (SUF), unter der Prämisse der vertraglich festgelegten Nutzungsbedingungen, kostenlos für wissenschaftliche Zwecke zur Verfügung gestellt. Die Bereitstellung erfolgt in vollständig anonymisierter Version über das FDZ-RV oder als schwach anonymisierte Version in Verbindung mit einem Gastaufenthalt im FDZ-BA/IAB.

Zur Grundgesamtheit gehören alle Versicherten, die zum 31. Dezember des Berichtsjahres mindestens 30 und höchstens 67 Jahre alt sind, deren Versichertenkonto zum Stichtag mindestens einen Eintrag enthält und nicht stillgelegt oder aufgrund des Todes des Versicherten aus der Stichprobe entnommen wurde. Die disproportional geschichtete Stichprobe wurde 1983 erstmals gezogen und seither als Panel fortgeschrieben. Die Fallzahlen belaufen sich auf insgesamt 60.809. Eine Repräsentativität der Ergebnisse, auf die Grundgesamtheit aller Versicherter bezogen, lässt sich durch entsprechende Hochrechnungen mit Hilfe des Hochrechnungsfaktors (Datenfeld: *HRF*) erreichen. Das hier untersuchte SUF „FDZ-RV – SUFBASiD07“ stellt eine 25 %-Stichprobe für die Jahrgänge 1940 bis 1977 aller inländischen deutschen Versicherten dar. Da in diesen Analysen lediglich westdeutsche Versicherte betrachtet

[24] Eine ausführliche Beschreibung zum Datenmatching findet sich in Hochfellner und Voigt (2010).

[25] Ab 1975 liegen Querschnittsdatensätze für Westdeutschland vor, die seit 1992 für die gesamte Bundesrepublik Deutschland fortgeführt werden.

werden, sind die Hochrechnungsfaktoren jedoch nicht erforderlich, um eine statistische Repräsentativität der Ergebnisse für die Grundgesamtheit zu erhalten.[26] Durch den zusätzlichen Ausschluss der ostdeutschen Bundesländer weisen die Anteile in den Schichten der als Datengrundlage verwendeten Stichprobe keine Disproportionalitäten mehr auf und entsprechen somit den Anteilen innerhalb der Grundgesamtheit (Westdeutschland).

Der Datensatz gliedert sich grob in drei Teile: Der variable Datenteil enthält zeitveränderliche biografiebezogene Personenmerkmale, insbesondere sozio-demografische Merkmale sowie taggenaue Informationen zu Beschäftigung, Leistungsbezug und Arbeitssuche. Außerdem enthält dieser Teil regionale und datentechnische Merkmale, alle Pflichtbeitrags-, Anrechnungs- und Berücksichtigungszeiten wie zum Beispiel Informationen zu Erziehungszeiten, Krankheit und Rente. Des Weiteren stehen Informationen zur Betriebszugehörigkeit, Zeiten der Arbeitssuche und Maßnahmen wie Qualifizierungen und Weiterbildungen zur Verfügung. Der fixe Datenteil enthält sämtliche datentechnischen und demografischen Personenmerkmale zum Stichtag sowie Angaben der fiktiven Rentenberechnung.[27] Dazu zählen alle Merkmale, die zur Grundleistungsbewertung der Rente herangezogen werden, wie die Anzahl der Kinder oder der Versicherungsstatus. Der dritte Teil beinhaltet Betriebsdaten aus dem Betriebs-Historik-Panel (BHP). Dieses Panel stellt Informationen zur Betriebsgröße sowie zur Beschäftigtenstruktur in den Unternehmen zum Stichtag eines jeden Jahres bereit.

Als EM-Rentner werden diejenigen Personen klassifiziert, die vor dem regulären Renteneintrittsalter Leistungen aus der gesetzlichen Rentenversicherung beziehen. Im BASiD-Datensatz sind Personen im Alter von 14 bis 67 Jahren enthalten, es werden in der vorliegenden Arbeit jedoch nur Personen von 14 bis 59 Jahren in die Analysen miteinbezogen, da ab dem 60. Lebensjahr keine klare Abgrenzung von Altersrentnern und EM-Rentnern möglich ist. Dies ist dem Umstand geschuldet, dass sowohl die Altersrente, als auch die EM-Rente aus der GRV finanziert werden und innerhalb des Datensatzes zwischen der Art der Rentenzahlung nicht differenziert werden kann. Inhaltlich lässt sich die Vorgehensweise begründen, da eine EM-Rente ab dem Alter 60 als substitutive Möglichkeit der Frühberentung gesehen werden kann.[28]

Die Identifizierung typischer sozioökonomischer Merkmale erwerbsgeminderter Personen erfolgt durch die Aufdeckung empirisch relevanter Determinanten einer EM. Durch das Matching der Daten entstehen neue Analysepotenziale für die Beantwortung dieser geisteswissenschaftlichen Forschungsfrage. Mit Hilfe des BASiD-Datensatzes stehen ausführliche institutionenübergreifende Informationen über die Lebenssituation von Individuen zur Verfügung, wodurch die erfassten Eigenschaften auf Einzelpersonen bezogen werden können und eine größere Heterogenität des Datensatzes entsteht.[29]

[26] Die Hochrechnungsfaktoren sind nur für das Jahr 2007 gegeben, sodass eine Paneldatenanalyse bei Verwendung dieser Methode nicht möglich ist.

[27] Die fixen Angaben werden stets zum Stichtag (31.12.2007) angegeben.

[28] Für eine Übersicht zu den unterschiedlichen Rentenarten vgl. beispielsweise Schmidt (1995), S. 16 ff.

[29] Vgl. Albrecht et al. (2007), S. 622.

Die Untersuchungen auf Paneldatenniveau erlauben Implikationen zu möglichen Kausalbeziehungen zwischen verschiedenen im Panel erhobenen Variablen, außerdem ist eine repräsentative Selektion sozioökonomischer Zielgruppen möglich. Weitere Vorteile des BASiD-Datensatzes liegen in der hohen Datenqualität durch Generierung der Daten aus RV-Konten, dem langen Beobachtungszeitraum, der Vermeidung von Antwortausfällen und Erinnerungsfehlern, den hohen Fallzahlen und der Vielzahl an Merkmalsausprägungen.[30] Nachteilig im Zusammenhang mit der Nutzung des Datensatzes ist die Tatsache, dass lediglich Forschungsfragen mit RV-Bezug beantwortet werden können und dass durch den Wegfall der Verstorbenen eine Verzerrung und damit eine Unterschätzung der Invalidisierungsraten von EM-Rentnern erfolgt. Aufgrund der statisch belegbaren höheren Sterblichkeit (bzw. geringeren ferneren Lebenserwartung) von EM-Rentnern und dem Wegfall dieser Personengruppe aus der Stichprobe sind die Schätzungen der Invalidisierungsraten nach unten hin verzerrt.[31] Trotz alledem sind die Daten geeignet, um erste Aussagen innerhalb der Paneldatenanalyse treffen zu können.

3.2 Methodik

Wie bereits beschrieben, analysiert diese Arbeit in welchem Ausmaß die schulische bzw. universitäre Bildung, das Erwerbseinkommen aus einer sozialversicherungspflichtigen Beschäftigung und der ausgeübte Beruf das Risiko einer Erwerbsminderung beeinflussen. Hierzu werden die jährlichen relativen Häufigkeiten der Erstzugänge der Rentenversicherten zu einer sozialversicherungsrechtlichen Erwerbsminderung, getrennt nach Bildungs-, Einkommens- und Berufsgruppen, berechnet und zunächst univariat analysiert. Die absoluten Erwerbsminderungsfälle sind in Relation zu den Versichertenjahren in Promille per annum (‰ p. a.) als relative EM-Risiken angegeben, wobei die Bezeichnungen EM-Rate, Invalidisierungsrate, Zugangsrate in EM, relative EM-Rentenzugänge, etc. synonym verwendet werden. Die deskriptiven Auswertungen ermöglichen eine Übersicht über den Datensatz und lassen eine Bewertung und Vergleichbarkeit der anschließenden multivariaten Analyse zu.

In dem BASiD-Datensatz stellt die (hoch-) schulische Ausbildung (Datenfeld: *BILD*) eine monatliche Verlaufsvariable dar, sodass einer erwerbsgeminderten Person der höchste bekannte Bildungsabschluss vor Eintritt der EM-Rente zugeordnet werden kann. Innerhalb der Kontrollgruppe (Personen ohne vorzeitige Berentung wegen EM) erfolgt die Zuordnung zu einer Bildungsgruppe über den höchsten bekannten Bildungsabschluss innerhalb des gesamten Beobachtungszeitraumes. Da jeder Person der höchste erreichte Bildungsstand eindeutig zugeordnet werden kann, erfolgt somit eine Risikoanalyse pro Versicherten. Dabei ist zu beachten, dass ein Fach- oder Hochschulabschluss als kombinierter Abschluss der Schul- und Berufsausbildung bewertet wird, da auf einen hochschulischen Abschluss zumeist der

[30] In der empirischen Sozialforschung tritt bei der Stichprobengenerierung mittels Befragungen das Phänomen der fehlerhaften Erinnerung zu vergangenem Verhalten am häufigsten auf. Vgl. hierzu Häder (2010), S. 309.

[31] Vgl. Kruse (2000), S. 121.

Berufseinstieg folgt.[32] Bei den allgemeinbildenden Schulabschlüssen wird zusätzlich nach Abschluss einer Berufsausbildung differenziert.

Das Einkommen eines Versicherten stellt die zweite sozioökonomische Einflussvariable dar, die als möglicher Risikoindikator für eine EM analysiert wird. Da der BASiD-Datensatz jedoch keine Informationen über das Einkommen der Versicherten bereitstellt, muss auf eine Proxy-Variable zurückgegriffen werden. Dabei dienen die jahresdurchschnittlichen persönlichen Entgeltpunkte eines Versicherten der Beobachtungszeiten in Erwerbstätigkeit und in Vollzeitbeschäftigung in der Analyse des EM-Risikos als Indikatorgröße für das Einkommen während der Erwerbsphase der untersuchten Personen.[33] Die Summe aller monatsbezogenen Entgeltpunkte verzeichnet alle Entgeltpunkte, die ein Versicherter in einem Monat erworben hat, unabhängig davon, ob die Entgeltpunkte aus einer Erwerbstätigkeit heraus resultieren, oder durch Berücksichtigungszeiten. Hierbei werden Entgeltpunkte aufgrund von Zweit- oder Drittbeschäftigung berücksichtigt, wie Zeiten ohne tatsächliche eigene Beitragszahlungen. Hierzu zählen die schulische Ausbildung, unbegrenzte und nicht erwerbsmäßige häusliche Pflege, die ersten zehn Jahre der Kindererziehung, als auch Zeiten der Arbeit im Haushalt, sowie Arbeitslosigkeit und der Bezuges von Altersrente. Um das reine Erwerbseinkommen in geeigneter Weise abzubilden, müssen die dafür angerechneten Entgeltpunkte extrahiert werden. Die Berechnungen wurden für die originären Entgeltpunkten in Beitragszeiten (Datenfeld: *MEGPT*) durchgeführt. Dieses Datenfeld gibt die Entgeltpunkte an, die aus der Haupterwerbstätigkeit resultieren. Somit lässt sich der Zusammenhang zwischen dem Einkommen aus der hauptberuflichen Tätigkeit und einer möglichen Invalidisierung untersuchen. Zur Zuordnung eines Versicherten in eine Einkommensklasse werden vier Quartile berechnet. In die Quartilsberechnung fließen nur jene Versicherte mit ein, die in ihrer Erwerbsphase mindestens einen Monat in Vollzeit tätig waren, um reine Teilzeitkräfte wegen der geringeren Arbeitszeit von vornherein aus der Analyse auszuschließen. Die Berechnung der Quartile selbst bzw. die Zuordnung der Versicherten in die entsprechende Einkommensklasse wird sowohl für die geschlechtsspezifische Betrachtung, als auch die geschlechtsneutrale Gesamtbetrachtung getrennt durchgeführt, um dem Umstand gerecht zu werden, dass zwischen Männern und Frauen systematische Einkommensunterschiede vorliegen.[34]

Die Erwerbsminderungsraten der Berufsgruppen werden auf Grundlage der Beobachtungsmonate der Versicherten mit gegenwärtiger oder zuletzt ausgeübter Berufstätigkeit ermittelt. Dabei erfolgt die Zuordnung der Versichertenzeiten anhand der monatlichen Berufsangaben eines Versicherten zu einer der Berufsgruppen nach der Blossfeld-Berufsklassifikation, um ausreichend große Kollektive zu analysieren. Diese Berufsklassifikation wurde auf Basis von Daten der Volks- und Berufszählung von 1970 entwickelt und mit dem Ziel konstruiert, die Berufsgruppen hinsichtlich ihrer durchschnittlichen schulischen und beruflichen Vorbildung sowie bezüglich der

[32] Vgl. Dietrich und Abraham (2008), S. 70.

[33] Es werden nur Versicherte betrachtet die 100 % der EP in einem westdeutschen Betrieb erwirtschaftet haben.

[34] Einen Überblick über die Literatur zur Theorie und Empirie geschlechtsspezifischer Lohnunterschiede liefert z. B. Hübler (2003).

beruflichen Aufgabengebiete möglichst homogen abzubilden.[35] Ein aus der amtlichen Statistik übernommenes Gliederungselement ist die Unterscheidung der beruflichen Aufgabengebiete nach den Wirtschaftssektoren, wobei eine Differenzierung zwischen Produktion, Dienstleistung und Verwaltung stattfindet. Zu den Produktionsberufen gehören zum Beispiel die Agrarberufe, Einfache und qualifizierte manuelle Berufe, Technikerberufe sowie alle Ingenieursberufe. Bei der deutschen amtlichen Berufsklassifikation steht die identische Aufgabe an zentraler Stelle. Im Unterschied zur International Standard Classification of Occupations (ISCO) ist die für die Berufsausübung typische Qualifikation in der Klassifikation der Berufe (KldB) nachrangig. Um diesen Aspekt zu berücksichtigen, wurde in der Berufsklassifikation nach Blossfeld bei der Differenzierung der manuellen Berufe der dominierende Anteil von Ungelernten als Kriterium herangezogen. Qualifizierte manuelle Berufe weisen höchstens einen Anteil von 40 % ungelernten Arbeitskräften auf. Die Anwendung solch einer Klassifikation bietet sich an, da eine Betrachtung einzelner Berufe aufgrund zu geringer Fallzahlen nicht möglich ist und eine Aggregation der Berufe stattfinden muss, um statistisch gesicherte Aussagen treffen zu können. Allerdings entfällt durch die Aggregation zu Berufsgruppen die Möglichkeit sämtliche Berufswechsel eines Versicherten abzubilden, sofern der Berufswechsel innerhalb einer homogenen Blossfeld-Berufsgruppe erfolgt. Dennoch bleibt eine Aggregation zu Berufsklassen sinnvoll, da die Aussagekraft der Ergebnisse wegen steigender Mobilitätsströme auf dem Arbeitsmarkt und einer zunehmenden Unübersichtlichkeit der Ergebnisse beeinträchtigt werden würde.[36]

Die Zuteilung der Versicherten in Einkommens- und Berufsgruppen erfolgt somit monatlich, da eine Erwerbsbiografie typischerweise mehrere Berufe bzw. verschiedene Einkommensstufen aufweist und somit keine eindeutige Zuordnung eines Versicherten in eine spezifische Einkommens- oder Berufsgruppe möglich ist. Somit sind die Invalidisierungsraten der beiden sozioökonomischen Risikofaktoren Beruf und Einkommen je Berufs- bzw. Einkommensklasse zu interpretieren. Eine detaillierte Beschreibung des BASiD-Datensatzes findet sich in den Publikationen des FDZ-RV.[37]

Als Erweiterung zur univariaten Analyse wird zusätzlich eine multivariate Analyse mit Hilfe des Cox-Modells (Proportionales Hazardmodell) durchgeführt, um den Effekt mehrerer erklärender Variablen auf eine statistisch abhängige Variable zu messen. Die Verwendung dieser Methodik ist in Studien mit ähnlicher Fragestellung bereits angewendet worden.[38] Diese Methode der Überlebenszeitanalyse wird häufig in der medizinischen Wissenschaft genutzt, um z. B. die Wirksamkeit von medikamentösen oder therapeutischen Behandlungen innerhalb zweier Untersuchungsgruppen zu testen. Das Modell ermöglicht auch Schätzungen eines anderen interessierenden Ereignisses wie bspw. die Zeit bis zu einer EM, sofern die Werte aller Einflussfaktoren der Personen gegeben sind.

[35] Vgl. Blossfeld (1985b), S. 69 ff.

[36] Vgl. Blossfeld (1985a), S. 181.

[37] Des Weiteren sei auf die Datensatzbeschreibung inkl. Codeplan und die Hinweise zur methodischen Umsetzung verwiesen (http://www.fdz-rv.de).

[38] Vgl. Albertsen et al. (2007), S. 78 ff.

Dieser Ansatz zur Modellierung von Einflussgrößen in einem Überlebenszeitmodell eignet sich, falls keine Informationen über die Verteilung der Überlebensdauer bekannt sind. Bezogen auf die oben genannte Forschungsfrage wird anhand der BASiD-Daten untersucht, welchen Einfluss die drei sozioökonomischen Einflussgrößen Bildung, Einkommen und Geschlecht auf die durchschnittliche EM-Rate haben. Somit wird die Überlebensdauer in diesem Kontext als die Zeit bis zum Eintritt in EM verstanden.[39]

In solchen Modellen gibt es oftmals das Problem, dass ein Teil der Daten rechtszensiert vorliegt, da Ausfallzeiten von Individuen über einen bestimmten Beobachtungszeitraum betrachtet werden. Eine rechtszensierte Beobachtung liegt demnach vor, sobald eine Untersuchungseinheit während der ganzen Studie nicht ausfällt, weil in diesem Fall nicht bekannt ist wann dieses Objekt ausfallen wird, sondern nur, dass die Ausfallzeit den Beobachtungszeitraum überschreitet.[40] Dies hat zur Folge, dass man unvollständige Informationen über Regressionsparameter erhält. Cox versuchte dem entgegenzuwirken, indem er Ausfallraten mit einer Hazardfunktion darstellt und diese zu bestimmten Zeitpunkten miteinander vergleicht. Beim vorliegenden Datensatz BASiD handelt es sich durch die unterschiedlichen Zusammensetzungen der Geburtsjahrgänge bei Beginn und Ende des Beobachtungszeitraums ebenfalls um zensierte Daten. Die Hazardfunktion ist gegeben durch φ:

$$\varphi(t;z) = \omega(z\beta)\varphi_0(t) \tag{1}$$

wobei φ_0 als Baseline Hazard,t als das Minimum von zwei Zufallsvariablen X_i (Eintritt des Zielereignisses von Person i) und Y_i (Verlassen des Beobachtungszeitraums von Person i), $z = z_{ik}$ der Kovariatvektor der Einflussgröße k der Person i und $\omega = e^{\beta}$ interpretiert werden.[41] Da nur der Effekt der Kovariate parametrisiert wird handelt es sich hierbei um ein semi-parametrisches Modell. $\beta = \beta_{ik}$ entspricht dem unbekannten, zu schätzenden Parametervektor.[42] Die Baseline Hazard gibt an wie die Hazardfunktion aussieht wenn alle Einflussfaktoren $z = 0$ sind. Die Hazardfunktion bezeichnet die Wahrscheinlichkeit je Zeitintervall, dass eine Erwerbsminderung bei einer Person eintritt, sofern sie bis zu diesem Beobachtungszeitpunkt nicht erwerbsgemindert wurde. Die Beobachtungen bestehen aus dem Tripel

$$\Psi = \{t_i ; z_i ; \delta_i\}. \tag{2}$$

Da es sich um rechtszensierte Daten handelt können nur bei Eintritt des Zielereignisses Rückschlüsse auf die Ausfallfunktion gezogen werden, daher muss zusätzlich eine Indikatorfunktion implementiert werden, die angibt, ob das Zielereignis bei Person i eintritt oder nicht.

[39] In der medizinischen Statistik werden oftmals Therapieeffekte untersucht, sodass das eintretende Ereignis dann als symptomatischer Tod durch Krankheit zu interpretieren ist.

[40] Vgl. Ziegler et al. (2007), S. e42.

[41] Vgl. Cox (1972), S. 189.

[42] Unter Kovariat wird in diesem Kontext die Einflussgröße auf die Hazardfunktion und damit auf die Überlebenswahrscheinlichkeit verstanden.

$$\delta_i = I\left\{X_i \leq Y_i\right\} \tag{3}$$

Die Vorteile dieser multivariaten Analyse sind die Anwendbarkeit auf rechtszensierte Überlebensdaten und dass keine Verteilungsannahme für die Überlebenszeiten getroffen werden muss. Dabei gilt zu beachten, dass die Werte aller Einflussfaktoren gegeben sein müssen und die auf das Zielereignis einwirkenden Effekte über die Zeit konstant sind. Diese Proportionalitätsannahme wird für die BASiD-Daten als gegeben angesehen. Hierbei werden 10 Zielereignisse pro Merkmal als erforderlich angesehen.[43]

Des Weiteren muss die hohe statistische Korrelation zwischen den Einflussvariablen Bildung, Einkommen und Beruf berücksichtigt werden. Um diesem Effekt Rechnung zu tragen, werden Interaktionsvariablen gebildet. Die modellierten Einflussgrößen aus dem BASiD-Datensatz sind das Geschlecht, die Zugehörigkeit zu einer Berufsgruppe, der Bildungsstand und die Einkommensklasse. Die Berufsklassifikationen wurden dazu auf drei, nach Qualifikationsniveau differenzierte, Gruppen aggregiert (Einfache (Berufsgruppen I-III), qualifizierte (Berufsgruppen IV-VI) und hochqualifizierte Berufe (Berufsgruppe VII)). Den Versicherten die im Untersuchungszeitraum erwerbsgemindert werden sowie den Versicherten die das Zielereignis im Beobachtungszeitraum nicht aufweisen wird der zuletzt ausgeübte Beruf zugeordnet. Der Bildungsstand ist in schulische (Haupt- und Realschule sowie Abitur) und hochschulische Ausbildung (FH und Hochschule) und das Einkommen in die im Folgenden ermittelten Quartile (Q-1 bis Q-4) aufgeteilt. Innerhalb der Cox Regression können vergleichende Aussagen zu einer Referenzgruppe getroffen werden. Die Referenzgruppe bezogen auf das Geschlecht stellen die weiblichen Versicherten dar und bezogen auf die drei sozioökonomischen Einflussfaktoren die hochqualifizierten Berufe, die Hochschulgebildeten und die Topverdiener.

4 Ergebnisse

4.1 Bildungsgruppen

Abbildung 1 weist die Zugänge in EM-Rente in Relation zur Kontrollgruppe aller aktiv Versicherten nach entsprechendem Bildungsstand aus. Die Ergebnisse zeigen, dass ein Versicherter mit zunehmendem Bildungsgrad tendenziell abnehmende Invalidisierungsraten aufweist. Bei einer geschlechtsspezifischen Differenzierung lassen sich allerdings Unterschiede ausmachen.

Bei männlichen Versicherten ist dieser Trend relativ deutlich zu beobachten. Die Zugangsraten in EM nehmen kontinuierlich mit steigender Bildung ab und lassen sich in drei rudimentäre Risikogruppen einteilen. Während männliche Hochschulabsolventen mit durchschnittlich 0,23 ‰ p. a. das geringste relative EM-Risiko aufweisen, lassen sich für Fachhochschulabsolventen (0,72 ‰ p. a.) und Abiturienten (0,84 ‰ p. a.) ähnliche Raten dokumentieren. Mit Abstand das größte EM-Risiko zeigen die Haupt- und Realschüler mit einem Invalidisierungsrisiko von durch-

[43] Vgl. Peduzzi et al. (1996), S. 1503.

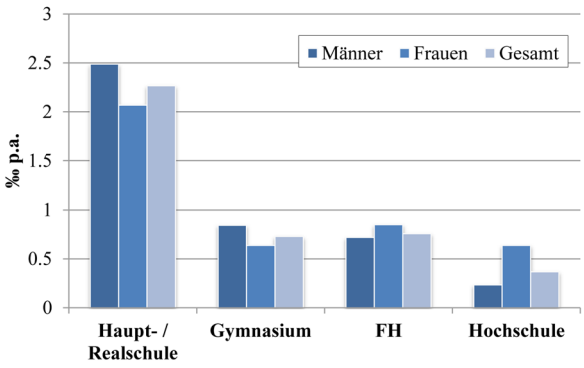


Abb. 1 EM-Risiken nach reinen Bildungsgruppen (eigene Darstellung, basierend auf BASiD-Datensatz, 2014)

schnittlich 2,49 ‰ p. a. auf, was in etwa dem 11-fachen des Risikos der Hochschulabsolventen entspricht.

Im Unterschied dazu sind bei den Frauen Inkonsistenzen zu beobachten. Beispielsweise liegt ein vergleichsweise hoher Anteil an Rentenzugängen in der Bildungsgruppe der Frauen mit einem Hochschulabschluss vor. Mit einem Wert von 0,64 ‰ p. a. sind diese Frauen gleich stark gefährdet wie Abiturientinnen (0,64 ‰ p. a.). Weibliche Versicherte mit Fachhochschulabschluss (FH-Abschluss) unterliegen mit 0,85 ‰ p. a. ebenfalls einem unerwartet hohen EM-Risiko und weisen somit sogar eine höhere durchschnittliche Zugangsrate auf, als Frauen mit Abitur. Diese Auffälligkeit wird im Folgenden näher untersucht.

Aus der unerwartet hohen EM-Rate wird die Hypothese abgeleitet, dass Frauen mit FH-Abschluss, im Vergleich zu analog gebildeten Männern oder gleichgeschlechtlichen Versicherten mit Abitur, in eher risikoexponierten Berufsgruppen mit geringerer erforderlicher Qualifikation arbeiten. Um daraus eventuelle Implikationen für die sekundäre Prämiendifferenzierung zu schließen, muss diese Bildungsgruppe einer separaten und detaillierteren Betrachtung unterzogen werden.

Tabelle 1 zeigt die Anteile der Versichertenmonate männlicher und weiblicher Versicherter mit FH-Abschluss bzw. Abitur in den einzelnen Berufsgruppen. Diese geben Aufschluss darüber, in welchen Berufsgruppen männliche und weibliche Versicherte innerhalb eines Bildungsstandes mit welchem prozentualen Anteil tätig sind. Fachhochschulabsolventen arbeiten demnach vermehrt in den qualifizierten bzw. hochqualifizierten Berufsgruppen.[44] Männer sind dabei häufiger in den hochqualifizierten Berufen tätig (36,5 %), Frauen arbeiten dagegen vermehrt in qualifizierten kaufmännischen bzw. Verwaltungsberufen (35,6 %) und der Gruppe der qualifizierten Dienstleistungsberufe (34,4 %). Unter Berücksichtigung der relativen EM-Rentenzugänge soeben genannter Berufsgruppen aus Abb. 5 in Abschn. 4.3 lässt sich obige Hypothese, dass FH-Absolventinnen in Berufen mit höherem EM-Risiko arbeiten, jedoch nicht bestätigen.

Eine alternative Erklärung bietet die sozialwissenschaftliche Literatur, die besagt, dass Frauen im Durchschnitt anfälliger für psychische Erkrankungen sind, welche vermehrt in den höheren Bildungsschichten und demnach in den (hoch-)qualifizier-

[44] Siehe Tab. 9 für eine nähere Beschreibung der einzelnen Blossfeld-Berufsgruppen.

Tab. 1 Prozentuale Anteile der Versichertenmonate von Abiturienten und Fachhochschulabsolventen (eigene Darstellung, basierend auf BASiD-Datensatz, 2014)

Blossfeld Berufsgruppe	Männer mit FH Abschluss %	Frauen mit FH-Abschluss %	Frauen mit Abitur %
1 Einfache manuelle Berufe	5,4	2,9	4,3
2 Einfache Dienstleistungen	2,6	2,9	6,7
3 Einfache kaufmännische u. Verwaltungsberufe	3,4	6,1	9,9
4 Qualifizierte manuelle Berufe	23,6	7,8	9,1
5 Qualifizierte Dienstleistungen	7,4	34,4	23,1
6 Qualifizierte kaufm. und Verwaltungsberufe	21,2	35,6	42,3
7 Hochqualifizierte Berufe	36,5	10,4	4,6

ten Berufsgruppen auftreten. Hierbei scheinen zwei Effekte aufzutreten: Der risikomindernde Effekt durch die geringere physische Belastung und konträr dazu der risikosteigernde Effekt der höheren psychischen Belastung. Die psychische Belastung entsteht beispielsweise durch die steigende Verantwortung im Beruf, der Vormachtstellung männlicher Beschäftigter und der damit verbundenen Diskriminierung von Frauen bzw. der diffizilen Vereinbarkeit von Familienplanung und Beruf.[45]

Vergleicht man die Anteile der Versichertenmonate von weiblichen Versicherten mit FH-Abschluss mit den Anteilen von Abiturientinnen, wird diese Vermutung unterstützt. Frauen mit Abitur arbeiten ebenfalls zum größten Teil in den qualifizierten Berufsgruppen 6 (42,3 %) und 5 (23,1 %). Die Gesamtanteile in diesen beiden Klassen sind somit ähnlich hoch, FH-Absolventinnen arbeiten zu 70,0 % in diesen beiden Berufsgruppen und Abiturientinnen zu 65,4 %. Die hohen relativen EM-Rentenzugänge von FH-Absolventinnen können demnach durchaus der höheren Anfälligkeit für psychische Erkrankungen geschuldet sein. Da BASiD allerdings keine Angaben zum krankheitsbedingten Verrentungsgrund beinhaltet, lässt sich diese Vermutung vorerst nicht überprüfen.

Die Ergebnisse zeigen, dass ein zunehmender Grad an Bildung mit tendenziell abnehmenden Invalidisierungsraten einhergeht. Dennoch sind bei geschlechtsspezifischer Betrachtung in homogenen Bildungsgruppen zum Teil große Unterschiede ermittelbar, wie beispielsweise in der Bildungsgruppe der Hochschulabsolventen, in der Frauen im Durchschnitt dreimal so stark gefährdet sind einer EM zu unterliegen wie gleichgebildete Männer. Neben den Faktoren Bildung und Geschlecht sind demnach weitere Faktoren zu berücksichtigen, um exakte Aussagen zum EM-Risiko treffen zu können. Eine autonome Betrachtung des Faktors Bildung ist nicht ausreichend, um valide Aussagen zur sekundären Prämiendifferenzierung treffen und sozialpolitische Implikationen erzielen zu können.

4.2 Einkommensgruppen

Neben der Bildung zählt unter anderem auch das Einkommen zu den wesentlichen Merkmalen, die den sozioökonomischen Status einer Person determinieren. Daher

[45] Vgl. Beermann et al. (2008), S. 78 ff.

Tab. 2 Ø Entgeltpunkte innerhalb der Einkommensquartile (eigene Darstellung, basierend auf BASiD-Datensatz, 2014)

Quartil	Männer	Frauen	Gesamt
25 %	0,75 EP	0,52 EP	0,64 EP
50 %	0,96 EP	0,75 EP	0,87 EP
75 %	1,21 EP	1,00 EP	1,11 EP
100 %	2,31 EP	2,25 EP	2,31 EP
Gesamt	1,31 EP	1,13 EP	1,19 EP

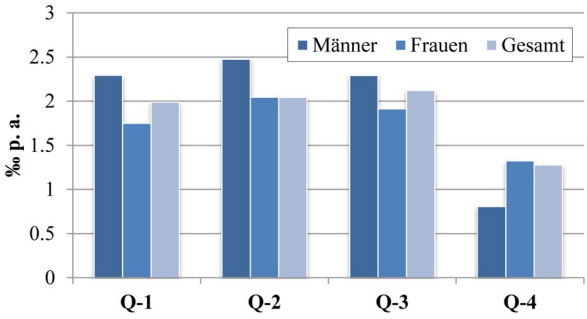


Abb. 2 EM-Risiko nach Einkommensquartil (eigene Darstellung, basierend auf BASiD-Datensatz, 2014). (Bei dieser Darstellung ist zu beachten, dass die jeweiligen Quartile getrennt voneinander ermittelt wurden (siehe Abschn. 3.3 **Methodik**))

wird im Folgenden der Zusammenhang zwischen dem Risiko einer Erwerbsminderung und dem Einkommen, gemessen durch die Höhe der originären Entgeltpunkte (EP) in Beitragszeiten, untersucht. Die nach Geschlecht differenzierten Einkommensquartile teilen die Versicherten in jeweils vier annähernd gleich große Einkommensklassen. In Tab. 2 sind die durchschnittlich ermittelten EP der drei Quartilsberechnungen dargestellt.

Abbildung 2 zeigt die EM-Raten für die soeben ermittelten Einkommensquartile der Männer und Frauen, sowie der Gesamtpopulation. Während die männlichen (weiblichen) Geringverdiener im Durchschnitt einem Risiko von 2,29 ‰ p. a. (1,75 ‰ p. a.) unterliegen, sinkt der Wert für die Topverdiener auf 0,81 ‰ p. a. (1,32 ‰ p. a.). Dennoch ist bei der geschlechtsspezifischen, als auch der geschlechtsneutralen Betrachtung keine klare Aussage möglich, ob das Einkommen einen mindernden oder steigernden Effekt auf das Risiko einer EM ausübt

Die Invalidisierungsraten nehmen beim Übergang vom ersten zum zweiten Quartil bei den Frauen und Männern zu und nehmen mit zunehmender Haupterwerbseinkommensgruppe wieder ab. In der Gesamtbetrachtung ist in den ersten drei Quartilen ein Anstieg des EM-Risikos zu verzeichnen, bevor die Invalidisierungsraten in Folge abnehmen. Da die Quartile jedoch getrennt voneinander ermittelt wurden, ist ein Vergleich der Gruppen untereinander relativ diffizil. Auffallend ist der Fakt, dass die weiblichen Versicherten lediglich im obersten Einkommensquartil eine höhere durchschnittliche EM-Zugangsrate aufweisen, was die obige These unterstützt, dass besonders die Frauen in hochqualifizierten bzw. gutbezahlten Berufen gefährdet sind erwerbsgemindert zu werden.

Es stellt sich jedoch die Frage, warum die Versicherten im untersten Einkommensquartil unerwartet niedrige EM-Zugangsraten aufweisen. Eine mögliche Erklärung könnte sein, dass diese Versicherten vermehrt in Teilzeitbeschäftigungen (TZ) inner-

Tab. 3 Prozentuale Anteile der Erwerbsmonate in Teilzeit (eigene Darstellung, basierend auf BASiD-Datensatz, 2014)

Quartil	Anteil TZ (Männer) %	Anteil TZ (Frauen) %	Anteil TZ (Gesamt) %
25 %	3,1	29,3	32,7
50 %	3,2	30,0	18,2
75 %	3,1	30,9	12,4
100 %	3,4	29,1	8,7
Gesamt	3,5	30,1	16,1

halb ihrer Erwerbsbiografie tätig sind, die aufgrund der geringeren zeitlichen Arbeitsbelastung auch mit einem geringeren EM-Risiko verbunden sind. Tabelle 3 zeigt die Anteile der Erwerbsmonate in TZ in Relation zu der gesamten Erwerbsbiografie eines Versicherten. Frauen arbeiten im Durchschnitt etwa 30,1 % ihrer Erwerbsphase in TZ, wohingegen der Anteil der Männer bei 3,5 % liegt. Dabei sind die Anteile der Männer bzw. Frauen in TZ in sämtlichen Einkommensquartilen nahezu identisch. Demnach indizieren die Ergebnisse, dass die unerwartet niedrige Invalidisierung innerhalb der sozioökonomischen Untersuchungsgruppe der weiblichen Geringverdiener nicht auf die relativ geringere Arbeitszeiten einer TZ zurückzuführen sind, da selbst die weiblichen Topverdiener zu etwa 29,1 % in TZ arbeiten. Eine Einkommensbetrachtung auf Basis der Entgeltpunkte aus hauptberuflicher Tätigkeit scheint daher nicht als Indikator zur Quantifizierung des EM-Risikos geeignet zu sein.

4.3 Berufsgruppen

Bereits im Abschnitt zur Analyse der Bildungsgruppen wurde die notwendige Betrachtung der Berufsgruppen erläutert. Betrachtet man zunächst die sektorale Aufteilung der Berufe nach Wirtschaftsbereichen (vgl. Abb. 3), zeigt sich, dass das höchste Risiko einer Invalidität in den Dienstleistungsberufen (2,90 ‰ p. a.) vorliegt, gefolgt von Produktions- (2,51 ‰ p. a.) und schließlich Verwaltungsberufen (1,81 ‰ p. a.). Eine identische Reihenfolge ergibt sich bei einer geschlechtsspezifischen Betrachtung der einzelnen Wirtschaftssektoren. Während Frauen (Männer) in Dienstleistungsberufen eine durchschnittliche EM-Rate von 2,49 ‰ p. a. (3,71 ‰ p. a.) aufweisen, folgen die Produktionsberufe mit 2,31 ‰ p. a. (2,59 ‰ p. a.) und die Verwaltungsberufe mit 1,99 ‰ p. a. (1,49 ‰ p. a.). Um präzisere Implikationen

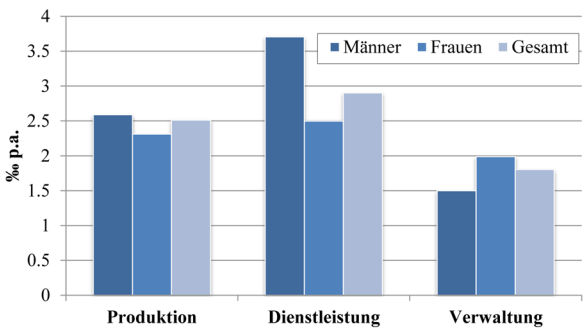


Abb. 3 EM-Risiken nach Wirtschaftsektoren (eigene Darstellung, basierend auf BASiD-Datensatz, 2014)

Tab. 4 Wirtschaftssektoren differenziert nach Blossfeld Berufsgruppen (eigene Darstellung, 2014)

Wirtschaftssektor	Blossfeld Berufskategorie
Produktionsberufe	**1** Agrarberufe
	2 Einfache manuelle Berufe
	3 Qualifizierte manuelle Berufe
	4 Techniker
	5 Ingenieure
Dienstleistungsberufe	**6** Einfache Dienstleistungen
	7 Qualifizierte Dienstleistungen
	8 Semiprofessionen
	9 Professionen
Verwaltungsberufe	**10** Einfache kaufmännische u. Verwaltungsberufe
	11 Qualifizierte kaufmännische u. Verwaltungsberufe
	12 Manager

schließen zu können, müssen die Sektoren jedoch weiter differenziert werden, da ansonsten keine Angaben über Schwankungen innerhalb einzelner Klassen vorliegen.

Nach der 12er-Berufsklassifikation von Blossfeld lassen sich Produktionsberufe in Agrar-, einfache manuelle bzw. qualifizierte manuelle Berufe, sowie Techniker und Ingenieure differenzieren. Der Dienstleistungssektor ist in einfache und qualifizierte Dienstleistungen, sowie Professionen bzw. Semiprofessionen unterteilt. Die Verwaltungsberufe lassen sich in einfache bzw. qualifizierte kaufmännische und Verwaltungsberufe sowie Manager klassifizieren. Eine Übersicht hierzu erfolgt in Tab. 4.

Eine Darstellung der EM-Raten der zwölf Berufsgruppen erfolgt in Abb. 4. Abgesehen von den qualifizierten manuellen Berufen haben innerhalb der Wirtschaftsbereiche der Produktion und Dienstleistung die männlichen Versicherten in den jeweiligen Berufsklassen höhere Invalidisierungsraten als die weiblichen Versicherten.[46] Die einfachen manuellen Berufe und einfachen Dienstleistungsberufe haben höhere Invalidisierungsraten als die einfachen kaufmännischen und Verwaltungsberufe. Die qualifizierten manuellen Berufe haben höhere Invalidisierungsraten als die qualifizierten Dienstleistungsberufe und qualifizierten kaufmännischen Berufe. Innerhalb der Wirtschaftssektoren (Berufsgruppen 1–5, 6–9 und 10–12) ist wiederum eine Tendenz abnehmender EM-Raten bei steigendem beruflichen Qualifikationsniveau erkennbar.

In der Hauptgruppe der Produktionsberufe sind vor allem die einfachen manuellen Berufe (3,39 ‰ p. a.) von einem hohen Risiko einer Erwerbsminderung betroffen. Hierbei handelt es sich unter anderem um Hilfsarbeiter, Bauhelfer, Schweißer und Straßenbauer. Zu den Dienstleistungsberufen, insbesondere der Gruppe der einfachen Dienstleistungen (3,98 ‰ p. a.), die den größten Anteil an EM-Rentenzugängen in dieser Hauptgruppe enthält, zählen beispielsweise Textil-, Raum- und Gebäudereiniger, Gastwirte und Kellner. Einfache kaufmännische und Verwaltungsberufe (2,53 ‰

[46] Männliche Versicherte tragen somit ein höheres EM-Risiko in den Berufsklassen der Agrarberufe, einfache manuelle Berufe, einfache bzw. qualifizierte Dienstleistungen und Techniker, sowie Semiprofessionen bzw. Professionen.

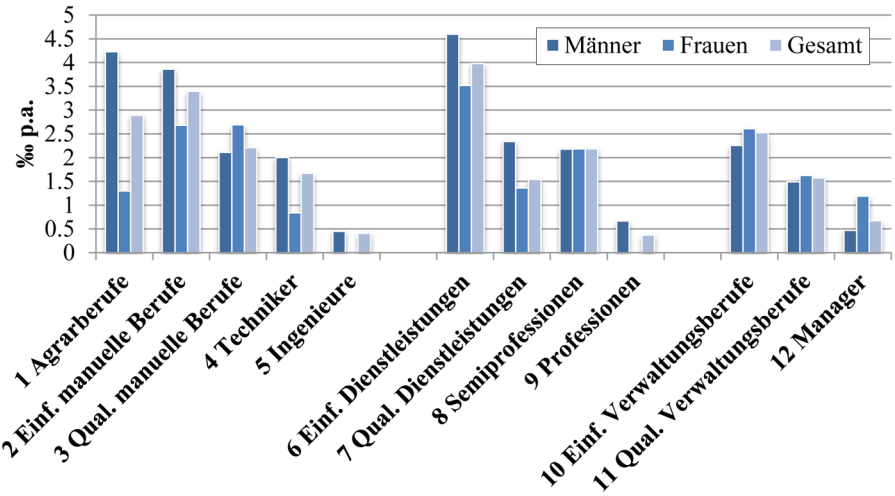


Abb. 4 EM-Risiken nach Blossfeld-Berufsklassifikation von Männern und Frauen (eigene Darstellung, basierend auf BASiD-Datensatz, 2014)

p. a.) sind innerhalb der Verwaltungsberufe die risikoexponierteste Berufsgruppe. Darunter fallen beispielsweise Telefonisten, Verkäufer und Verkaufshilfen, Kassierer, oder Bürohilfskräfte. Neben diesen soeben genannten Berufsgruppen, die innerhalb des jeweiligen Sektors ein besonders hohes Risiko aufweisen, fällt die Gruppe der Agrarberufe (2,89 ‰ p. a.) auf, in der besonders bei männlichen Versicherten relativ viele EM-Fälle eintreten. Hierunter fallen Landwirte, Tierzüchter, familieneigene Landarbeitskräfte und Waldarbeiter. Dies ist ebenfalls eine Berufsgruppe mit hohen körperlichen Anforderungen, welches ein wesentlicher Auslöser für den Eintritt einer EM sein kann.

Weiter bleibt zu erwähnen, dass nach den obigen Ausschlusskriterien in den Berufsgruppen der Ingenieure und der Professionen keine Rentenzugänge innerhalb der weiblichen Versicherten vorliegen und somit auch keine Invalidisierungsraten ermittelt werden konnten. Infolgedessen wurde die 12er-Klassifikation von Blossfeld für die folgenden Analysen auf sieben Berufsgruppen aggregiert. Die Zuordnung erfolgt zu einfachen, qualifizierten bzw. hochqualifizierten Berufen der jeweiligen Wirtschaftssektoren und ist anhand der Tab. 5 nachvollziehbar. Durch die Aggregation zur 7er-Klassifikation entsteht ein weitaus strukturierteres Bild. Wie erwartet nehmen die Invalidisierungsraten mit steigendem Qualifikationsniveau ab.

In Abb. 5 werden die EM-Raten der adjustierten Blossfeld Berufsklassifikation dargestellt. Während in einfachen Berufen noch Unterschiede der EM-Raten zwischen den Wirtschaftssektoren auszumachen sind, nehmen die Differenzen mit zunehmendem Qualifikationsniveau ab.[47] Demnach scheint auch eine isolierte Betrachtung von Geschlecht und Berufsgruppe nicht ausreichend zu sein, um das

[47] Innerhalb der Hochqualifizierten Berufe kann ausschließlich nach Geschlecht und nicht nach Wirtschaftssektor unterschieden werden, da hier die hochqualifizierten Berufe des Produktions-, Dienstleistungs- und Verwaltungssektors enthalten sind.

Tab. 5 Adjustierte Blossfeld-Berufsklassifikation (eigene Darstellung, 2014)

Adjustierte Berufskategorie	Blossfeld Berufskategorie
I Einfache Produktionsberufe	**1** Agrarberufe
	2 Einfache manuelle Berufe
II Einfache Dienstleistungen	**6** Einfache Dienstleistungen
III Einfache Verwaltungsberufe	**10** Einfache kaufmännische u. Verwaltungsberufe
IV Qualifizierte Produktionsberufe	**3** Qualifizierte manuelle Berufe
	4 Techniker
V Qualifizierte Dienstleistungen	**7** Qualifizierte Dienstleistungen
	8 Semiprofessionen
VI Qualifizierte Verwaltungsberufe	**11** Qualifizierte kaufmännische u. Verwaltungsberufe
VII Hochqualifizierte Berufe	**5** Ingenieure
	9 Professionen
	12 Manager

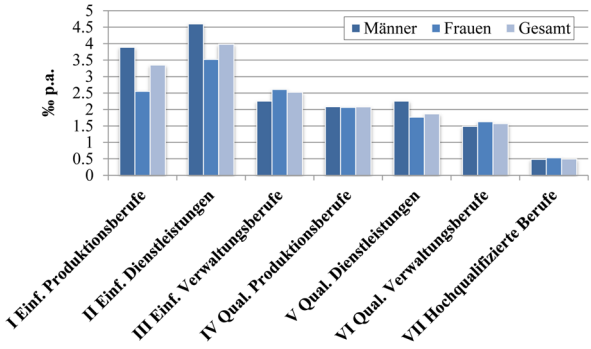


Abb. 5 EM-Risiken nach adjustierter Berufsklassifikation (eigene Darstellung, basierend auf BASiD-Datensatz, 2014)

EM-Risiko hinreichend zu quantifizieren. Aufgrund des Zusammenhangs zwischen Bildung und ausgeübter Berufstätigkeit müssen „Berufe mit einem gleichen oder ähnlichen Bildungsniveau hinsichtlich ihres Risikos für eine Erwerbsminderung […] im Zusammenhang betrachtet werden."[48] Daher wird nachstehend eine kombinierte Analyse von Bildung und Berufsausbildung vorgenommen und im darauffolgenden Abschnitt eine Betrachtung des gemeinsamen Effekts von Bildungs-, Einkommens- und Berufsgruppen mit Hilfe der Cox-Regressionsanalyse.

4.4 Kombinierte Bildungs- und Berufsgruppen

Die vorangegangenen Kapitel haben gezeigt, dass keine der betrachteten sozioökonomischen Statusvariablen das Risiko einer EM präzise genug bestimmen kann, nicht zuletzt wegen der Wechselbeziehungen zwischen Bildung, Einkommen und Beruf. Abbildung 6 zeigt die EM-Risiken aufgeteilt nach kombinierter Schul- und Berufsausbildung. Versicherte mit einem Haupt- bzw. Realschulabschluss tragen das höchste Risiko einer EM. Dieses Risiko verringert sich mit dem Abschluss einer Aus-

[48] Mika (2013), S. 391.

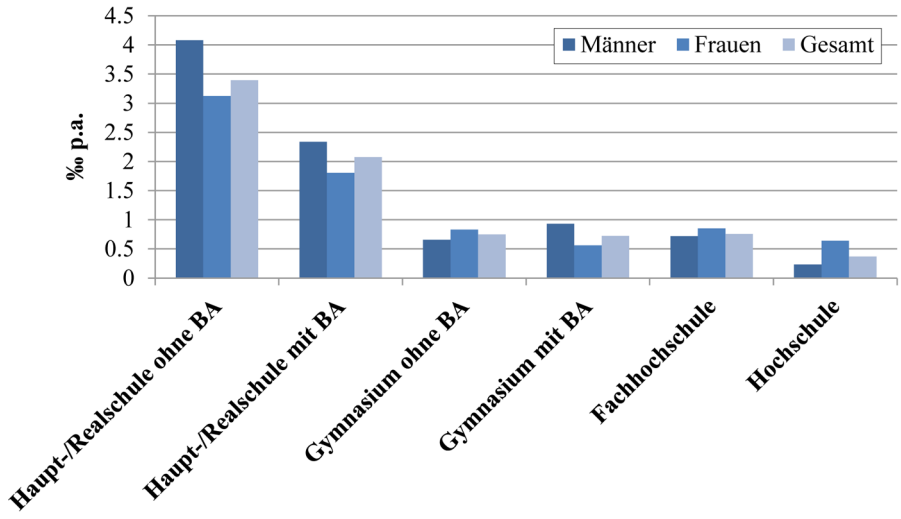


Abb. 6 EM-Risiken nach kombinierter Bildungs- und Berufsausbildung (eigene Darstellung, basierend auf BASiD-Datensatz, 2014)

bildung und den damit verbundenen Möglichkeiten in risikoärmere Berufsgruppen zu gelangen. Während Versicherte mit Haupt- oder Realschulabschluss ohne Berufsausbildung im Durchschnitt einem EM-Risiko in Höhe von 3,39 ‰ p. a. unterliegen, sinkt das Risiko für gleichgebildete Versicherte mit abgeschlossener Berufsausbildung (BA) auf durchschnittlich 2,08 ‰ p. a. In der Gruppe der Abiturienten dagegen sind relativ geringe Differenzen zu beobachten, wobei das Risiko bei männlichen Abiturienten nach einer BA sogar leicht von 0,66 ‰ p. a. auf 0,93 ‰ p. a. ansteigt. Die Ursachen hierfür werden im Folgenden eruiert.

In Tab. 6 werden die prozentualen Anteile der Versichertenmonate bei einer Haupt- oder Realschulbildung mit und ohne Abschluss einer Ausbildung gegenüber gestellt. Während die Versicherten ohne entsprechende Berufsausbildung zum größten Teil (69,9 %) in den einfachen Produktions- und Dienstleistungsberufen, und damit in den risikoexponiertesten Berufen der adjustierten 7er-Klassifikation, tätig sind, wechseln die Personen mit entsprechender Ausbildung eher in höherqualifizierte Berufsgruppen mit geringerem Risiko einer EM. Sowohl männliche, als auch weibliche Versicherte mit geringster Bildung ohne abgeschlossener BA sind zum größten Anteil in den einfachen Produktions- und Dienstleistungsberufen tätig (Frauen: 68,4 %/Männer: 73,3 %). Gleichgebildete Männer mit BA arbeiten in den einfachen (23,4 %) und qualifizierten Produktionsberufen (40,4 %). Frauen dagegen sind nach Abschluss der BA häufig in den qualifizierten Dienstleistungen (20,4 %) oder in qualifizierten Verwaltungsberufen (25,1 %) tätig. Der Anteil der männlichen (weiblichen) Versicherten in den beiden riskantesten Berufsgruppen sinkt von 73,3 % (68,4 %) auf 37,0 % (26,6 %).

Tabelle 7 zeigt die Anteile der Versichertenmonate von männlichen und weiblichen Abiturienten innerhalb der 7er-Klassifikation. In Bezug auf das Risiko einer EM besteht kein wesentlicher Unterschied, ob Abiturienten eine BA abschließen.

Tab. 6 Anteile der Versichertenmonate von Haupt- und Realschülern mit und ohne abgeschlossener Berufsausbildung (BA) (eigene Darstellung, basierend auf BASiD-Datensatz, 2014)

Blossfeld Berufsgruppe	Männer		Frauen		Gesamt	
	ohne BA %	mit BA %	ohne BA %	mit BA %	ohne BA %	mit BA %
I Einf. Produktionsberufe	52,3	23,4	33,5	13,5	39,3	18,4
II Einf. Dienstleistungen	21,0	13,6	34,9	13,1	30,6	13,4
III Einf. Verwaltungsberufe	2,3	4,1	8,8	17,8	6,8	10,9
IV Qual. Produktionsberufe	16,1	40,4	10,5	8,8	12,2	24,6
V Qual. Dienstleistungen	3,6	3,7	5,2	20,4	4,7	12,0
VI Qual. Verwaltungsberufe	4,1	12,4	6,6	25,1	5,8	18,7
VII Hochqualifizierte Berufe	0,7	2,5	0,4	1,4	0,5	2,0

Tab. 7 Anteile der Versichertenmonate von Abiturienten mit und ohne abgeschlossener Berufsausbildung (BA) (eigene Darstellung, basierend auf BASiD-Datensatz, 2014)

Blossfeld Berufsgruppe	Männer		Frauen		Gesamt	
	ohne BA %	mit BA %	ohne BA %	mit BA %	ohne BA %	mit BA %
I Einf. Produktionsberufe	13,3	7,5	6,7	3,4	9,8	5,2
II Einf. Dienstleistungen	11,5	7,5	10,8	5,2	11,1	6,2
III Einf. Verwaltungsberufe	9,0	6,1	13,2	8,7	11,2	7,6
IV Qual. Produktionsberufe	21,4	22,3	8,1	9,5	14,4	15,0
V Qual. Dienstleistungen	9,5	8,7	21,5	23,6	15,8	17,2
VI Qual. Verwaltungsberufe	28,0	36,7	35,3	44,9	31,8	41,4
VII Hochqualifizierte Berufe	7,3	11,1	4,4	4,7	5,8	7,5

Die prozentualen Anteile der Versichertenmonate in den verschiedenen Berufsgruppen zeigen, dass die Ausbildung sich nicht auf die berufliche Orientierung und dementsprechend auf das Invalidisierungsrisiko auswirkt. Die männlichen Abiturienten arbeiten jeweils in den qualifizierten Produktions- (ohne BA: 21,4 % / mit BA: 22,3 %) und Verwaltungsberufen (ohne BA: 28,0 % / mit BA: 36,7 %) Die Frauen hingegen sind jeweils zum größten Anteil in qualifizierten Dienstleistungen (ohne BA: 21,5 % / mit BA: 23,6 %) und Verwaltungsberufen (ohne BA: 35,3 % / mit BA: 44,9 %) tätig. Die EM-Raten der Abiturienten sind sowohl für Männer, als auch für Frauen ähnlich hoch.

4.5 Cox Regression

Die bisherigen Ergebnisse haben gezeigt, dass bspw. selbst in homogenen Bildungsgruppen die durchschnittlichen EM-Raten durch den Abschluss einer Berufsausbildung oder die Unterteilung nach unterschiedlichen Berufsgruppen zum Teil deutlich variieren können. Demzufolge ist eine gemeinsame Betrachtung der Einflüsse sinnvoll. Dabei ist jedoch zu beachten, dass die drei Einflussgrößen Bildung, Einkommen und Beruf Wechselwirkungen aufweisen. Eine statistische Korrelation zwischen diesen Größen ist nicht nur aus theoretischer Sicht plausibel, sondern ein empirisch belegtes Ergebnis der Sozialforschung.[49] Daher wird im Folgenden der kollektive Einfluss auf eine mögliche EM unter Verwendung der Cox Regression analysiert und die Ergebnisse der Interaktionsvariablen interpretiert.

Gemäß der Cox Regressionsanalyse werden die Regressionskoeffizienten $\beta=(\beta_1, \ldots, \beta_k)$ aus den Daten mit Hilfe der Maximierung einer Partiellen Likelihood-Funktion $\mathcal{L}(\beta)$ geschätzt. Die Partielle Maximum Likelihood-Funktion ist definiert als:

$$\mathcal{L}(\beta) = \prod_{j=1}^{m} \frac{\exp(\beta z_{(j)})}{\sum_{h \in R_j} \exp(\beta z_h)} \tag{4}$$

mit dem Kovariatvektor $z_{(j)}$ eines Individuums zum Ereigniszeitpunkt $t_{(j)} = t_{(1)} \leq \ldots \leq t_{(m)}$ und der Indexmenge R_j, bestehend aus den Individuen, die unmittelbar vor dem Zeitpunkt $t_{(j)}$ unter Risiko stehen.[50] Die Regressionskoeffizienten geben die erwartete Veränderung des Hazards bezogen auf die Variierung der Einflussvariablen um eine jeweilige Einheit der Indikatorvariablen. In Tab. 8 sind die Ergebnisse des proportionalen Hazard Modells dargestellt. Aus den Regressionskoeffizienten lassen sich adjustierte Hazard Ratios ($\exp(\beta)$) als Maß für die Stärke des Zusammenhangs berechnen. Der adjustierte Hazard Ratio der Variable Geschlecht bedeutet somit, dass Männer gegenüber Frauen einem 21,9 % höheren Risiko unterliegen erwerbsgemindert zu werden. Personen aus den einfachen Berufsgruppen mit niedriger Bildung und niedrigem Einkommen (**Einf. Beruf*Schulische Bildung*EQ 1**) unterliegen im Vergleich zur Referenzgruppe der Qualifizierten, hochgebildeten Topverdiener einem 86,3 % höherem Risiko, die Qualifizierten ungebildeten Geringverdiener dagegen nur noch zu 59,1 %. Der gleiche Effekt ist auch für die inferior gebildeten Versicherten aus dem zweiten (Reduzierung von 132,1 % auf 124,0 %) und dem dritten (Reduzierung von 132,4 % auf 91,8 %) Quartil. Das Qualifikationsniveau im Beruf scheint demnach einen hohen Einfluss auf das Risiko einer EM unter sonst gleichen Bedingungen aufzuweisen, was die Ergebnisse aus der deskriptiven Analyse bestätigt. Der Effekt der höheren Bildung konnte in diesem Modell aufgrund zu gering besetzter Subgruppen nicht untersucht werden und somit, nur zwei Bildungsgruppen modelliert wurden, wobei eine als Referenzgruppe dient. Werden

[49] Vgl. Shavit und Müller (1998).

[50] Unter Risiko stehen alle Individuen, die zu dem jeweiligen Zeitpunkt noch nicht zensiert sind und bei denen noch keine Erwerbsminderung eingetreten ist.

Tab. 8 Cox Regression (eigene Darstellung, basierend auf BASiD-Datensatz, 2014)

	Exp (β)	*p*-Wert	95 % Konfidenzintervall	
Geschlecht	1,219	0,000	1,110	1,339
Einf. Beruf*Schulische Bildung*EQ-1	1,863	0,000	1,581	2,194
Qual. Beruf*Schulische Bildung*EQ-1	1,591	0,000	1,270	1,993
Einf. Beruf*Schulische Bildung*EQ-2	2,321	0,000	1,999	2,694
Qual. Beruf*Schulische Bildung*EQ-2	2,240	0,000	1,873	2,678
Einf. Beruf*Schulische Bildung*EQ-3	2,324	0,000	2,015	2,682
Qual. Beruf*Schulische Bildung*EQ-3	1,918	0,000	1,649	2,231

jedoch die Variablen Bildung und Berufsgruppe konstant gehalten und der Effekt eines höheren Einkommensquartils betrachtet (**EQ-2** und **EQ-3**), erhöhen sich die Ausfallraten. Höheres Einkommen scheint das EM-Risiko somit nicht zu reduzieren, was die obigen Erkenntnisse ebenfalls bestätigt.

Das Konfidenzintervall gibt den Schwankungsbereich an, in dem der Schätzer mit 95 %iger Wahrscheinlichkeit liegt. In der obigen Regressionsanalyse schwanken die ermittelten Hazards jeweils um ungefähr 30 %. Zur Ermittlung der Signifikanz der geschätzten Regressionsparameter wird der *p*-Wert herangezogen. Dieser gibt an, ob die Regressoren einen systematischen Einfluss auf die zu erklärende Variable aufweisen. Sämtliche Variablen innerhalb des Cox-Modells sind zum 1 %-Niveau und somit hoch signifikant.

5 Diskussion

Nach intuitiver Erwartung und in wesentlicher Übereinstimmung mit der Vielzahl an empirischen Befunden besteht ein enger Zusammenhang zwischen sozialer und gesundheitlicher Situation der Bevölkerung. Das Invaliditätsrisiko einer Person ist umso geringer, je höher ihr sozioökonomischer Status ist, der vor allem durch den erreichten Bildungsabschluss, dem Einkommensniveau und der beruflichen Stellung geprägt ist. Die hier durchgeführten Analysen der BASiD-Daten bestätigen dies zum großen Teil, für einige Bildungs-, Einkommens- und Berufsgruppen gilt dies jedoch nur bedingt.

Die Ergebnisse zeigen bspw. dass das Risiko erwerbsgemindert zu sein im untersten Einkommensquartil sowohl für Frauen als auch Männer geringer ist als im zweiten und dritten Einkommensquartil, was nicht am Anteil in Teilzeit begründet liegt. Somit kann die generelle Behauptung, dass vor allem Personen mit niedrigen Einkommen dem höchsten EM-Risiko ausgesetzt sind nicht vollständig untermauert werden. Auf der anderen Seite zeigt sich jedoch auch, dass die Gruppe im höchsten Einkommensquartil deutlich niedrigere EM-Raten aufweist als die anderen drei Quartile.

Des Weiteren entspricht die unterschiedliche geschlechtsspezifische Risikoverteilung in den einzelnen Bildungs- und Einkommensgruppen nicht der Intuition, zumindest nicht auf dem ersten Blick. Während die EM-Raten der Frauen in den unteren Bildungs- und Einkommensgruppen unterhalb bzw. auf gleichem Niveau der Raten der Männer verläuft, ist das Bild in der jeweils obersten Gruppe genau umgekehrt.

So unterliegen beispielsweise Akademikerinnen im Durchschnitt einem knapp dreimal so hohem Risiko erwerbsgemindert zu werden wie gleichgebildete Männer (vgl. Abb. 1) und die weiblichen Bestverdiener haben ein 63 % höheres Risiko als ihre männlichen Pendants (vgl. Abb. 2). Ein Grund für die Umkehrung kann in einem zunehmenden Stresslevel der sich in diesen Gruppen wiederfindenden Berufsgruppen begründet sein. Aufgrund einer höheren psychischen Belastung durch mehr Verantwortung im Job und die möglicherweise zusätzliche Vereinbarkeit von Familie und Beruf machen Frauen im Durchschnitt anfälliger für psychische Erkrankungen.[51] Demzufolge existieren mit steigendem Einkommens und/oder Bildungsgrad zwei gegenläufige Effekte, wodurch der Zusammenhang zwischen den Faktoren und dem EM-Risiko nicht eindeutig ist. Diese Zusammenhänge gilt es in der Zukunft weiter und granularer zu untersuchen, insbesondere falls die psychische Belastung im Beruf in der Zukunft weiter zunimmt.

Sowohl dieses Ergebnis als auch die Aufteilung der Bildungs- und Einkommensgruppen nach Berufsgruppen verdeutlichen, dass eine Beschreibung des EM-Risikos allein über die sozioökonomischen Statusvariablen Bildung oder Einkommen nicht ausreicht. Obwohl der ausgeübte Beruf einen geeigneteren Indikator für das EM-Risiko darstellt, kann dieser innerhalb BASiD-Daten lediglich in Form der Blossfeld Berufsklassifikation nachvollzogen werden. Noch besser wäre eine Verwendung von Tätigkeitsschlüsseln, die in dem verfügbaren Datensatz jedoch nur als statische Variable vorliegen und demzufolge für die hier durchgeführte Analyse nicht geeignet sind.

Die Resultate indizieren ein elementares Dilemma der Invaliditätsversicherung sowohl in der gesetzlichen Rentenversicherung als auch innerhalb der privaten Versicherungswirtschaft. Gerade die Berufsgruppen mit den höchsten EM-Risiken und damit dem höchsten Absicherungsbedarf sind zum einen mit einem relativ geringen Einkommen ausgestattet und zum anderen sind die Erwerbsbiografien stärker durch Arbeitslosigkeit unterbrochen. Demzufolge fällt auf der einen Seite die Höhe der gesetzlichen Absicherung relativ gering aus, auf der anderen Seite sind die finanziellen Möglichkeiten einer privaten Risikoabsicherung eingeschränkten. Lösungsansätze für die zweite Herausforderung sind z. B. in alternativen Deckungskonzepten wie der Funktionellen Invaliditätsversicherung zu finden.[52]

Weiterhin bestätigt die Analyse deutlich, dass für die aktuarielle Kalkulation privater Invaliditätsversicherungen eine sehr sorgfältige Betrachtung der z. T. risikotechnisch stark inhomogenen Versichertenkollektive zwingend geboten ist. Die Tatsache, dass auch Personen mit sehr hohem sozioökonomischem Status dem Risiko einer EM unterliegen, ist ebenfalls für den Absicherungsbedarf einer privaten Invaliditätsversicherung von Bedeutung. Bei einer Realisierung des verbleibenden Risikos drohen entsprechend hohe Einkommensausfälle, so dass sich auch bei diesen deutlich weniger risikoexponierten Teilkollektiven die Prüfung einer geeigneten privaten Absicherung empfiehlt.

Das große Spektrum an Ergebnissen zeigt auch Implikationen für die Versicherungswissenschaft. So bietet BASiD, trotz der beschriebenen Limitationen aus

[51] Vgl. Beermann et al. (2008), S. 78 ff.

[52] Vgl. Henck (2014), S. 88.

wissenschaftlicher Perspektive, eine große Datenbasis, die im Kontext der Sozialversicherungstheorie eine Grundlage für weitere Fragestellungen darstellt. Nachdem ein Überblick über den Datensatz an sich und die Zugangsraten verschiedener sozioökonomischer Bevölkerungsgruppen aufgezeigt wurde, kann darauf aufbauend weiteren Forschungsfragen im Zusammenhang mit dem Risiko einer Invalidität nachgegangen werden. So lässt sich beispielsweise der Zusammenhang zwischen weiteren einkommensmindernden sozialen Erwerbssituationen wie Arbeitslosigkeit oder Arbeitsunfähigkeit und Invalidität untersuchen. Dadurch ließe sich dem Umstand gerecht werden, dass eine EM im Vor- bzw. Nachlauf mit teilweise langen Krankheits- und Arbeitslosenzeiten verbunden ist, die ebenfalls bestimmende Faktoren des Armutsrisikos darstellen. Nachteilig ist in diesem Zusammenhang zu erwähnen, dass BASiD keine Angaben zum Haushaltseinkommen bereithält, welches zur Ermittlung des Armutsrisikos geeigneter wäre, da Einkommenseinbußen durch andere Haushaltsmitglieder unter Umständen kompensiert werden können. Indem die gesamte Erwerbshistorie vor und nach Eintritt einer EM analysiert werden kann, lassen sich darauf aufbauend eventuell Schwellenwerte ermitteln, mit denen aus vergangenen Arbeitslosen- und Krankenzeiten auf die Wahrscheinlichkeit des Eintritts einer EM geschlussfolgert wird. Weiterhin ist die Bestimmung der Reaktivierungsraten oder die Berechnung der Einkommensabnahmen infolge von Arbeitsunfähigkeit, Arbeitslosigkeit, geringfügiger oder Teilzeitbeschäftigung interessant, um über die Länge der EM und Höhe des Einkommensausfalls weitere Schlüsse zur Ermittlung des eigentlich vorhandenen finanziellen Risikos durch EM ziehen zu können. Eine Cox-Regression ist eine adäquate Methode, um Aussagen zu Invalidisierungsraten und deren Interdependenzen treffen zu können. Durch die Identifizierung prognostisch wichtiger Risikofaktoren einer EM-Rente und der Bildung entsprechender Risikoscores sind individuelle Prognosen möglich. Die Aufnahme weiterer erklärender Variablen, wie beispielsweise dem Gesundheitszustand der Versicherten sowie Arbeitslosen- und Krankheitszeiten in die Cox-Regressionsanalyse könnte sich ebenfalls als sinnvoll erweisen und ein genauer spezifiziertes Modell ermöglichen.

Anhang

Tab. 9 Blossfeld Berufsklassifikation. (Eigene Darstellung in Anlehnung an Blossfeld (1985a), S. 182)

Bezeichnung der Berufsgruppe	Beschreibung der Berufsgruppe	Beispiele
Produktion		
Agrarberufe (AGR)	Berufe mit dominant landwirtschaftlicher Orientierung	Landwirte, Tierzüchter, Familieneigene Landarbeitskräfte, Gärtner, Waldarbeiter, etc.
Einfache manuelle Berufe (EMB)	Alle manuellen Berufe, die 1970 mindestens einen 60prozentigen Anteil von Ungelernten aufweisen	Förderleute, Schießbauer, Steinbrecher, Papier- und Zellstoffhersteller, Holzaufbereiter, Druckerhelfer, Schweißer, Nieter, Löter, Hilfsarbeiter, Bauhelfer, Gleisbauer, Straßenbauer, etc.
Qualifizierte manuelle Berufe (QMB)	Alle manuellen Berufe, die 1970 mindestens einen 40prozentigen Anteil von Ungelernten aufweisen	Glasbläser, Buchbinder, Schriftsetzer, Schlosser, Feinmechaniker, Elektriker, Funk- und Fernsehgerätebauer, Weinküfer, Brauer, Zimmerer, etc.
Techniker (TEC)	Alle technischen Fachkräfte	Maschinenbautechniker, Techniker des Elektrofaches, Bau- und Vermessungstechniker, Berg- und Hüttenbautechniker, etc.
Ingenieure (ING)	Hochqualifizierte Fachkräfte zur Lösung naturwissenschaftlicher und technischer Probleme	Architekten, Bauingenieure, Elektroingenieure, Fertigungsingenieure, Chemiker, Physiker, Mathematiker, etc.
Dienstleistungen		
Einfache Dienste (EDI)	Alle einfachen persönlichen Dienste	Wäscher, Raum- und Gebäudereiniger, Gastwirte, Kellner, etc.
Qualifizierte Dienste (QDI)	Im wesentlichen Ordnungs- und Sicherheitsberufe sowie qualifizierte Dienstleistungsberufe	Polizisten, Feuerwehrleute, Makler, Schienenfahrzeugführer, Rechtspfleger, Photographen, Friseure, Hauswirtschaftsberater, etc.
Semiprofessionen (SEMI)	Dienstleistungsberufe, die sich durch eine Verwissenschaftlichung der Berufsposition auszeichnen	Krankenschwester, Sozialarbeiter, Sozialpädagogen, Real- und Volksschullehrer, etc.
Professionen (PROF)	Freie Berufe und hochqualifizierte Dienstleistungsberufe	Zahnärzte, Ärzte, Apotheker, Richter, Gymnasiallehrer, sozial- und Geisteswissenschaftler, etc.
Verwaltung		
Einfache kaufmännische Verwaltungsberufe (EVB)	Relativ unqualifizierte Büro- und Handelsberufe	Posthalter, Telefonisten, Verkäufer- und Verkaufshilfen, Kassierer, Maschinenschreiber, Bürohilfskräfte, etc.
Qualifizierte kaufmännische und Verwaltungsberufe (QVB)	Berufe mit mittleren und höheren verwaltenden und distributiven Funktionen	Bankfachleute, Speditionsfachleute, Großhandelskaufleute, Datenverarbeitungsfachleute, Bürofachkräfte, etc.
Manager (MAN)	Berufe, die die Kontrolle und Entscheidungsgewalt über den Einsatz von Produktionsfaktoren besitzen sowie Funktionäre in Organisationen	Unternehmer, Geschäftsführer, Organisatoren, Geschäftsbereichsleiter, Abgeordnete, Minister, Verbandsleiter, Funktionäre

Literatur

Albertsen, K., Lund, T., Christensen, K.B., Kristensen, T.S., Villadsen, E.: Predictors of disability pension over a 10-year period for men and women. Scand. J. Public Health. **35**(1):78–85 (2007)

Albrecht, M., Loos, S., Schiffhorst, G.: Sozioökonomische Situation von Personen mit Erwerbsminderung – Eine Analyse auf Basis von SOEP-Daten. Dtsch. Rentenversicher. **10**(2007):621–650 (2007)

Arbeitnehmerkammer B.: Risiken für eine Erwerbsminderungsrente. Politikthemen – Gesundheit (2013)

Bäcker, G., Bispinck, R., Hofemann, K.: Zur Aktualität „alter" sozialer Risiken: Erwerbsminderung. In: Bäcker, G., Heinze, R. (Hrsg.) Soziale Gerontologie in gesellschaftlicher Verantwortung, S. 51–68. VS Verlag für Sozialwissenschaften, Wiesbaden (2013)

Beermann, B., Brenscheidt, F., Siefer, A.: Unterschiede in den Arbeitsbedingungen und-belastungen von Frauen und Männern. In: Badura, B., Schröder, H., Vetter, C. (Hrsg.) Fehlzeiten-Report 2007 Arbeit, Geschlecht und Gesundheit, S. 69–82. Springer Medizin Verlag Heidelberg, Heidelberg (2008)

Blossfeld, H.-P.: Berufseintritt und Berufsverlauf – Eine Kohortenanalyse über die Bedeutung des ersten Berufs in der Erwerbsbiographie. Mitt. Arbeitsmarkt Berufsforsch. **18**(2):177–197 (1985a)

Blossfeld, H.-P.: Bildungsexpansion und Berufschancen: Empirische Analysen zur Lage der Berufsanfänger in der Bundesrepublik. Campus, Frankfurt (1985b)

Börsch-Supan, A.: Population aging, social security design, and early retirement. J. Ins. Theor. Econ. (JITE)/Z. gesamte Staatswiss. **148**(4):533–557 (1992)

Börsch-Supan, A.: Incentive effects of social security on labor force participation: evidence in Germany and across Europe. J. Public Econ. **78**(1):25–49 (2000)

Brussig, M.: Weiter steigendes Renteneintrittsalter, mehr Renteneintritte aus stabiler Beschäftigung, aber zunehmend geringere Altersrenten bei Langzeitarbeitslosen. Institut Arbeit und Qualifikation, Universität Duisburg-Essen (2012)

Cox, D.: Regression models and life tables. J. Royal Stat. Soc. B. **34**, 187–220 (1972)

Dietrich, H., Abraham, M.: Eintritt in den Arbeitsmarkt. In: Hinz, T., Abraham, M. (Hrsg.) Arbeitsmarktsoziologie: Probleme, Theorien, empirische Befunde, S. 69–98. VS Verlag für Sozialwissenschaften, Wiesbaden (2008)

DRV (Deutsche Rentenversicherung): Versichertenbericht 2014– Statistische Analysen zu den Versicherten der Deutschen Rentenversicherung, Deutsche Rentenversicherung Bund (2014)

Gravseth, H.M., Bjerkedal, T., Irgens, L.M., Aalen, O.O., Selmer, R., Kristensen, P.: Life course determinants for early disability pension: a follow-up of Norwegian men and women born 1967–1976. Eur. J. Epidemiol. **22**(8):533–543 (2007)

Gruber, J., Wise, D.: Social security programs and retirement around the world. Res. Lab. Econ. **18**(1):40 (1999)

Häder, M.: Empirische Sozialforschung – Eine Einführung. Springer-Verlag. Berlin (2010)

Hagen, C., Himmelreicher, R.K., Kemptner, D., Lampert, T.: Soziale Unterschiede beim Zugang in Erwerbsminderungsrente: Eine Analyse auf Basis von Scientific Use Files des Forschungsdatenzentrums der Rentenversicherung (FDZ-RV). RatSWD Research Notes, No. 44 (2010)

Henck, R.: Positive Marktfähigkeit. Versicherungswirtschaft. **10**, 88–89 (2014)

Himmelreicher, R.K., Sewöster, D., Scholz, R., Schulz, A.: Die fernere Lebenserwartung von Rentnern und Pensionären im Vergleich. WSI-Mitteilungen. **61**(5):274–280 (2008)

Hochfellner, D., Voigt, A.: Improving the content of administrative data by linking different register-based data sources. European Conference on Quality in Official Statistics (2010)

Hollederer, A.: Erwerbslosigkeit, Gesundheit und Präventionspotenziale. VS Verlag für Sozialwissenschaften, Wiesbaden (2011)

Hübler, O.E.: Geschlechtsspezifische Lohnunterschiede (Gender-specific wage differentials). Mitt. Arbeitsmarkt Berufsforsch. **36**(4):539–559 (2003)

Kaldybajewa, K., Kruse, E.: Erwerbsminderungsrenten im Spiegel der Statistik der gesetzlichen Rentenversicherung – Unterschiede und Gemeinsamkeiten zwischen Männern und Frauen. RVaktuell. **8**, 206–216 (2012)

Karlsson, N.E., Carstensen, J.M., Gjesdal, S., Alexanderson, K.A.: Risk factors for disability pension in a population-based cohort of men and women on long-term sick leave in Sweden. Eur. J. Public Health. **18**(3):224–231 (2008)

Krokstad, S., Johnsen, R., Westin, S.: Social determinants of disability pension: a 10-year follow-up of 62.000 people in a Norwegian county population. Int. J. Epidemiol. **31**(6):1183–1191 (2002)

Kruse, E.: Sterblichkeit und fernere Lebenserwartung von Versichertenrentnern der gesetzlichen Rentenversicherung – Aktuelle Ergebnisse einer Sterbetafelberechnung für 1996/1998. Deutsche Rentenversicherung, 3–4/2000, 121–138 (2000)

Lampert, T., Kroll, L.E., Dunkelberg, A.: Soziale Ungleichheit der Lebenserwartung in Deutschland. Polit. Zeitgesch. **42**, 11–18 (2007)

Macintyre, S., McKay, L., Der, G., Hiscock, R.: Socio-economic position and health: what you observe depends on how you measure it. J. Public Health. **25**(4):288–294 (2003)

Månsson, N.O., Råstam, L., Eriksson, K.F., Israelsson, B.: Socioeconomic inequalities and disability pension in middle-aged men. Int. J. Epidemiol. **27**(6):1019–1025 (1998)

Märtin, S., Zollmann, P.: Erwerbsminderung – Ein erhebliches Armutsrisiko: Empirische Befunde zur sozioökonomischen Situation von Personen mit Erwerbsminderung. Informationsdienst Soziale Indikatoren. **49**, 1–5 (2013)

Mielck, A.: Soziale Ungleichheit und Gesundheit. Empirische Ergebnis, Erklärungsansätze, Interventionsmöglichkeiten. Verlag Hans Huber, Bern (2000)

Mielck, A.: Soziale Ungleichheit und Gesundheit. Einführung in die aktuelle Diskussion. Verlag Hans Huber, Bern (2005)

Mika, T.: Risiken für eine Erwerbsminderung bei unterschiedlichen Berufsgruppen. Bundesgesundheitsblatt-Gesundheitsforschung-Gesundheitsschutz. **56**(3):391–398 (2013)

Naegele, G., Sporket, M.: Perspektiven einer lebenslauforientierten Ältere-Arbeitnehmer-Politik. In: Naegele, G. (Hrsg.) Soziale Lebenslaufpolitik, S. 449–473. VS Verlag für Sozialwissenschaften, Wiesbaden (2010)

Peduzzi, P., Concato, J., Kemper, E., Holford, T.R., Feinstein, A.R.: A simulation study of the number of events per variable in logistic regression analysis. J. Clin. Epidemiol. **49**(12):1373–1379 (1996)

Rehfeld, U.: Gesundheitsbedingte Frühverrentung. Gesundheitsberichterstattung des Bundes Heft 30 (2006)

Riphahn, R.T.: Disability retirement among German men in the 1980s. Ind. Lab. Relat. Rev. **52**(4):628–647 (1999)

Samuelsson, Å., Alexanderson, K., Ropponen, A., Lichtenstein, P., Svedberg, P.: Incidence of disability pension and associations with socio-demographic factors in a Swedish twin cohort. Soc. Psychiatry psychiatr. Epidemiol. **47**(12):1999–2009 (2012)

Schmidt, D.: Die sozialmedizinische Begutachtung in der Rentenversicherung. In: Verband Deutscher Rentenversicherungsträger VDR. (Hrsg.) Sozialmedizinische Begutachtung in der gesetzlichen Rentenversicherung, S. 83 ff. Gustav Fischer Verlag, Stuttgart (1995)

Shavit, Y., Müller, W.: From school to work – a comparative study of educational qualifications and occupational destinations. Oxford University Press, New York (1998)

SVR (Sachverständigenrat zur Begutachtung der Entwicklung im Gesundheitswesen): Koordination und Qualität im Gesundheitswesen. Bd I: Korporative Koordination und Wettbewerb, Sozioökonomischer Status und Gesundheit, Strategien der Primärprävention. Kohlhammer Verlag, Stuttgart (2006)

Wurm, S., Tesch-Römer, C.: Gesundheit älterer Erwerbstätiger. In: Kuhlmey, A., Schaeffer, D. (Hrsg.) Alter, Gesundheit und Krankheit, S. 131–143. Verlag Hans Huber, Bern (2008)

Ziegler, A., Lange, S., Bender, R.: Überlebenszeitanalyse: Die Cox-Regression. Dtsch. med. Wochenschr. 132(S 01):e42-e44 (2007)

Module 2

The Impact of Population Aging on the German Statutory Pension System — A Probabilistic Approach

Vanella, P. / Rodriguez Gonzalez, M. / Wilke, C. (2021)

published in:
Hannover Economic Papers (HEP), No. 688.

The Impact of Population Aging on the German Statutory Pension Insurance – A Probabilistic Approach [i]

Patrizio Vanella (Corresponding Author) [ii]

Helmholtz Centre for Infection Research
Department of Epidemiology
Inhoffenstr. 7, DE-38124 Braunschweig
patrizio.vanella@helmholtz-hzi.de
+49 531 6181 3121

Miguel Rodriguez Gonzalez

Gottfried Wilhelm Leibniz Universität Hannover
Center for Risk and Insurance
Demographic and Insurance Research Center
Otto-Brenner-Str. 7, DE-30159 Hannover
mr@ivbl.de

Christina B. Wilke

FOM Hochschule für Oekonomie & Management
Professorin für Volkswirtschaftslehre sowie Wissenschaftliche Leitung des KompetenzCentrums für angewandte Volkswirtschaftslehre (KCV)
Hochschulzentrum Bremen
Linzer Str. 7, DE-28359 Bremen
christina.wilke@fom.de

Abstract

The demographic transition is a phenomenon affecting many industrialized societies. These economies are experiencing a decline in mortality alongside low fertility rates – a situation that puts social security systems under severe pressure. To implement appropriate reform measures, adequate forecasts of the future population structure, specifically in pay-as-you-go systems are needed. We propose a probabilistic approach to forecast the numbers of pensioners in Germany up to 2040, considering trends in population development, labor force participation, and early retirement as well as the effects of further pension reforms. A principal component analysis is used for dimensionality reduction and consideration of cross-correlational effects between age- and sex-specific pension rates for both old-age and disability pensions. Time series methods enable the inclusion of autocorrelation effects in the model and the simulation of future uncertainty. The model predicts that, in the median, the numbers of old-age pensioners will increase by almost 5 million individuals from 2017 to 2036, alongside increases in disability pensions by 2036, given the raising of the legal retirement ages following the introduced regulations. After that point, a moderate decrease can be expected. The results show a clear need for further reforms, if the German statutory pension system is to be sustainable in the long run.

Keywords: Population Aging; Stochastic Forecasting; Principal Component Analysis; Time Series Analysis; Applied Econometrics; Public Pension Systems; Social Policy.

JEL: C53, H55, J11.

[i] We would like to express our thanks to Andreas Dannenberg from the DRV for his patience in not only providing much of the underlying pension data for our study but also offering valuable information on the limitations and problems associated with it. Moreover, we appreciate the critical discussion of an earlier version of the model by J.-Matthias Graf von der Schulenburg, which helped to improve the final model significantly

[ii] Patrizio Vanella currently works at the Helmholtz Centre for Infection Research. The study was mainly conducted during his time at the University of Hannover.

1 Introduction

Countries with low fertility and decreasing mortality rates struggle with an aging population structure and negative natural population growth (OECD 2018). Decreasing mortality means longer periods of pension claims as long as retirement ages are not adjusted proportionally to the increases in life expectancy. C.p., low fertility results in a smaller workforce in the long run (Zuchandke et al. 2014). In Western Europe, for instance, mortality has been decreasing almost monotonically since the 1970s (Vanella 2017), whereas replacement-level fertility has not been reached yet (Vanella and Deschermeier 2019). For countries applying a Bismarck-type pension system (pay-as-you-go)[1], this particular demographic development results in double financial distress: The elderly are at increased risk of suffering from old-age poverty, while a growing share of labor income generated by the working population has to be transferred to the elderly (Goffart 2018). Demographic aging combined with pay-as-you-go schemes thus affects the financial sustainability of pension systems if that trend is not averted by policy reforms.

Demographic forecasts are of great importance for both researchers and policymakers, to ensure that pay-as-you-go systems, in particular, remain financially viable in the long run. However, population forecasts are rarely of a probabilistic nature; instead, deterministic projections are mostly conducted (see, e.g., European Commission 2018; OECD 2018; Pötzsch and Rößger 2015). These approaches result in equally deterministic pension projections because they rely on the underlying population predictions (see, e.g., Vogt 2017; Werding 2011; Wilke 2009). Population and pension forecasts should be probabilistic, since those models can quantify the uncertainty of the prediction, and thus, an assessment of the expected precision of the predicted development is possible (see, for instance, Keilman et al. 2002; Dunstan and Ball 2016).

[1] Pension payments are redistributed from the labor force to the pensioners within the same period (see, e.g., Graf von der Schulenburg and Lohse 2014 on this).

In the case of Germany, payments out of the statutory pension insurance *(DRV)* are based on this original Bismarckian principle (Wilke and Börsch-Supan 2009). Public pension payments constitute the largest share of retirement income in Germany at approximately 63% (Federal Ministry of Labour and Social Affairs 2019). Therefore, future old-age income will depend heavily on changes in the size and structure of the population, which are essential for the financial stability of the DRV. The DRV should ensure a certain living standard for its pensioners while not overloading the working population with excessively heavy contributions to the pension system (Vogt 2017).

Since potential pension reforms should be based on new and adequate forecasts of the future development of the DRV (Zuchandke et al. 2014), the present contribution provides a stochastic forecast of the year-end old-age and disability pensioner numbers receiving payments from Germany through the year 2040. We use principal component analysis (PCA) for dimensionality reduction and consideration of cross-correlation between the age- and sex-specific pension rates (ASSPRs), and the connections among retirement, disability, and legal retirement age are covered as well. Time series models include autocorrelation of the ASSPRs, providing the methodological framework for quantification of future uncertainty in these predictions. Combined with a fully probabilistic population forecast model developed in earlier studies (Vanella 2017; Vanella and Deschermeier 2018, 2019, 2020), a forecast of the future numbers of pensioners is elaborated. The model takes trends in labor force participation and early retirement, along with demographic trends such as decreasing mortality and morbidity, into consideration implicitly by time series analysis. The effects of previous pension reforms are captured to some extent by an econometric model in the forecast. The simulation not only returns the median age- and sex-specific retired and officially disabled population up to the year 2040 but also quantifies the uncertainty in the forecast, illustrated with 75% and 90% prediction intervals (PIs) for each year, age and sex.

The remainder of this paper is structured as follows. The next section presents an overview of German pension reforms since the 1980s. Section 3 gives a literature review on forecasts and projections for statutory pension systems with special emphasis on stochastic approaches on the one hand and studies of Germany on the other hand. We will then describe the method and data used for our analysis and present a selection of the results generated by our forecast. The model is applied to Germany but is in principle applicable to other countries as well, especially those that apply a Bismarck-type social security system. The paper will conclude with a discussion of the results and limitations, giving an outlook of opportunities for further research.

2 The German Pension Insurance and its demography-related Reforms

Demographic aging puts pension systems under pressure, which is not solely a problem of the German economy, but is also recognized by other industrialized countries, which are hit similarly hard or even heavier than Germany by the demographic trends. Countries with low fertility and decreasing mortality, such as Italy (Baldacci and Tuzi 2003), Japan (Ogawa 2005), Finland (Koissi 2006), China (Wang et al. 2019) or Croatia (Tomaš 2020) have recognized the need for pension reforms as well and are discussing possible potential reforms.

The timing of pension claims is an individual decision. However, there is strong evidence for the effects of policy reforms on social security and retirement decisions or expectations (Börsch-Supan 1992, 2000; Coppola and Wilke 2014; Buchholz et al. 2013). Moreover, social policy can try to influence retirement decisions by bonus-malus systems to affect retirement behavior as well as labor force supply (Gruber and Wise 2000).

Since the late 1980s, the German government has passed a series of pension reforms as countermeasures to the demographic aging process. In 1989, the *Rentenreformgesetz 1992 (RRG 1992)* was the first reform with a clear demographic agenda: it raised the legal retirement age

for female and unemployed persons from 60 years to 65 (at that time the standard legal retirement age for men) until 2008 and was one important measure for containing the number of future retirees. Moreover, the exceptional early retirement age of 63 years for persons who had been employed for at least 35 years was abolished[2] (RRG 1992). Furthermore, whereas early retirement without monetary "sanctions" had previously been possible, the reform introduced a financial bonus-malus system for the individual retirement decision. Since that reform, every month of premature pension claims reduces the monthly pension payments by 3‰. On the contrary, each month of delayed pension claims beyond the individual legal retirement age is rewarded with an increase of 5‰ in monthly pension payments (Wilke 2009).

The *Wachstums- und Beschäftigungsförderungsgesetz (WFG)* in 1996 *(WFG 1996)* accelerated the increases in the legal retirement ages for unemployed and females even further, underlining the urgency of the policy measures. Due to the RRG 1992, the increase in the retirement age of these two groups would have ended at the target age of 65 in 2018 (RRG 1992, §41 I). However, the WFG required that mark to be reached in 2007 for unemployed men and 2010 for women. The legal retirement age for severely disabled persons was increased from 60 to 63 years between the years 2000 and 2006 following the *Rentenreformgesetz 1999* (RRG 1999).

According to the so-called *Riester reform* of 2001, a new pension formula was introduced that linked individual pension payments to the overall development of labor income and old-age saving rates in society over time. In 2004, this new pension formula was enhanced by adding the so-called *sustainability factor*, which is directly connected to the system dependency ratio.[3] Therefore, this adjustment considers directly the overall demographic and labor market development when determining pension payments (Wilke 2009). The effects of taking into account

[2] In 2014, the German government returned to a similar measure, with a legal retirement age of 63 years for persons who have 45 years of social security payments (Bundesregierung 2013). This change is considered in our model as well.

[3] The ratio of number persons exceeding a certain age (mostly 65 years) over the number of persons in the assumed working-age, e.g. 15-64 years (Wilke 2009).

the system dependency ratio into the benefit calculation compared to considering the life expectancy as alternative reform options, was analyzed in a simulation study (see Fehr and Habermann 2006).

The *RV-Altersgrenzenanpassungsgesetz* from 2007 was the latest reform aimed at responding to the demographic aging process in Germany. The standard legal retirement age will now increase gradually to 67 years until 2031. The legal retirement age for severely disabled individuals is adjusted accordingly from 63 to 65 years and for the small group of mineworkers from 60 to 62 years (RV-AltAnpG 2007). These differing retirement ages find direct consideration in our forecast model. Therefore, the average annual retirement ages for different retirement groups are illustrated in Appendix A for historical, current, and future time horizons.

3 Forecasts of Pension Demand with Special Emphasis on Germany

Wilke and Börsch-Supan (2009) simulate the labor force in Germany until 2050 using scenario analyses of the development of the population and trends in labor force participation. The combination of two demographic and four different labor market scenarios gives eight trajectories of the labor force in Germany by 2050. Börsch-Supan and Berkel (2004) estimate individual probabilities of retirement under different socio-economic criteria in an econometric framework using data from the German Socio-Economic Panel Study (SOEP). Bucher-Koenen and Wilke (2009) apply the results of these two studies to estimate the long-term effect of the RV-AltAnpG 2007 (see Section 2) by simulating different scenarios for the labor force participation rates and the population's adjustment of its average retirement age to the increasing legal retirement ages of the reform.

Estimation of future financial development and thus the potential need for intervention in the DRV is generally based on deterministic projections of the population, combined with the legal

retirement age and assumptions on the development of the labor market. Mostly, simple statistics such as the old-age dependency ratio are consulted for this (e.g., Pötzsch and Rößger 2015; European Commission 2018). Wilke (2009) and Holthausen et al. (2012) propose a detailed model for long-term projections of the future financial outlook for a wide range of German social security reforms until the year 2100. These analyses include many factors, such as population development, labor force participation, and policy reforms. They introduce a complex model that can show the future demand for social security based on subjective assumptions about future demographic and economic development. Werding (2011, 2013) projects the financial outlook of the DRV using the population projections by Destatis, deriving possible trends in labor force participation from micro census data and modeling future macroeconomic growth with a Cobb-Douglas production function. From these partial models, the scenarios for the future old-age dependency ratio and the resulting financial expenses for old-age pensions until 2060 are derived. The EU and the OECD offer similar projections for their respective member countries on an annual basis (see, e.g., European Commission 2018; OECD 2018).

All models are very detailed and provide suggestions for further model advances. They are quite restrictive in their assumptions, however, which is inevitable for deterministic models. Furthermore, the assumptions on fertility and migration development are in many cases questionable because the total fertility rate (TFR) is generally assumed to be constant. Vanella and Deschermeier (2019) show that a naïve forecast of the TFR for Germany performs rather poorly, when assuming a constant TFR. Drawbacks of some simulations are that they do not include the increase in the legal retirement ages as a result of the pension reform of 2007, thereby overestimating the number of old-age retirees. Deterministic methods generally have some limitations because they are restricted to a limited number of scenarios whose respective probabilities of occurrence are mostly not quantified. Thus, stochastic forecasts in demographic research are gaining popularity as an alternative to common deterministic projections that use scenarios to address future uncertainty (Istat 2018; Keilman et al. 2002; Lee 1998). Stochastic

forecasts based on simulations are less prone to subjective decision-making and provide a huge number of possible future outcomes while being able to quantify their likelihood. Keilman et al. (2002) propose a probabilistic population forecast model, which is applied to Norway until 2050. Fertility is forecast using a multivariate autoregressive moving average (ARIMA) model, including the TFR, the mean age at childbearing (MAC), the variance in the MAC, and the minimum reproductive age as four parameters. Alho and Spencer (2005) propose a probabilistic forecast approach to the old-age dependency ratio, based on a stochastic model of population forecasting for Finland. Their method could help formulate social policy reforms that include flexible adjustments of the legal retirement age. Li et al. (2009) estimate the aging effect in the Chinese population as a proxy of the pension demand by deriving the future old-age dependency ratio. They do so by constructing a probabilistic population forecast through stochastic modeling of the demographic components fertility, mortality, and international migration. These partial forecasts are performed through a combination of quantitative and qualitative model assumptions as baseline scenarios for future development. Uncertainty is quantified by assuming a similar future risk for the demographic components in China compared to a pool of European countries over the distant past, as proposed in Alho and Spencer (2005). The net migration in the mean is assumed according to the UN projection (see United Nations 2007). The uncertainty of future migration is assumed to be similar to past trends for Europe, as given in Alho and Nikander (2004). The resulting population forecast is used to estimate simulations of the future old-age dependency ratio. Ahn et al. (2005) apply a similar method for a stochastic projection of the financial outlook of the Spanish pension insurance through 2050. Giang and Pfau (2008) generate a partially probabilistic projection of the financial pension outlook for Vietnam until 2100. Fertility and mortality are estimated by the popular Lee-Carter models for these two components (see Carter and Lee 1992; Lee and Carter 1992; Lee 1993), whereas the modeling procedure for international migration is not clearly described in the paper and appears to be deterministic. Assuming stationarity for the labor force participation rates, the authors

derive estimates for the age- and sex-specific numbers of contributors to the social security system. Giang and Pfau (2008) extract the projections of future pensioner numbers. These entities are used for a stochastic estimation of the future old-age dependency ratio. Forecasting a range of economic factors, the future outlook for contributions into the pension insurance as well as the demand for pension entitlements is approximated. Tomaš (2020) generates a stochastic cohort-component forecast of the population in Croatia until the year 2060. He estimates a time series model of the new annual pensioners, which leads to a stochastic forecast of the pensioner old-age pension numbers. He then computes different scenarios to illustrate the effect of the population development on the pension payments.

Lipps and Betz (2005) forecast the population in Germany until 2050 stochastically by running 500 trajectories. Mortality and fertility are estimated for West and East Germany separately. Age-specific mortality rates are forecast using the Lee-Carter model for mortality, while the TFR is assumed to be a random walk process. The age schedule for the fertility rates is assumed Gaussian, with a converging MAC over the long term. Under these assumptions, the distribution of age-specific fertility rates (ASFRs) is simulated. The total net migration is assumed to be an autoregressive process of order one (AR(1)) (see, e.g., Shumway and Stoffer 2011 on AR processes). Simulating the net migration and the age distribution, the future population is estimated as well. The trajectories for the population are used for computation of the old-age dependency ratio, in the respective paper defined as the ratio of people over 60 years of age to the population between 20 and 59. Härdle and Myšičková (2009) propose a probabilistic cohort-component forecast for the population in Germany through 2058. Age-specific mortality and fertility rates are forecast by applying the respective Lee-Carter models. International migration is modeled separately for immigration and emigration, where the total numbers for both statistics are estimated by AR(1) models. The age structures of the migrants are approximated by

Kernel density estimation.[4] As a result of the population forecast, the authors forecast the old-age dependency ratio for retirement ages 65 and 67. Using a status quo assumption, the authors derive a stochastic projection of the future social insurance premium rate and the average replacement rate.

More details on the data and methods used in the more significant studies on pension forecasting mentioned in this section are given in Appendix C. One common merit of the presented studies is the indirect derivation of the retired population over the labor force participation and the resident population. That does not include the population living abroad while receiving pension payments in the country under study. In the case of a country such as Germany, where the net migration of the native population above retirement age is mostly negative (Federal Ministry of Labour and Social Affairs 2018; Vanella and Deschermeier 2018), this leads to systematic underestimation of the retired population. Our model is not only based on a fully probabilistic population forecast, but includes trends in prevalence rates of old-age and disability pensions as well stochastically. The combination of these two pension types in a joint model is another innovative feature of our model. Details will be presented in the next section.

4 Method and Data

In this section, we propose a joint probabilistic forecast model for the number of old-age pensions and disability pensions by sex and age of the pensioners. In the first step, past age- and ASSPRs for old-age and disability pensions are estimated. The data have been accumulated from three sources: the German Federal Statistical Office *Destatis*, the *DRV,* and the Federal Health Reporting Service *(gbe-bund),* provided by Destatis and the Robert Koch Institute

[4] See, e.g., Härdle et al. (2004) on that.

(RKI). Thus, we used the year-end sex-specific stocks of old-age pensioners by age (in years)[5] for the years 1992-2009 from the gbe-bund database (Destatis 2018a).

It is not advisable to use data before 1992 because the integration of pensions for citizens from the former German Democratic Republic *(DDR)* into the DRV after the German reunification did not happen before 1992 (RÜG 1991). Therefore, data until 1991 are available for West Germany only. Furthermore, the DRV was reformed in 1992, transforming disability pensions for persons who had already passed their subjective legal retirement age into old-age pensions (RRG 1992). The data for 2010-2017 was downloaded from the statistics portal of the DRV (Statistikportal der Rentenversicherung 2020a). Because the gbe-bund data originate from the DRV as well, we ensure that our data sets are consistent.

We estimate the pension rates for ages 60 to 64 for both genders. Old-age pensions for persons above these age limits are cumulated for consistency reason. This does not bias the results because retirement risk does not change significantly among these age groups (Börsch-Supan and Berkel 2004). However, there is still some difference due to the undercounting of international migration (Vanella and Deschermeier 2018), but the grouping decreases the dimensionality of the data and mitigates the error naturally arising from the population updating in the old-age population (Vanella 2017).

One advantage of our approach is that we take into account the numbers of persons residing abroad who receive pension payments from the DRV; previous approaches have not done this. Disability pensions are not discriminated by age, but simply by sex and type of disability (full or partial). The reason for this is, that separating by age would lead to implausible estimates in some cases. The data for the years 2010-2017 were downloaded from the statistical database of

[5] The ages 60-99 are annually and the ages above 99 are grouped.

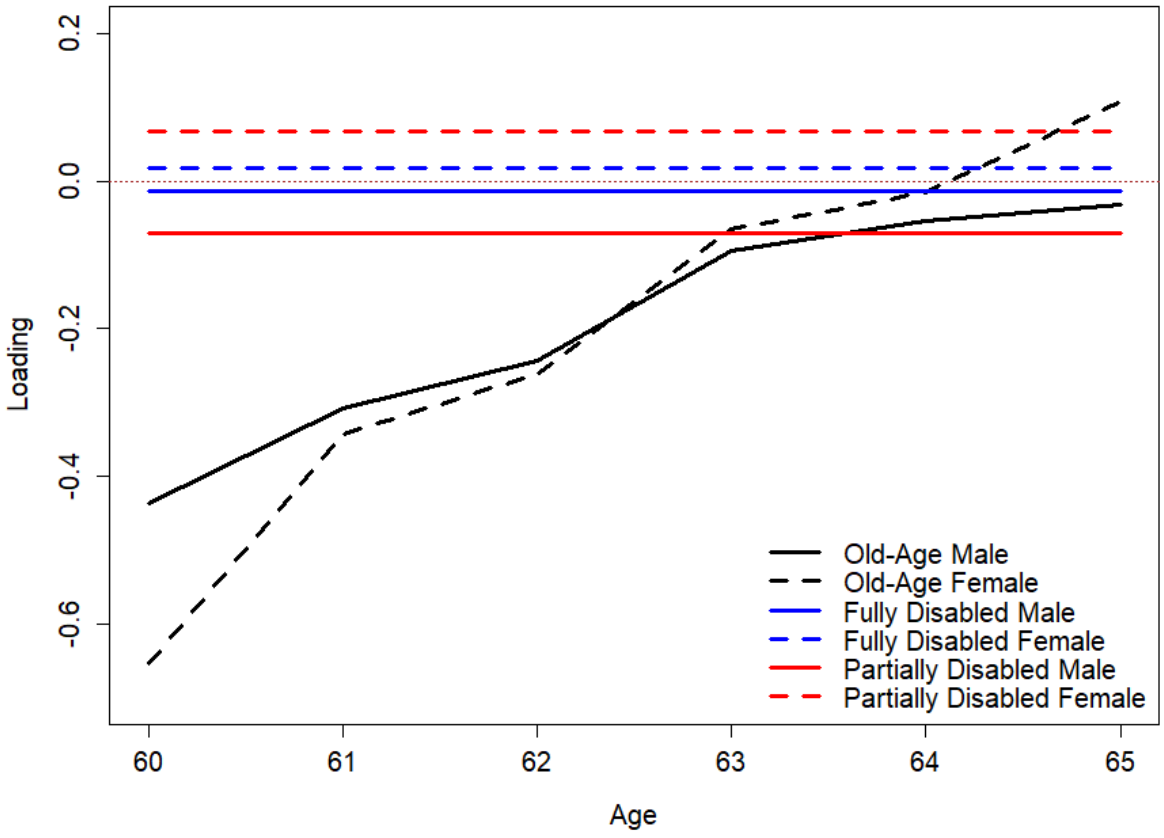
the DRV (Statistikportal der Rentenversicherung 2020b), and the data for 2000-2009 are available at the DRV research homepage (Forschungsportal der Deutschen Rentenversicherung 2018). The data for 1992-1999 was provided by the DRV on demand (Deutsche Rentenversicherung Bund 2018). Year-end population estimates for 1992-2017 by sex and age based on the 2011 census have been downloaded from the Human Mortality Database (2019).

The pension counts are divided by the population estimates, allowing us to calculate annual ASSPRs for the period 1992-2017. The resulting data matrix has 16 columns as conglomerates of 16 time series of ASSPRs. Basing the model on the ASSPRs has the advantage of including the possibility of a return into the labor force indirectly in our data. Another advantage of our approach is that we take into account the numbers of persons receiving pension payments from the DRV while residing abroad, which, to our knowledge, previous studies did not. As stated above, earlier approaches tend to estimate labor force participation rates first and derive pension rates from those. That approach has a major limitation, since it ignores the population receiving pension payments while living abroad. For Germany, this leads to a systematic underestimation of the pension numbers because the number of persons living abroad after retiring is certainly larger than vice versa (Deutsche Rentenversicherung Bund 2017; Vanella and Deschermeier 2018).

We apply PCA (see, e.g., Chatfield and Collins 1980; Handl 2010; Vanella 2018 for a comprehensive description and application of the method) to the matrix of the logistically transformed ASSPRs with 1.03 as the upper limit, which is approximately the historical maximum rate for Germany. This transformation prevents the simulations for the ASSPRs to take unrealistically high values (see Vanella and Deschermeier 2019 for a similar application for age-specific fertility rates). The PCA approach allows us to minimize the effective dimension of the data while also covering the correlations between the time series in our model (Vanella 2018). The principal components (*PCs)* are linear combinations of all ASSPRs, which are correlated to these

while being uncorrelated to each other (Chatfield and Collins 1980; Vanella 2018). The correlations (or *loadings*) between the first PC and the logistically transformed ASSPRs are illustrated in Figure 1.

Figure 1. Loadings of the first Principal Component

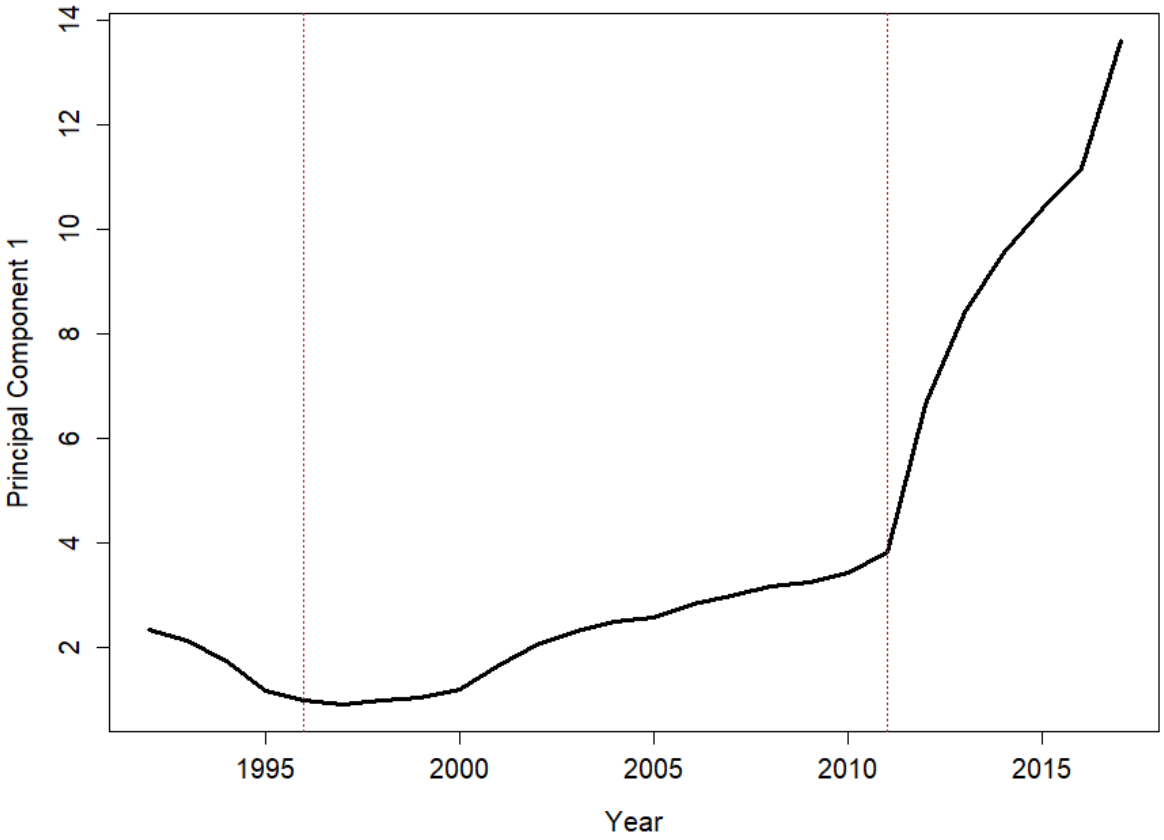


Source: Own calculation and design.

Principal Component 1 *(PC1)* is negatively correlated with the rates of old-age pensioners in the pre-legal retirement ages and with the rates of disabled males. Moreover, its loadings are positive for disabled females. Positive trends in PC1 are therefore, c.p., associated with decreases in early retirement rates. Disability pension rates of males decrease c.p. with increases, while the females rates increase instead. PC1 explains approximately 91% of the total variance in the logistically transformed ASSPRs. Figure 2 shows the historical course of PC1. The years

1996 and 2011 are marked by vertical lines to stress that in the following years the effects of the RRG 1992 and the RV-AltAnpG 2007 started to kick in (see Appendix A).

Figure 2. Past Course of Principal Component 1



Source: Own calculation and design.

PC1 has a decreasing trend until the late 1990s. It increases almost monotonically shortly after 1997 and has an even steeper slope since 2012, strongly implying a connection of PC1 to the past pension reforms that introduced raises in the legal retirement ages, as explained in Section 2.

To test our a priori stated hypothesis about PC1 to some extent and to integrate the effects of the legal retirement ages on it for our forecast model of the future pensioner numbers, we iteratively fit an explanatory model for PC1 with the mean annual retirement ages as exogenous variables. Those variables are derived from the sources presented in Section 2. The results of

the different iterations are given in Table 1, with standard errors for the coefficients in brackets. For informative purposes only, we also report the R^2 and adjusted R^2 for each model.

Table 1. Model Estimates for Principal Component 1[6]

Retirement Age	Model 1.1	Model 1.2	Model 1.3	Model 1.4
Intercept	- 4,426*** (709)	-4,326*** (625)	- 4,551*** (555)	- 3,907*** (474)
ln(Standard)	711** (258)	669*** (218)	732*** (202)	579*** (198)
35 Years Long Insured	0.52 (0.65)	0.37 (0.46)	-	-
45 Years Long Insured	0.31 (0.26)	0.3 (0.25)	0,41* (0.21)	-
Severely Disabled	- 0.21 (0.63)	-	-	-
Unemployed	- 0.43* (0.23)	- 0.44* (0.22)	- 0.32* (0.16)	- 0.14 (0.14)
Women	0.64*** (0.21)	0.58*** (0.14)	0.58*** (0.14)	0.58*** (0.15)
ln(Mineworkers)	344*** (107)	363*** (88)	356*** (86)	358*** (92)
$\boldsymbol{R^2}$	0.9912	0.9911	0.9908	0.9891
Adj. $\boldsymbol{R^2}$	0.9878	0.9883	0.9885	0.987
AIC	34.51	32.66	31.54	34.06
BIC	45.83	42.73	40.35	41.6

Source: Own calculation and design.

[6] One asterisk means statistical significance on a 10% level against H_0: $\beta_x = 0$, with β_x being the x[th] coefficient. Two asterisks indicate a 5% significance level and three asterisks mean 1%.

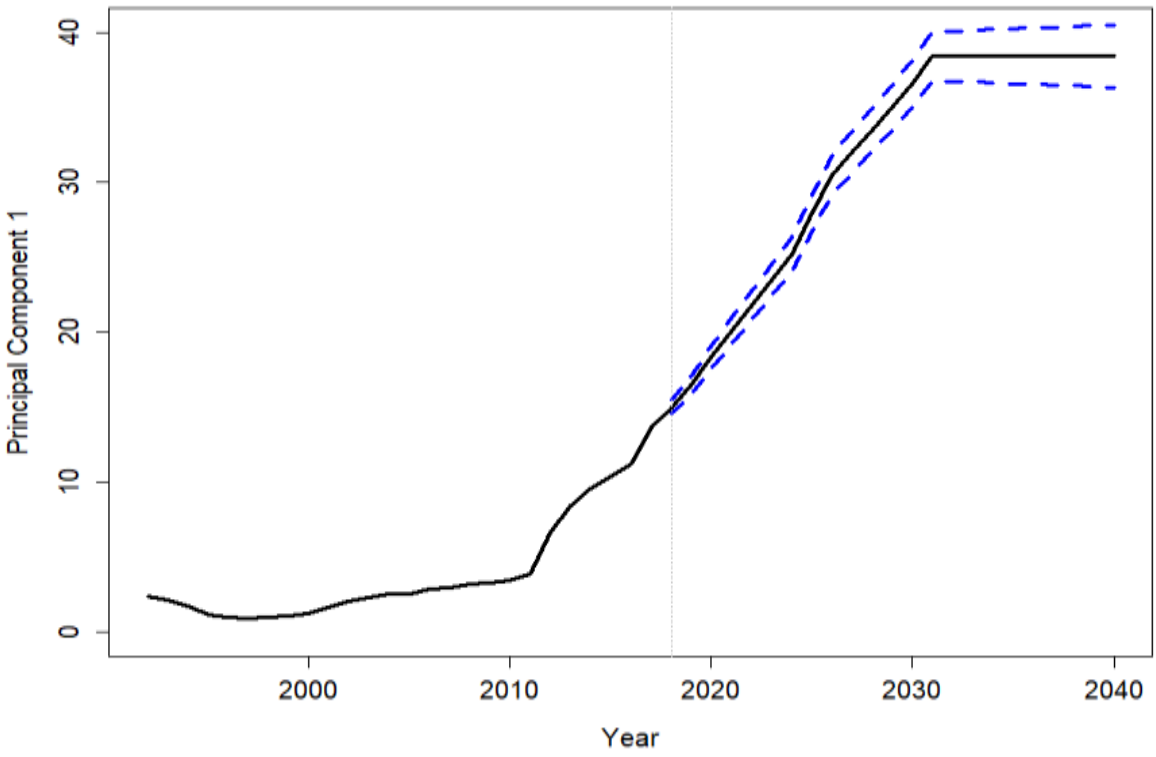
The models all show high joint significance. For the standard legal retirement age and the legal retirement age of mineworkers, the natural logarithms are put into the model, since the scatter-plots suggest a logarithmic connection between the two variables and PC1. We optimize the model iteratively by omitting the variable with the smallest individual significance in each iteration. We finally choose the model, which minimizes Akaike's Information Criterion (AIC) and the Bayesian Information Criterion (BIC). Both are minimized by Model 1.3. Omitting more variables leads to worsening model fits, as indicated by increases in the AIC and the BIC in Model 1.4. The final model accentuates the effects of the standard legal retirement age, the earlier legal retirement age for persons with 45 years of social insurance payments alongside the legal retirement ages of females and mineworkers on PC1. The PC stresses developments in very early retirement between age 60 and 62, an age group where most retirement stems from mineworkers. For example, in 2016, over 70% of the pensioner numbers among male 60-year-olds were mineworkers (Deutsche Rentenversicherung Bund 2017a). The coefficient for the legal retirement age of unemployed persons is negative, which appears strange at first. One possible explanation might be, that an increasing legal retirement age for unemployed might set incentives for them to retire early instead of applying for welfare services for longer periods (Brussig 2012).

After smoothing the data to the quantified model, we fit a Box-Jenkins time series model to the data (see Box et al. 2016). Based on the autocorrelation function (ACF) and the partial autocorrelation function (PACF), we identify a random walk as the most appropriate model for the error term (see, e.g., Shumway and Stoffer 2016 on ARMA processes, ACFs and PACFs). The forecast model for PC1 is therefore

$$p_1(y) = -4{,}551.43 + 731.96\ln(s_y) + 0.41l_y - 0.32u_y + 0.58f_y + 355.66\ln(b_y) + r_y + \varepsilon_y, \quad (1)$$

with $\varepsilon_y \sim \mathcal{NID}(0, 0.37^2)$, $\ln(s_y)$ being the natural logarithm of the mean standard legal retirement age, l_y being the mean legal retirement age after being insured 45 years, u_y being the mean legal retirement age for unemployed persons, f_y being the mean legal female retirement age and b_y being the mean legal retirement age of mineworkers in year y, as calculated in Appendix A. r_y is the difference between the actual value of PC1 in period y and its mean estimate according to Model 1.3. The forecast of PC1 with 75% PIs is illustrated in Figure 3.

Figure 3. Forecast of Principal Component 1 with 90% PI



Source: Own calculation and design.

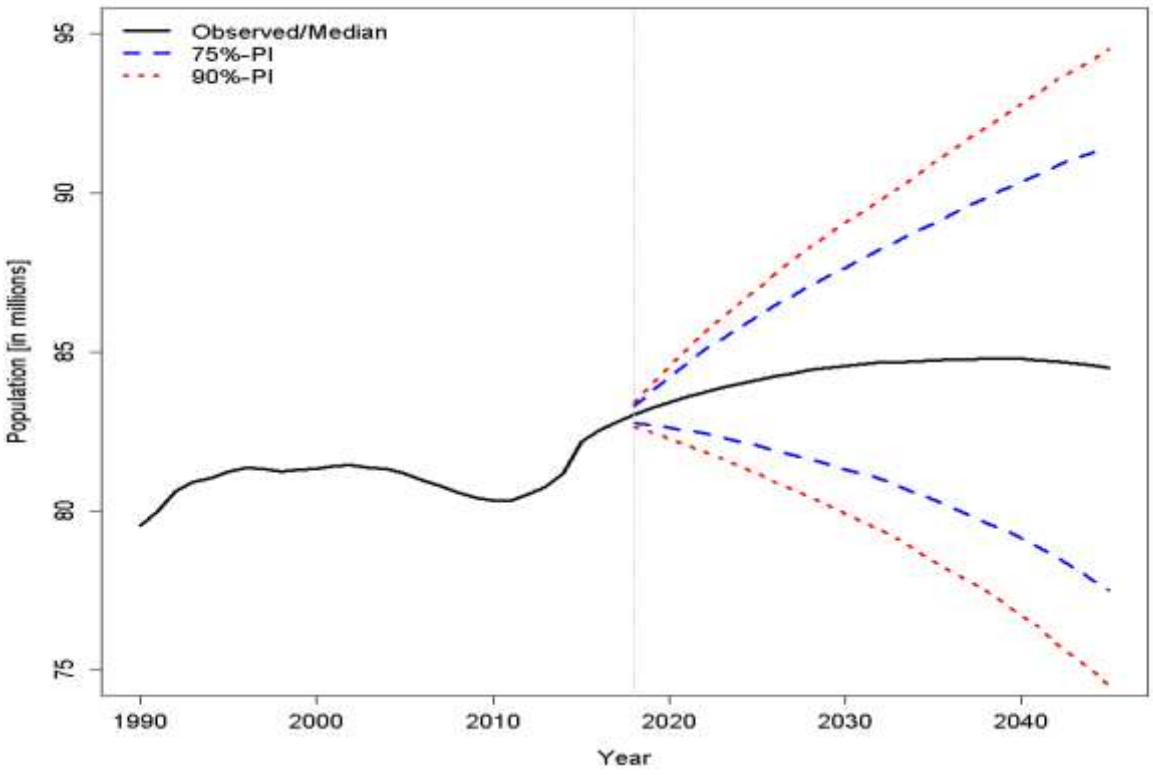
The remaining 15 PCs are assumed to be random walk processes, as they show no clear trending behavior and this allows for including the surplus risk generated by them reasonably well. The fitted PC models are used for future simulation of the 10,000 trajectories until 2040 via Wiener processes (see, e.g., Vanella 2018 on these). In this way, the stochasticity of all variables is considered in the forecast model (Vanella 2017). The trajectories of the PCs can easily

be re-transformed into trajectories of the ASSPRs (Vanella 2018). These are multiplied by the trajectories resulting from the probabilistic population forecast for Germany conducted by Vanella and Deschermeier (2020). In this way, trajectories of the pensioner numbers are derived through 2040.

5 Results

We will now present selected results of the population forecast by Vanella and Deschermeier (2020), which constitutes the basis of the pension forecast conducted in the present contribution. Figure 4 shows the forecast of the future total population through 2045 with 75% and 90% PIs.

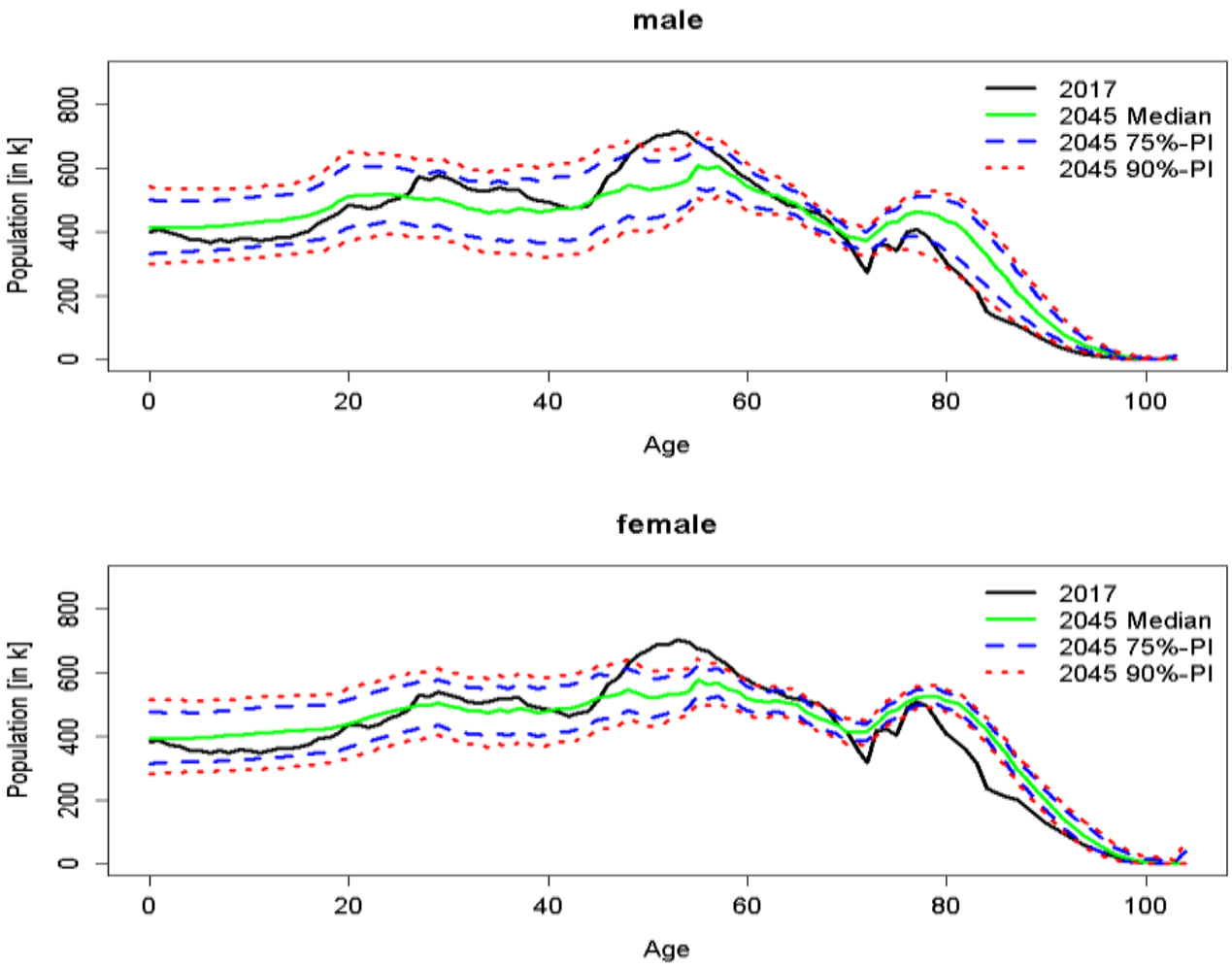
Figure 4. Population until 2045 with 75% and 90% PIs



Source: Vanella and Deschermeier (2020).

There is a high probability that the total population will increase over the forecast horizon. The population in the median forecast for December 31st, 2040 will be slightly below 85 million. In light of the pension fund, the population structure is of high relevance. Figure 5 compares the estimated age- and sex-specific population on December 31st, 2017 with the median forecast and the 75% and 90% PIs for each age and both sexes. The uncertainty in the future population is substantial, to a large extent due to the high stochasticity in international migration. This accentuates why it is advantageous for forecasting population and pensions on a probabilistic basis.

Figure 5. Population by Sex and Age on Dec 31, 2017 and 2040



Source: Vanella and Deschermeier (2020).

Obviously, the increase in the population results from clear growth in the population in the pension age group, whereas the population in the typical labor age group is expected to decrease by then. The old-age dependency ratio resulting from the population structure is often used as a representative statistic for future pressure on the DRV, as illustrated in Section 3. Table 2 gives a selection of the simulation results of Vanella and Deschermeier (2020) by three age groups.

Table 2. Forecast Population (in millions) for Selected Years and Three Age Groups with 75% PIs

Year	Young Median	Young 75% PI Lower Bound	Young 75% PI Upper Bound	Working Age Median	Working Age 75% PI Lower Bound	Working Age 75% PI Upper Bound	Old Median	Old 75% PI Lower Bound	Old 75% PI Upper Bound
2017	15.252			51.804			15.736		
2021	15.573	15.354	15.799	51.588	51.178	52.012	16.428	16.357	16.500
2025	16.122	15.675	16.563	50.755	49.958	51.568	17.233	17.064	17.398
2029	16.642	15.948	17.337	49.396	48.224	50.559	18.446	18.181	18.715
2033	17.031	16.065	17.985	47.845	46.346	49.325	19.812	19.439	20.188
2037	17.086	15.853	18.311	47.065	45.233	48.871	20.630	20.127	21.118
2041	16.974	15.510	18.481	47.352	45.211	49.513	20.389	19.744	21.013
2045	16.835	15.124	18.609	47.829	45.340	50.382	19.844	19.020	20.603

Source: Vanella and Deschermeier (2020).

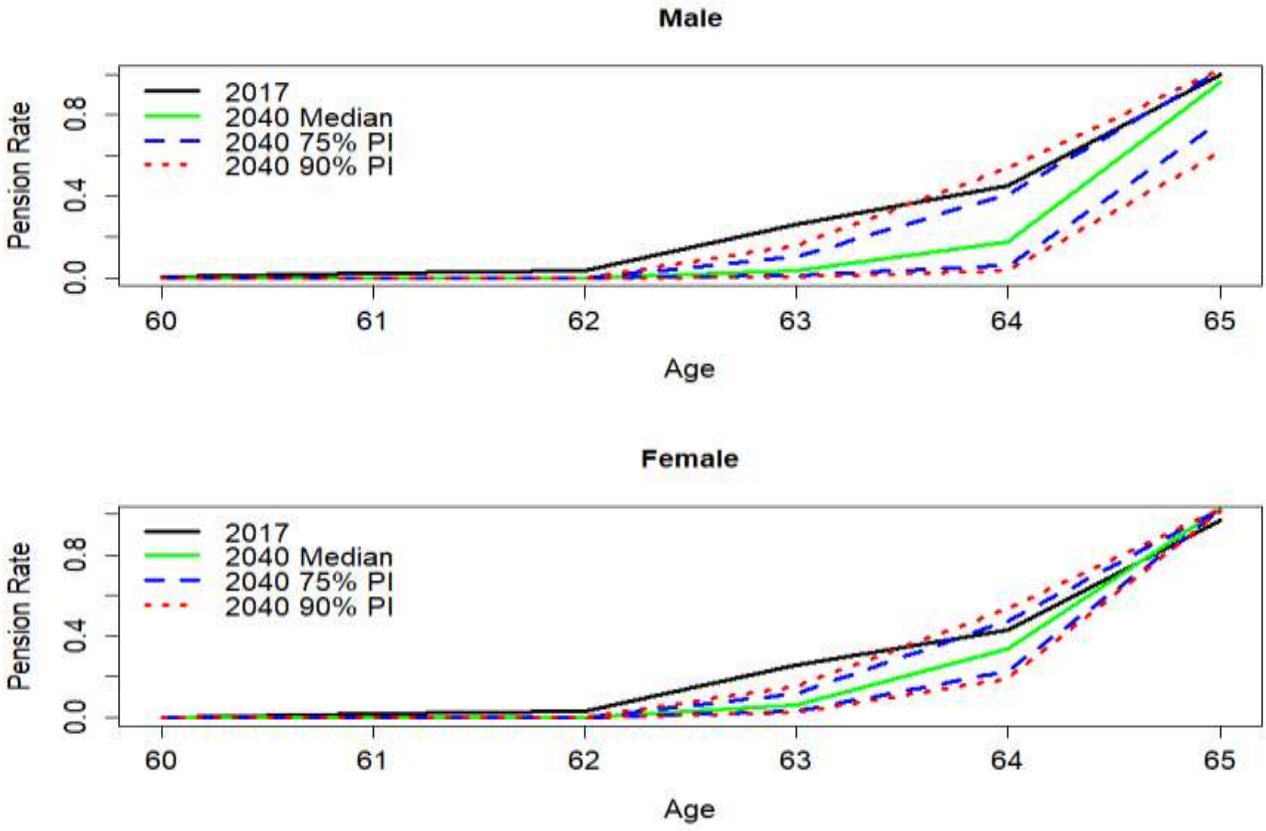
In our context, the forecasts of the working-age population[7]and the old-age population[8]. At high probability, we observe a strongly increasing old-age dependency ratio due to a decreasing

[7] Defined by Vanella and Deschermeier (2020) as persons aged 20-66 years of age.
[8] The old-age population here is defined as the population aged 67 and above.

working-age population[9] until the late 2030s alongside an increasing population in the pension age group.

Our modeling approach provides more insight into the actual pension numbers because the predicted population at this stage is multiplied by the age- and sex-specific risks of pension claim estimated by our PC time series method. The trajectories of the PCs are transformed back into trajectories of the ASSPRs, as mentioned above. The trajectories can be used to estimate quantiles of the forecast to construct PIs. Figure 6 illustrates the ASSPRs for old-age pensions at year-end 2017 in comparison to the predicted ASSPRs in the median trajectory with 75% and 90% PIs at the end of the forecast horizon.

Figure 6. Age- and Sex-specific Pension Rates in 2017 and 2040

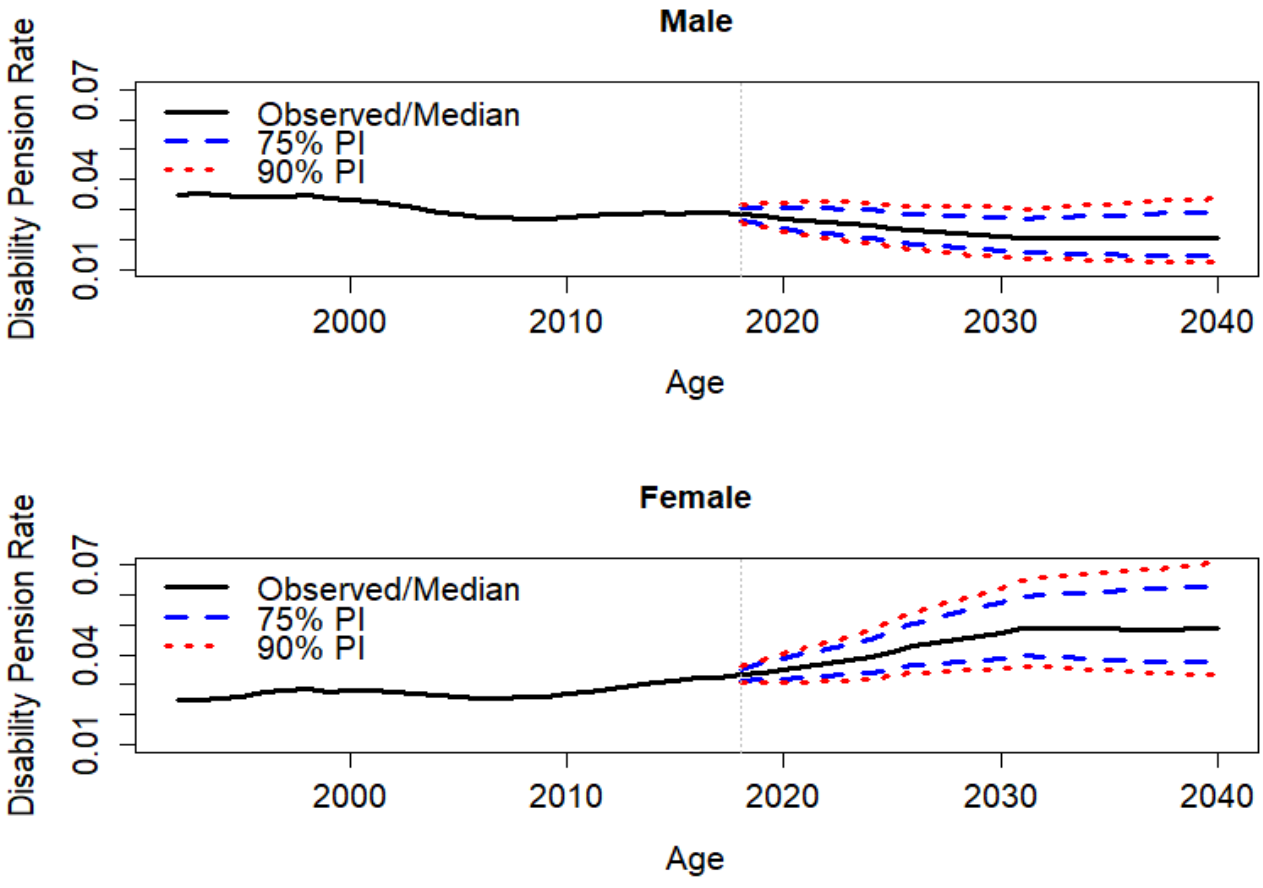


Source: Statistikportal der Rentenversicherung (2020a); Human Mortality Database (2019); Own calculation and design.

[9] Remember, that this does not even include labor force participation (see, for instance, Fuchs et al. 2018 on this), but simply refers to the age group.

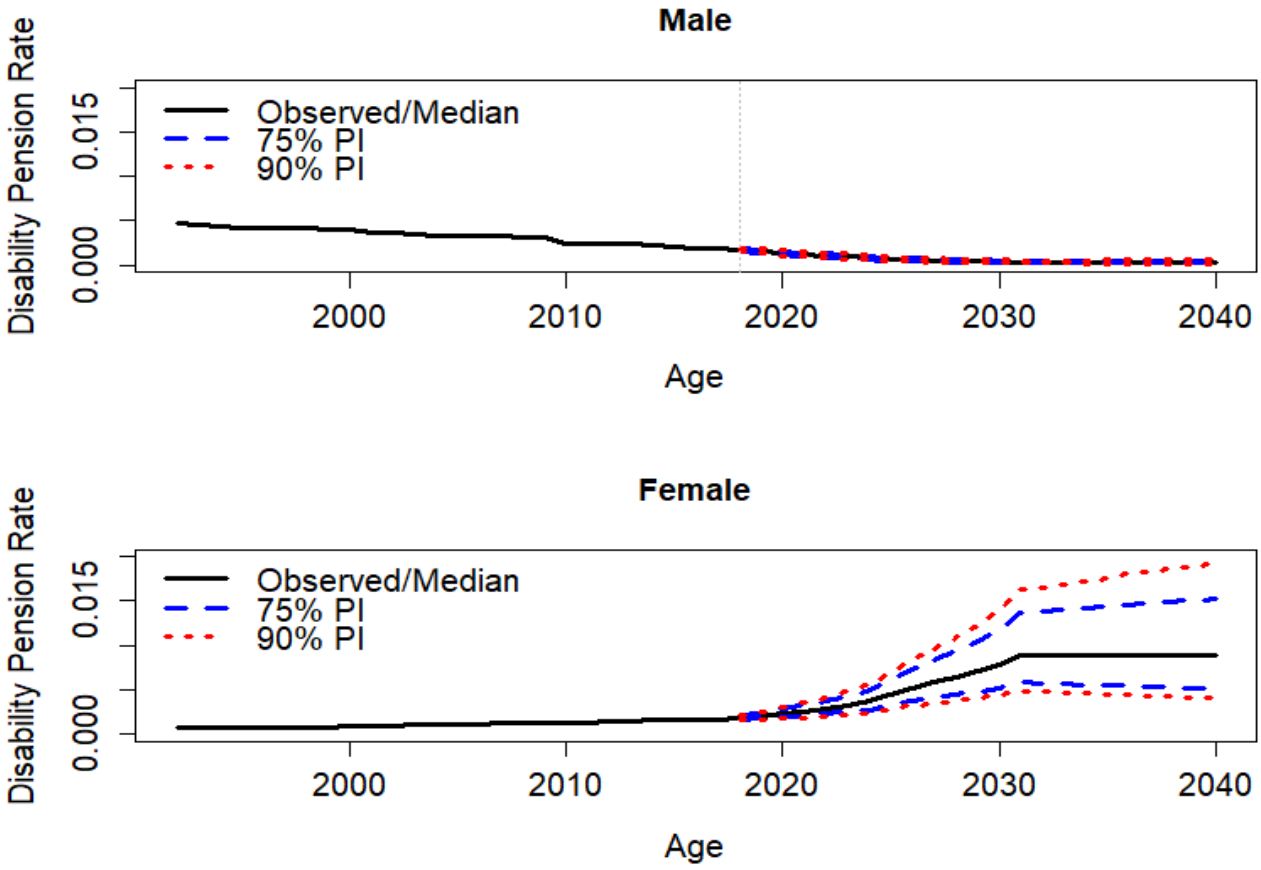
For the age group of people under 65 years, a decrease in the prevalence of old-age pension claims is probable as a result of the pension reform of 2007 described in Section 2, as these reforms push the standard legal retirement age to 67 years. For the age group older than that, the changes for the males will be subtle, whereas the ASSPRs of the females will almost certainly increase. This stems from the high labor force participation rates of the female population born since the baby-boom years (Fuchs et al. 2018). The preceding generations participated less in the labor market because their primary profession was mostly motherhood and housekeeping (Hertrampf 2008).

Figure 7. Forecast of Full Disability Pension Rate by Sex



Source: Deutsche Rentenversicherung Bund (2018); Forschungsportal der Deutschen Rentenversicherung (2018); Statistikportal der Rentenversicherung (2020b); Human Mortality Database (2019); Own calculation and design.

Figure 8. Forecast of Partial Disability Pension Rate by Sex

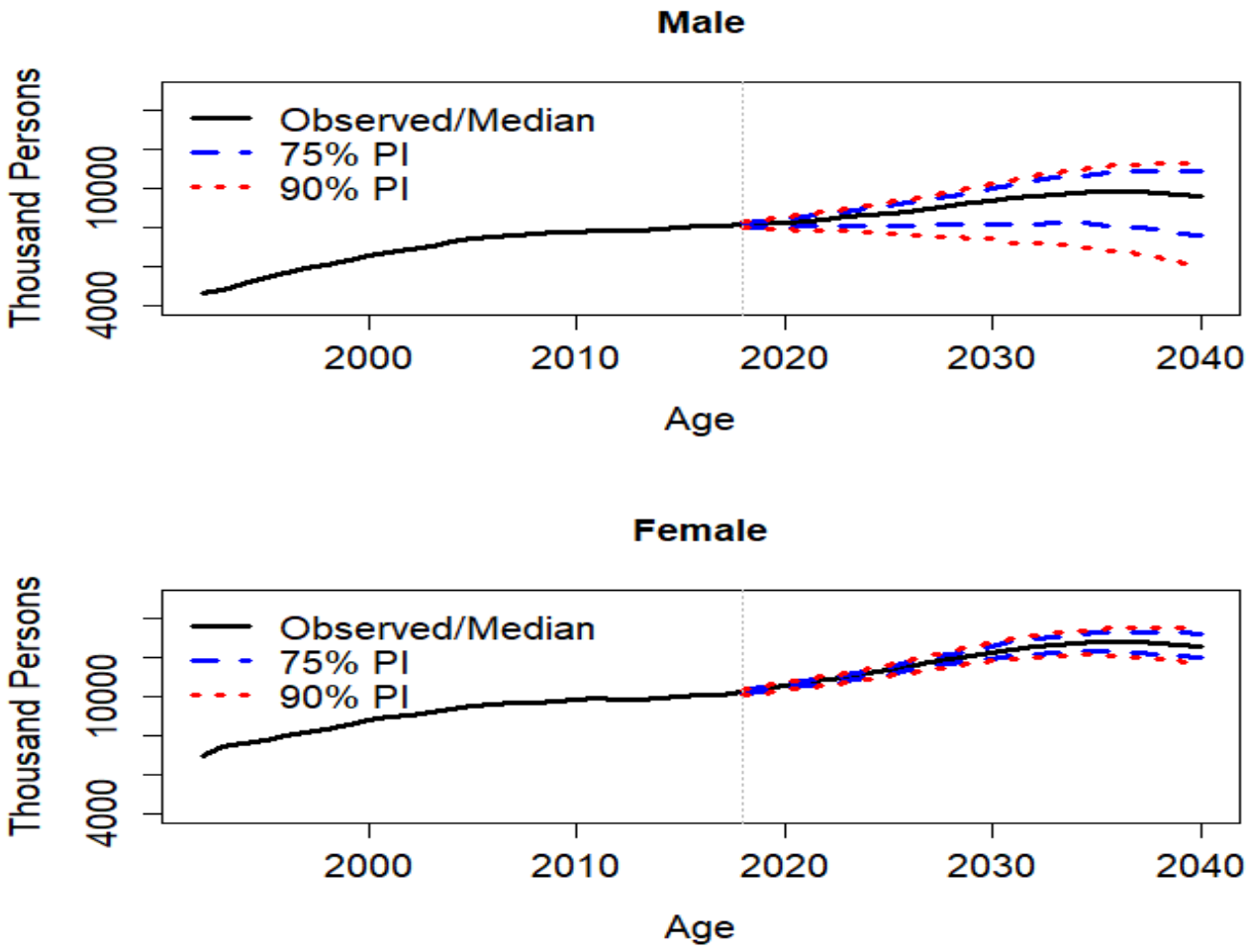


Source: Deutsche Rentenversicherung Bund (2018); Forschungsportal der Deutschen Rentenversicherung (2018); Statistikportal der Rentenversicherung (2020b); Human Mortality Database (2019); Own calculation and design.

Figures 7 and 8 give the past and future overall rates of disability pensions by sex and type of pension. For both types of disability pension, we will observe decreasing overall rates for the males and increases for the females. This can be explained by decreasing age-specific disability risks for the males due to healthier life circumstances and a decreasing share of persons working in the physically exhausting fields of work, which more often precede disabilities (Rodriguez Gonzalez et al. 2015). The trends for females are much different. First, the susceptibility to serious disabilities in the high age groups for the females excels the males' strongly (Vanella et al. 2020). Second, due to the increasing labor force participation rates of the females, they are to a higher degree eligible to disability pensions in comparison to the preceding generations.

Multiplication of the ASSPRs derived in this study with the age- and sex-specific population estimated by Vanella and Deschermeier (2020) results in forecasts of the future pension numbers. Figure 9 illustrates the resulting forecast of the total numbers of old-age retirees by sex.

Figure 9. Forecast of Old-Age Pensioners by Sex until 2040

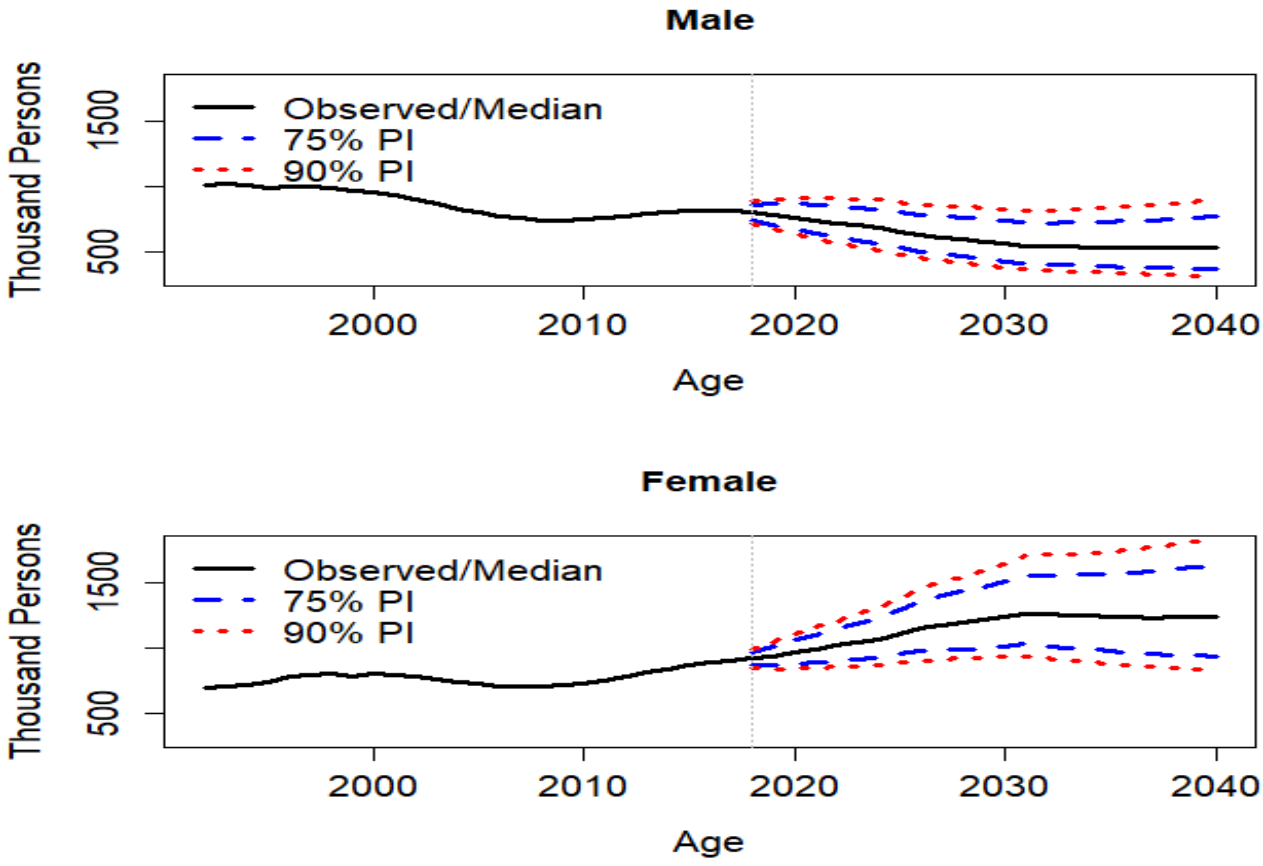


Source: Destatis (2018a); Statistikportal der Rentenversicherung (2020a); Vanella and Deschermeier (2020); Own calculation and design.

In the mean, we observe a monotonically increasing number of old-age pensioners for both sexes until the mid-2030s. The increase is especially large until the late 2020s, the period in which the strongest birth cohorts reach their respective retirement ages. After this point, there is a high probability that the total number of retirees will increase further, but at decreasing

rates. This trend is caused by slightly decreasing birth cohorts entering their retirement ages, combined with the effects of the pension reforms since 1992, which imply lower age-specific old-age pension rates. The decreasing trend after the mid-2030s echoes the weaker birth cohorts since the 1970s, which can also be observed in Table 2. Overall, we see that the number of old-age pensioners will increase from 8.1 million to 9.9 million in the median for the males and from 10.1 to 12.8 million for the females between 2017 and 2036, the year with the predicted maximum for both genders. These results include demographic trends and the labor market participation effect. These results show the massive increase in retirees occurring over the forecast horizon. The increase in legal retirement ages by two years obviously does not suffice to address demographic development from the perspective of the DRV.

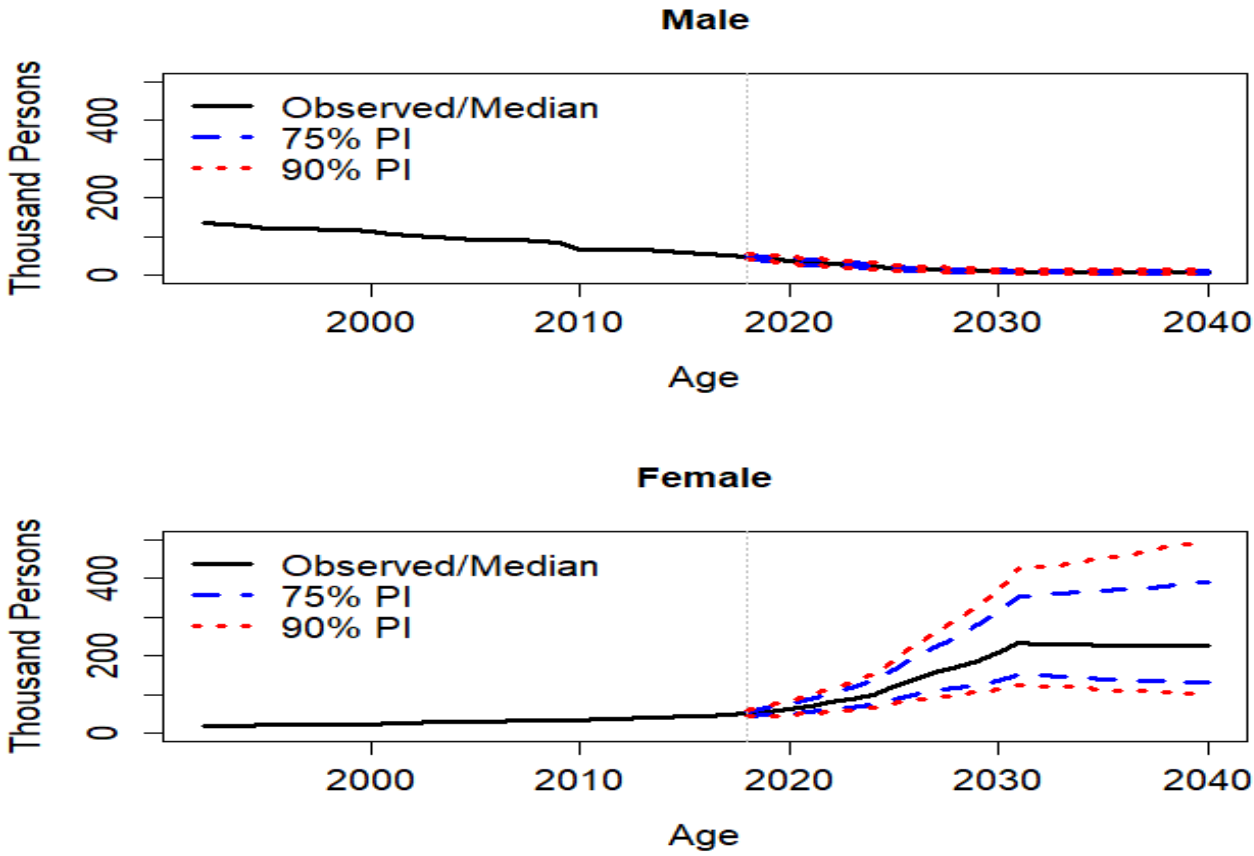
Figure 10. Forecast of Full Disability Pensions



Source: Deutsche Rentenversicherung Bund 2018; Forschungsportal der Deutschen Rentenversicherung 2018; Statistikportal der Rentenversicherung 2020b; Vanella and Deschermeier 2020; Own calculation and design.

Figures 10 and 11 show the cumulated forecasts of the numbers of disability pensions for fully and partially disabled persons by sex, respectively. The long-term trend for males is negative because the relative prevalence of disability decreases as illustrated in Figure 8. On the other hand, the increase in the legal retirement age means, c.p., an increase in the risk of disability pension claims. These trends are superimposed on the demographic trends for the females; therefore, increasing numbers of pensioners can be expected until the early 2030s. After that point, the strong birth cohorts enter the legal retirement age, so the disability pension numbers will probably decrease again slightly because of the decrease in the population numbers in the respective age group.

Figure 11. Forecast of Partial Disability Pensions



Source: Deutsche Rentenversicherung Bund 2018; Forschungsportal der Deutschen Rentenversicherung 2018; Statistikportal der Rentenversicherung 2020b; Vanella and Deschermeier 2020; Own calculation and design.

It can be concluded that the pension reforms that increase the legal retirement rates not only contain the increase in old-age retiree numbers but also increase the numbers of disability pensions until the early 2030s. Especially for the females, the increase in the legal retirement age might lead to a sharp increase in the number of cases in which a disability pension will be claimed. This is an effect of increasing female labor force participation rates in combination with the increasing legal retirement age, as there will be more women active in the labor market and therefore "eligible" for disability pensions; in the past, these women might have retired earlier.

To conclude, we see that a trivial analysis based on simple statistics such as the old-age dependency ratio does not suffice for a thorough forecast of the demand for statutory pension payments. An age-specific and joint forecast of old-age and disability pensions is needed for a full understanding of the real sensitivity of the pension system to reforms and demographic developments. Moreover, a stochastic approach includes the high uncertainty of the complex system of interacting population trends, labor market effects, and the regulations of the pension system.

6 Discussion

Even though our main result concerning an increasing number of future pensioners is very robust, our approach has some limitations. For example, the model does not consider age-specific pension rates of disability rates. This approach was tested as well, but did not give plausible loadings for all variables. Therefore, disability pensions are only discriminated by sex and type of pension. Moreover, the model does not include widow and orphan pensions. There are two reasons for this: First, regarding disabled persons under 60, inclusion in the model could give

false indications of sensitivity to retirement ages.[10] Second, the data for this type of pension is not available in the form needed to fit our model. Third, we would need data or strong assumptions on nuptial behavior, eradicating the advantages of the chosen probabilistic approach to some degree.

Further studies might include these types of pensions in their analyses. To provide a full picture of not only the numbers of pensions but also their volumes, an enhanced pension model should include all kinds of pensions covered by the DRV as well as the development of the labor market. A joint model for the labor market and pensions would present a meaningful extension, as the labor market and the pension system are basically two sides of the same coin and influence one another heavily. Moreover, the present contribution was restricted to persons instead of economic entities such as monetary units. Such deeper analyses require forecasts of economic development as well. Because our pension model is fully probabilistic, the associated economic model should also be probabilistic. Drawing stochasticity from one source only, as done in previous studies, would create a biased picture of reality by creating some kind of pseudo-stochasticity. Further research might add forecasts addressing the financial effects using a probabilistic economic model and might elaborate on the approaches presented in Section 3 within a probabilistic framework.

7 Conclusions

The present study showed the effect of future demographic development in Germany on the numbers of old-age and disability pensioners of the public pension system. Due to the aging of the baby-boom generation, we expect the numbers of old-age pensioners to increase by almost

[10] Those effects of course do not exist because persons do not "decide to die" based on the pension policy regime.

5 million persons, from 18 million in 2017 to 23 million in 2036. An increase holds even under increasing legal retirement ages, as adopted in the 2007 pension reform. Stochastic modeling for trajectories with high mortality rates equally shows increasing pensioner numbers. The pension reforms targeting obvious demographic trends do help mitigate the effects of the aging process to some extent but are far from sufficient.

Further reforms concerning the three basic parameters of the DRV in Germany are thus inevitable: the pension contribution rate, the pension level, and the legal retirement age. Furthermore, proposals regarding the financing option, such as a shift to a tax-funded system or the implementation of state-owned funds, are likewise being discussed. Furthermore, demography and labor market policy could offer another option for the long-term stabilization of the pension system. A larger number of retirees means that there is a need for a proportional increase in the labor force, assuming that the labor market offers enough jobs to support this increase. Because fertility influences the labor market only after approximately 20 years, a short- or mid-term effect can only be achieved by either decreasing emigration of the labor force or increasing the immigration of qualified workers, who can be integrated into the labor market quickly.[11]

Improvements on our modeling approach, as indicated in Section 6, might be considered in further studies, enhancing the model by a more detailed economic approach, which takes the pension formula into account an predicts the future payments of the DRV.

[11] Guest 2008, for example, also discusses measures to stimulate labor force participation rates of the elderly population, the fertility rate and higher immigration, alongside other measures like superannuation or health and care policy.

References

Ahn, N, Alonso-Meseguer, J, García, JR: A Projection of Spanish Pension System under Demographic Uncertainty. *Documento de Trabajo* 2005-20. Madrid: Fundación de Estudios de Economía Aplicada (2005)

Alho, JM, Nikander, T: Uncertain Population of Europe: Summary Results from a Stochastic Forecast. *UPE Report* D12/27.10.2004. Helsinki: Tilastokeskus (2004)

Alho, JM, Spencer, BD: *Statistical Demography and Forecasting.* Springer Science+Business Media: New York (2005)

Baldacci, E, Tuzi, D: Demographic Trends and Pension System in Italy: an Assessment of 1990s Reforms. *Labour* 17(Special Issue), 209 – 240 (2003)

Börsch-Supan, AH: Population Aging, Social Security Design, and Early Retirement. *Journal of Institutional and Theoretical Economics* 148(4), 533 – 557 (1992)

Börsch-Supan, AH: Incentive effects of social security on labor force participation: evidence in Germany and across Europe. *Journal of Public Economics* 78(1-2), 25 – 49 (2000)

Börsch-Supan, AH, Berkel, B: Pension Reform in Germany: The Impact on Retirement Decisions. *FinanzArchiv (Public Finance Analysis)* 60(3), 393 – 412 (2004)

Box, GEP, Jenkins, GM, Reinsel, GC, Ljung, GM: *Time Series Analysis: Forecasting and Control.* John Wiley & Sons: Hoboken (2016)

Brussig, M: Weiter steigendes Renteneintrittsalter, mehr Renteneintritte aus stabiler Beschäftigung, aber zunehmend geringere Altersrenten bei Langzeitarbeitslosen. Aktuelle Entwicklungen beim Rentenzugang. *Altersübergangs-Report* 2012-02. IAQ – Institute for Work, Skills and Training, Universität Duisburg-Essen.

Bucher-Koenen, T, Wilke, CB: Zur Anhebung der Altersgrenzen. *Sozialer Fortschritt (German Review of Social Policy)* 58(4), 69 – 79 (2009)

Buchholz, S, Rinklake, A, Blossfeld, HP: Reversing Early Retirement in Germany: A Longitudinal Analysis of the Effects of Recent Pension Reforms on the Timing of the Transition to Retirement and on Pension Incomes. *Comparative Population Studies* 38(4), 881 – 906 (2013)

Bundesregierung: Deutschlands Zukunft gestalten: Koalitionsvertrag zwischen CDU, CSU und SPD: 18. Legislaturperiode. https://www.bundesregierung.de/Content/DE/_Anlagen/2013/2013-12-17-koalitionsvertrag.pdf?blob=publicationFile (2013). Accessed 12 December 2017

Carter, LR, Lee, RD: Forecasting demographic components: Modeling and forecasting US sex differentials in mortality. *International Journal of Forecasting* 8(3), 393 – 411 (1992)

Chatfield, C, Collins, AJ: *Introduction to Multivariate Analysis.* Chapman & Hall: Boca Raton, London, New York, Washington (1980)

Coppola, M, Wilke, CB: At What Age Do You Expect to Retire? Retirement Expectations and Increases in the Statutory Retirement Age. *Fiscal Studies* 35(2), 165 – 188 (2014)

Destatis: *Bevölkerung und Erwerbstätigkeit: Gestorbene nach Alters- und Geburtsjahren sowie Familienstand 1948-2003* (2005). Data provided on 18 March 2016

Destatis: *Wanderungen zwischen Deutschland und dem Ausland 1993-2010 nach Einzelaltersjahren und Geschlecht* (2015d). Data provided on 2 September 2015

Destatis: *Gestorbene 2004-2010 nach Alters- und Geburtsjahren* (2017). Data provided on 15 August 2017

Destatis: *Statistik des Rentenbestands, Deutsche Rentenversicherung Bund.* http://www.gbe-bund.de (2018a). Accessed 29 May 29 2018.

Deutsche Rentenversicherung Bund: *Statistik der Deutschen Rentenversicherung Band 209: Rente 2016.* Deutsche Rentenversicherung Bund: Berlin (2017)

Deutsche Rentenversicherung Bund: *Rentenbestand am 31.12.1992-1999, Renten nach SGB VI wegen verminderter Erwerbsfähigkeit* (2018). Data provided on 7 June 2018

Dunstan, K, Ball, C: Demographic Projections: User and Producer Experiences of Adopting a Stochastic Approach. *Journal of Official Statistics* 32(4), 947 – 962 (2016)

European Commission: *The 2018 Aging Report: Economic & Budgetary Projections for the 28 EU Member States (2016-2070). Institutional Paper 079*. Publications Office of the European Union: Luxembourg (2018)

Federal Ministry of Labour and Social Affairs: *Bericht der Bundesregierung über die gesetzliche Rentenversicherung, insbesondere über die Entwicklung der Einnahmen und Ausgaben, der Nachhaltigkeitsrücklage sowie des jeweils erforderlichen Beitragssatzes in den künftigen 15 Kalenderjahren gemäß § 154 Abs. 1 und 3 SGB VI (Rentenversicherungsbericht 2019).* Federal Ministry of Labour and Social Affairs: Berlin (2019)

Federal Ministry of Labour and Social Affairs: *Die Rentenbestände in der gesetzlichen Rentenversicherung in der Bundesrepublik Deutschland.* Federal Ministry of Labour and Social Affairs: Berlin (2018)

Fehr, H, Habermann, C: Pension Reform and Demographic Uncertainty: The Case of Germany. *Journal of Pension Economics and Finance* 5(1), 69 – 90 (2006)

Forschungsportal der Deutschen Rentenversicherung: *Rentenbestand am 31.12.2000-31.12.2009, Renten nach SGB VI wegen verminderter Erwerbsfähigkeit.* http://forschung.deutsche-rentenversicherung.de/ForschPortalWeb/ (2018). Accessed 5 June 2018.

Fuchs, J, Söhnlein, D, Weber, B, Weber, E: Stochastic Forecasting of Labor Supply and Population: An Integrated Model. *Population Research and Policy Review* 37(1), 33 – 58 (2018)

Giang, TL, Pfau, WD: Demographic Changes and the Long-Term Pension Finances in Vietnam: A Stochastic Actuarial Assessment. *Population Aging* 1(2-4), 125 – 151 (2008)

Goffart, D: Zeitbombe Altersversorgung. *Focus* 36/2018, 52 – 60 (2018)

Graf von der Schulenburg, JM, Lohse, U: *Versicherungsökonomik: Ein Leitfaden für Studium und Praxis.* Verlag Versicherungswirtschaft: Karlsruhe (2014)

Gruber, J, Wise, DA: Social Security Programs and Retirement around the World. *Research in Labor Economics* 18(1), 1 – 40 (2000)

Guest, R: Evaluating Public Policy Responses to the Economic Burden of Population Ageing with Application to Australia. *Journal of Population Research* 25(2), 99 - 118 (2008)

Härdle, WK, Müller, M, Sperlich, S, Werwatz, A: *Nonparametric and Semiparametric Models.* Springer-Verlag: Berlin, Heidelberg (2004)

Härdle, WK, Myšičková, A: Stochastic Population Forecast for Germany and its Consequence for the German Pension System. *SFB 649 Discussion Paper* 2009-009. Humboldt Universität zu Berlin, School of Business and Economics: Berlin (2009)

Handl, A: *Multivariate Analysemethoden: Theorie und Praxis multivariater Verfahren unter Berücksichtigung von S-Plus.* Springer-Verlag: Heidelberg, Dordrecht, London, New York (2010)

Hertrampf, S: *Ein Tomatenwurf und seine Folgen. Eine neue Welle des Frauenprotestes in der BRD.* Bundeszentrale für politische Bildung. http://www.bpb.de/gesellschaft/gender/frauenbewegung/35287/neue-welle-im-westen (2008). Accessed on 15 February 2018.

Holthausen, A, Rausch, J, Wilke, CB: MEA-PENSIM 2.0: Weiterentwicklung eines Rentensimulationsmodells, Konzeption und ausgewählte Anwendungen. *MEA Discussion Papers* 03-

2012. Max Planck Institute for Social Law and Social Policy, Munich Center for the Economics of Aging: Munich (2012)

Human Mortality Database: Germany, Population Size (abridged). University of California, Berkeley (USA), and Max Planck Institute for Demographic Research (Germany). www.mortality.org or www.humanmortality.de. Accessed 7 July 2019

Istat: *Il futuro demografico del paese. Previsioni regionali della popolazione residente al 2065 (base 1.1.2017).* Istituto Nazionale di Statistica : Roma (2018)

Keilman, N, Dinh, QP, Hetland, A: Why population forecasts should be probabilistic – illustrated by the case of Norway. *Demographic Research* 6(15), 409 – 454 (2002)

Koissi, MC: Longevity and adjustment in pension annuities, with application to Finland. *Scandinavian Actuarial Journal* 2006(4), 226 – 242 (2006)

Lee, RD: Stochastic demographic forecasting. *International Journal of Forecasting* 8(3), 315 – 327 (1992)

Lee, RD: Modeling and forecasting the time series of US fertility: Age distribution, range, and ultimate level. *International Journal of Forecasting* 9(2), 187 – 202 (1993)

Lee, RD: Probabilistic Approaches to Population Forecasting. *Population and Development Review* 24(Supplement: Frontiers of Population Forecasting), 156 – 190 (1998)

Lee, RD, Carter, LR: Modeling and Forecasting U.S. Mortality. *Journal of the American Statistical Association* 87(419), 659 – 671 (1992)

Li, Q, Reuser, M, Kraus, C, Alho, JM: Ageing of a giant: a stochastic population forecast for China, 2006 – 2060. *Journal of Population Research* 26(1), 21 – 50 (2009)

Lipps, O, Betz, F: Stochastische Bevölkerungsprojektion für West- und Ostdeutschland. *Zeitschrift für Bevölkerungswissenschaft (Comparative Population Studies)* 30(1), 3 – 42 (2005)

OECD: *OECD Pensions Outlook 2018.* OECD Publishing: Paris (2018). https://doi.org/10.1787/pens_outlook-2018-en

Ogawa, N: Population aging and policy options for a sustainable future: the case of Japan. *Genus* 61(3-4), 369 – 410 (2005)

Pötzsch, O, Rößger, F: *Germany's Population by 2060. Results of the 13th coordinated population projection.* Destatis: Wiesbaden (2015)

Rodriguez Gonzalez, M; Lohse, R; Schröder, M; Krohn, S; Zuchandke, A: Sozioökonomische Analyse des Erwerbsminderungsrisikos – Eine Untersuchung anhand von BASiD-Daten. *Zeitschrift für die gesamte Versicherungswissenschaft (German Journal of Risk and Insurance)* 104(2), 151 – 178 (2015)

RRG: Gesetz zur Reform der gesetzlichen Rentenversicherung. *Bundesgesetzblatt Teil I*, Nr. 1989/60, 2261 – 2395 (1992)

RRG: Gesetz zur Reform der gesetzlichen Rentenversicherung. *Bundesgesetzblatt Teil I*, Nr. 1997/85, 2998 – 3038 (1999)

RÜG: Gesetz zur Herstellung der Rechtseinheit in der gesetzlichen Renten- und Unfallversicherung. *Bundesgesetzblatt Teil I*, Nr. 1991/46, 1606 – 1708 (1991)

RV-AltAnpG: Gesetz zur Anpassung der Regelaltersgrenze an die demografische Entwicklung und zur Stärkung der Finanzierungsgrundlagen der gesetzlichen Rentenversicherung. *Bundesgesetzblatt Teil I*, Nr. 2007/16, 554 – 575 (2007)

RVLeistVerbG: Gesetz über Leistungsverbesserungen in der gesetzlichen Rentenversicherung. *Bundesgesetzblatt Teil I*, Nr. 2014/27, 787 – 790 (2014)

Shumway, RH, Stoffer, DS: *Time Series Analysis and Its Applications: With R Examples*. Springer Science+Business Media: New York, Dordrecht, Heidelberg, London (2016)

Statistikportal der Rentenversicherung: *Rentenbestand: Renten wegen Alters nach SGB VI.* https://statistik-rente.de/drv/ (2020a). Accessed 20 January 2020

Statistikportal der Rentenversicherung: *Rentenbestand: Renten wegen verminderter Erwerbsfähigkeit nach SGB VI.* https://statistik-rente.de/drv/ (2020b). Accessed 20 January 2020

Tomaš, I: A stochastic forecast for the Croatian pension system. *Public Sector Economics* 44(1), 41 – 98 (2020)

United Nations: *World Population Prospects: The 2006 Revision.* United Nations: New York (2007)

Vanella, P: A principal component model for forecasting age- and sex-specific survival probabilities in Western Europe. *Zeitschrift für die gesamte Versicherungswissenschaft (German Journal of Risk and Insurance*) 106(5), 539 – 554 (2017)

Vanella, P: Stochastic Forecasting of Demographic Components Based on Principal Component Analyses. *Athens Journal of Sciences* 5(3), 223 – 246 (2018)

Vanella, P, Deschermeier, P: A stochastic Forecasting Model of international Migration in Germany. In: Kapella, O., Schneider, N.F., Rost, H. (eds.) *Familie – Bildung – Migration: Familienforschung im Spannungsfeld zwischen Wissenschaft, Politik und Praxis. Tagungsband zum 5. Europäischen Fachkongress Familienforschung,* pp. 261 – 280. Verlag Barbara Budrich : Opladen, Berlin, Toronto (2018)

Vanella, P, Deschermeier, P: A Principal Component Simulation of Age-Specific Fertility – Impacts of Family Policy on Reproductive Behavior in Germany. *Population Review* 58(1), 78 – 109 (2019)

Vanella, P, Deschermeier, P: A Probabilistic Cohort-Component Model for Population Forecasting – The Case of Germany. *Journal of Population Ageing, online first.* doi: 10.1007/s12062-019-09258-2 (2020)

Vanella, P; Heß, M, Wilke, CB: A probabilistic projection of beneficiaries of long-term care insurance in Germany by severity of disability. *Quality & Quantity: International Journal of Methodology, online first.* doi: 10.1007/s11135-020-00968-w (2020)

Vogt, V: Die Projektion der langfristigen Entwicklung der gesetzlichen Rentenversicherung: Methodische Vorgehensweise und empirische Ergebnisse. In: Altmeppen, K.D., Zschaler, F., Zademach, H.M., Böttigheimer, C., Müller, M. (eds.) *Nachhaltigkeit in Umwelt, Wirtschaft und Gesellschaft: Interdisziplinäre Perspektiven*, pp. 149 – 170. Springer VS: Wiesbaden (2017)

Wang, H, Huang, J, Yang, Q: Assessing the Financial Sustainability oft he Pension Plan in China: The Role of Fertility Policy Adjustment and Retirement Delay. *Sustainability* 11(3), 883.

Werding, M: Demographie und öffentliche Haushalte: Simulationen zur langfristigen Tragfähigkeit der gesamtstaatlichen Finanzpolitik in Deutschland. *Arbeitspapier* 3/2011. Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung: Wiesbaden (2011)

Werding, M: *Modell für flexible Simulationen zu den Effekten des demographischen Wandels für die öffentlichen Finanzen in Deutschland bis 2060: Daten, Annahmen und Methoden.* Dokumentation im Auftrag der Bertelsmann Stiftung: Ruhr Universität Bochum (2013)

WFG: Gesetz zur Umsetzung des Programms für mehr Wachstum und Beschäftigung in den Bereichen der Rentenversicherung und Arbeitsförderung. *Bundesgesetzblatt Teil I*, Nr. 1996/48, 1461 – 1475 (1996)

Wilke, CB: *German Pension Reform.* Peter Lang Internationaler Verlag der Wissenschaften: Frankfurt (a.M.) (2009)

Wilke, CB, Börsch-Supan, AH: Zur mittel- und langfristigen Entwicklung der Erwerbstätigkeit in Deutschland. *Zeitschrift für ArbeitsmarktForschung (Journal of Labour Market Research)* 42(6) (2009)

Zuchandke, A, Lohse, U, Graf von der Schulenburg, JM: Financial sustainability of the German statutory pension scheme through 2060 – Can higher fertility rates and immigration mitigate the financial pressure? *Zeitschrift für die gesamte Versicherungswissenschaft (German Journal of Risk and Insurance)* 103(3), 283 – 299 (2014)

List of Abbreviations

ACF	autocorrelation function
AIC	Akaike's Information Criterion
ARIMA	autoregressive integrated moving average
ASFR	age-specific fertility rate
ASSPR	age- and sex-specific pension rate
BIC	Bayesian Information Criterion
DDR	German Democratic Republic
c.p.	ceteris paribus
DRV	Deutsche Rentenversicherung
MAC	mean age at childbearing
PACF	partial autocorrelation function
PCA	principal component analysis
PI	prediction interval
RKI	Robert Koch Institute
RRG	Rentenreformgesetz
RÜG	Renten-Überleitungsgesetz
RV-AltAnpG	Rentenversicherungs-Altersgrenzenanpassungsgesetz
TFR	total fertility rate
WFG	Wachstums- und Beschäftigungsförderungsgesetz

Appendix A: Mean Retirement Ages

Table 3. Past, Current, and Future Mean Annual Legal Retirement Ages

Year	Stand-ard	35 Years Insured	45 Years Insured	Severely Disabled	Unem-ployed	Women	Mine-workers
1992	65.000	63.000	63.000	60.000	60.000	60.000	60.000
1993	65.000	63.000	63.000	60.000	60.000	60.000	60.000
1994	65.000	63.000	63.000	60.000	60.000	60.000	60.000
1995	65.000	63.000	63.000	60.000	60.000	60.000	60.000
1996	65.000	63.000	63.000	60.000	60.000	60.000	60.000
1997	65.000	63.000	63.000	60.000	60.292	60.000	60.000
1998	65.000	63.000	63.000	60.000	60.792	60.000	60.000
1999	65.000	63.000	63.000	60.000	61.292	60.000	60.000
2000	65.000	63.292	63.292	60.292	61.792	60.292	60.000
2001	65.000	63.792	63.792	60.792	62.292	60.792	60.000
2002	65.000	64.292	64.292	61.292	62.792	61.292	60.000
2003	65.000	64.792	64.792	61.792	63.292	61.792	60.000
2004	65.000	65.000	65.000	62.292	63.792	62.292	60.000
2005	65.000	65.000	65.000	62.792	64.292	62.792	60.000
2006	65.000	65.000	65.000	63.000	64.792	63.292	60.000
2007	65.000	65.000	65.000	63.000	65.000	63.792	60.000
2008	65.000	65.000	65.000	63.000	65.000	64.292	60.000
2009	65.000	65.000	65.000	63.000	65.000	64.792	60.000
2010	65.000	65.000	65.000	63.000	65.000	65.000	60.000
2011	65.000	65.000	65.000	63.000	65.000	65.000	60.000
2012	65.083	65.083	65.083	63.000	65.083	65.083	60.292
2013	65.159	65.159	65.159	63.000	65.159	65.159	60.538
2014	65.235	65.235	63.000	63.000	65.235	65.235	60.614
2015	65.311	65.311	63.000	63.292	65.311	65.311	60.689
2016	65.386	65.386	63.167	63.538	65.386	65.386	60.765
2017	65.462	65.462	63.333	63.614	65.462	65.462	60.841
2018	65.538	65.538	63.500	63.689	65.538	65.538	60.917
2019	65.614	65.614	63.667	63.765	65.614	65.614	61.000

2020	65.689	65.689	63.833	63.841	65.689	65.689	61.167
2021	65.765	65.765	64.000	63.917	65.765	65.765	61.300
2022	65.841	65.841	64.167	64.000	65.841	65.841	61.433
2023	65.917	65.917	64.333	64.167	65.917	65.917	61.567
2024	66.000	66.000	64.500	64.300	66.000	66.000	61.700
2025	66.167	66.167	64.667	64.433	66.167	66.167	61.833
2026	66.300	66.300	64.833	64.567	66.300	66.300	62.000
2027	66.433	66.433	65.000	64.700	66.433	66.433	62.000
2028	66.567	66.567	65.000	64.833	66.567	66.567	62.000
2029	66.700	66.700	65.000	65.000	66.700	66.700	62.000
2030	66.833	66.833	65.000	65.000	66.833	66.833	62.000
2031	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2032	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2033	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2034	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2035	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2036	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2037	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2038	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2039	67.000	67.000	65.000	65.000	67.000	67.000	62.000
2040	67.000	67.000	65.000	65.000	67.000	67.000	62.000

Source: RRG (1992); WFG (1996); RRG (1999); RV-AltAnpG (2007); Bundesregierung (2013:72); RVLeistVerbG (2014); Own calculation and design.

Appendix B: Correlation Matrix of Mean Retirement Ages

Table 4. Correlation Matrix of Different Legal Retirement Ages over the Period 1992 to 2016

	Standard	35 Years Insured	45 Years Insured	Severely Disabled	Unem-ployed	Women	Mine-workers
Standard	1	0.87	0.52	0.82	0.75	0.78	0.96
35 Years Insured	0.87	1	0.72	0.99	0.97	0.96	0.89
45 Years Insured	0.52	0.72	1	0.7	0.72	0.64	0.47
Severely Disabled	0.82	0.99	0.7	1	0.99	0.98	0.86
Unem-ployed	0.75	0.97	0.72	0.99	1	0.98	0.79
Women	0.78	0.96	0.64	0.98	0.98	1	0.84
Mine-workers	0.96	0.89	0.47	0.86	0.79	0.84	1

Source: Own calculation and design.

Appendix C: Comparison of Selected Pension Projections

Table 5. Overview of Selected Studies on Pension Forecasting

Study	Baseline Data	Methods and Assumptions	Results	Coun-tries	Forecast Horizon
Alho and Nikander (2004)	Smoothed Age- and sex-specific mortality rates (ASSMRs) over preceding 30-year period Smoothed/interpolated/extrapolated Age-specific fertility rates (ASFRs) for females aged 15-49 in 2002 Estimated overall net migration and age pattern for 1990-2000 Estimated Jump-off population on January 1, 2003	Age-, sex-, and country-specific rates of decline in the ASSMRs assumed by linear extrapolation until 2030, after that constant ASSMRs in point forecast Assumed future total fertility rates (TFRs) in 2050, linear interpolation for the intermediate years; Mean age at childbearing (MAC) assumed to increase to 31 years by 2017, constant age schedule thereafter Net migration constant for ten years, then linear increase to presumed ultimate level Simulate 3,000 trajectories for each demographic component by AR(1) models including auto- and cross-correlations	Stochastic forecast of age- and sex-specific population (ASSP) Stochastic forecast of age-dependency ratio	19 EU and Schengen countries	2004-2050
Ahn, Alonso-Meseguer and García (2005)	Smoothed ASSMRs 1998-2002 ASFRs in 2002 Estimated overall net migration and age pattern for 1990-2000	Population forecast model similar to Alho and Nikander (2004) with 1,500 trajectories LFPR assumed to increase exponentially until a stated maximum (average of EU countries), thereafter kept constant	Stochastic forecast of ASSP Deterministic projection of	Spain	2004-2050

	Estimated Jump-off population on January 1, 2003 Labor force participation rate (LFPR), employment and unemployment rate in 2000 Data on unemployment benefits in 2000 from Spanish Labor Force Survey	Derive working-age population from population and LFPR forecasts Unemployment rate assumed to decrease linearly to 4.5% in 2015, constant thereafter Derivation of employed and unemployed population Labor productivity growth assumed to increase to 2 in 2019, constant thereafter Projection of GDP as sum of growth rate in employed population number and labor productivity Wage increases assumed equal at same rate as labor productivity Forecast of persons entering old-age pension or other types of pensions annually Calculation of pension contributions as share of labor income	macroeconomic development Pseudo-probabilistic projection of financial balance of pension system		
Lipps and Betz (2005)	Numbers of deaths by age and sex 1954-2000 Numbers of births by mother's age (15-49) 1973-2000 Population by sex and age 1954-2000	Forecast of ASSMRs following Lee and Carter (1992) TFR assumed random walk process; MAC forecast by logistic growth model; age schedule assumed Gaussian Net migration number assumed AR(1) process 500 trajectories sampling from estimated demographic models	Stochastic forecast of ASSP Stochastic forecast of old-age dependency ratio (OADR)	East and West Germany separately	2001-2050

Giang and Pfau (2008)	Mortality rates by five-year age groups 1999-2005 Fertility rates by five-year age groups (15-49) 1990-2005 Net migration structure of Japan 2005 Estimated Jump-off population 2005 by five-year age groups and sex Population active contributor age structure from Vietnam Household Living Standards Survey 2004 LFPR from annual surveys 1996-2005 Quinquennial Urbanization projections by UN 2005-2050 Inflation rates 1994-2005 Real investment return for pension fund assets 1996-2005 Real wage growth 1992-2005	Forecast of ASSMRs following Lee and Carter (1992) Forecast of ASFRs following Lee (1993); sex ratio of births assumed 1.06:1 for boys to girls as derived from past data; long-term TFR assumed 1.85, following UN assumptions Net migration constant LFPRs from 2005 assumed constant over forecast horizon Projected active labor force derived from population forecast and LFPRs Statutory pension coverage rate assumed to increase to 66% by 2105 Mean retirement ages assumed 57 and 51 years for males and females, respectively Average length of employment from past data Active contributors at average retirement ages assumed to change status into pensioner Economic variables stochastically simulated with log-normal distributions	Pseudo-stochastic pension fund forecast (1,000 iterations); migration and labor market variables deterministic	Vietnam	2005–2105
Härdle and Myšičková (2009)	ASSMRs 1956-2006 ASFRs (15-49) 1950-2006	Forecast of ASSMRs following Lee and Carter (1992) Forecast of ASFRs following Lee (1993)	Stochastic population forecast (5,000 iterations)	Germany	2007-2058

	Age- and sex-specific immigration and emigration ASSP on January 1, 2007	Total immigration and emigration by sex modeled by fit AR(1) models Age structure of migrants estimated by estimated kernel density Status Quo scenario for labor market participation, income pension system	Stochastic OADR, taking pension reform of 2007 into account Projection of pension premium rate and average pension level deterministic by nature, taking stochastic population into account		
Wilke (2009)	ASSMRs after World War II ASSP on December 31, 2005 Population projections by Destatis LFPRs from micro census Danish LFPRs	Different scenarios regarding future development of mortality, fertility and migration Different scenarios about labor force participation Different scenarios about unemployment rates Different assumptions about economic growth and development of wages Different assumptions about retirement age Different scenarios for disability risks	Wide range of possible deterministic scenarios for future development of pension fund, contribution rates and pension levels taking German pension system fully into account	Germany	2006-2100

Werding (2013)	ASSMRs 2000-2008 ASFRs (15-49) 2008 Age- and sex-specific immigration and emigration 2008 ASSP on December 31, 2008 LFPRs by sex and age (15-64) 1991-2010 LFPRs by sex and age (65-74) 2000, 2005 and 2010 Labor force, social insured employed and unemployed persons by qualification from micro census 1991-2010 Data on wages by sex and qualification Estimated unemployment rates by qualification Economic data	Forecast of ASSMRs following Lee and Carter (1992) TFR assumed constant on 2008 level; fixed age schedule following Gaussian function for ASFRs Total immigration and emigration assumed to increase to 800,000 and 650,000 to 2020 respectively, constant thereafter; age schedules similar to 2008 Female LFPRs converge to males' Deterministic projection economic, labor market and educational variables	Deterministic projections of numbers of active insured and number and structure of pensioners, contribution rates and pension levels	Germany	2009-2060
European Commission (2018)	Demographic, labor market and economic data	Scenario analyses for the variety of variables	Deterministic pension expenditure projections	28 EU member states	2016-2070
OECD (2018)	Demographic, labor market and economic data	Scenario analyses for the variety of variables	Deterministic pension expenditure projections	OECD-/G20-countries	2017-2060

Our study	Deaths by sex and age 1952-2016 Births by age of mother (13-52) 1968-2016 Age- and sex-specific immigration and emigration 1990-2016 Immigration and emigration by age group, sex and nationality ASSP 2010-2016 Pension numbers by age, sex and type (old-age, disability) 1992-2016 Forecast of age- and sex-specific survival rates following Vanella (2017) Forecast of ASFRs following Vanella and Deschermeier (2019) Forecast of age- and sex-specific net migration following Vanella and Deschermeier (2018a) Forecast of ASSP from Vanella and Deschermeier (2018b)	Forecast of pension rates by age, sex and pension type (old-age, full disability, partial disability) by time series forecast of principal component model Derivation of pension numbers from forecast pension rates and population Monte Carlo simulation (10,000 trajectories)	Stochastic forecast of pension rates by age and sex for old-age pensions, full disability pensions and partial disability pensions Stochastic forecast of numbers of old-age pensioners, fully disabled and partially disabled aged 60 and older	Germany	2017-2040

Source: Own representation.

Module 3

The Global Financial Crisis, the EMU Sovereign Debt Crisis and International Financial Regulation: Lessons from a Systematic Literature Review

Meier, S. / Rodriguez Gonzalez, M. / Kunze, F. (2021)

Published in:
International Review of Law and Economics, Vol. 65. DOI:
https://doi.org/10.1016/j.irle.2020.105945.

International Review of Law and Economics 65 (2021) 105945

Contents lists available at ScienceDirect

International Review of Law and Economics

The global financial crisis, the EMU sovereign debt crisis and international financial regulation: lessons from a systematic literature review

Samira Meier [a,*], Miguel Rodriguez Gonzalez [b], Frederik Kunze [c]

[a] Mendel University in Brno, Zemědělská 1665, 61300 Brno-sever-Černá Pole, Czech Republic
[b] Gottfried Wilhelm Leibniz University Hannover, Otto-Brenner-Straße 7, 30159 Hannover, Germany
[c] Norddeutsche Landesbank Girozentrale, Friedrichswall 10, 30159 Hannover, Germany

ARTICLE INFO

Article history:
Received 31 August 2019
Received in revised form
15 September 2020
Accepted 17 September 2020
Available online 3 October 2020

JEL classification:
H12
K23

Keywords:
EMU
Sovereign debt crisis
Global financial crisis
Financial regulation
Banking sector
Insurance industry
Financial markets
Policy reform

ABSTRACT

To ensure the safety and soundness of the global financial system as well as individual financial institutions and to reduce systemic risk, numerous policy measures and regulatory reforms have been brought forward as a reaction to the Global Financial Crisis and the European Sovereign Debt Crisis. Simultaneously, numerous academic works have critically reviewed these developments. Therefore, based on a dataset of 455 papers, this article intends to structure the multitude of publications and provide a comprehensive overview of post-crisis regulatory research publications. Studies can be roughly divided into three overarching clusters: publications identifying causes of the crisis, articles focusing on policy and reform reactions, and literature investigating whether these reforms fit their purpose. A holistic and systematic review allows us to extract relevant recommendations and areas of action to prevent such a crisis in the future.

1. Introduction

Financial regulation has become increasingly important, since the reputation of economics as a profession has undoubtedly come under critical scrutiny with the mostly unforeseen outbreak of the last two major crises in the US and Europe (Toarna and Cojanu, 2015). Moreover, the bursting of the internet bubble, the global financial crisis (GFC), and the European sovereign debt crisis (SDC) have jointly generated costs in the world economy of approximately USD 30 trillions (see Taskinsoy, 2019). There are also indications that the causes of many crises are often similar. Overbeek (2012), for example, cites overaccumulation as the main driver of financial markets since the 1980s. As a result, it seems reasonable to address the reasons for the last two major financial crises in the world's two largest economies in a literature survey. To avoid such enormous financial repercussions in the future, scholars have delivered a large variety of critical examinations of the financial and sovereign debt crises and the decisive role of regulatory circumstances in order to eliminate such deficiencies. Thus, the question arises as to what extent the regulatory institutions and framework conditions were insufficient or could even have encouraged crises. Second, the question must be answered as to which measures or automatism influenced regulators' decisions on how to counteract the crisis. Finally, it is important to consider the extent to which new or ongoing regulatory adjustments or innovations influence the occurrence and course of future crises. Thus, to organize our discussion, we structured the paper into three sections (see Fig. 1) based on the identified crisis-related regulatory literature. This investigation was divided into three areas:

- Firstly, several authors deal with the causes and triggers of crises and stress situations.

* Corresponding author.
E-mail address: xmeier@mendelu.cz (S. Meier).

https://doi.org/10.1016/j.irle.2020.105945
0144-8188/

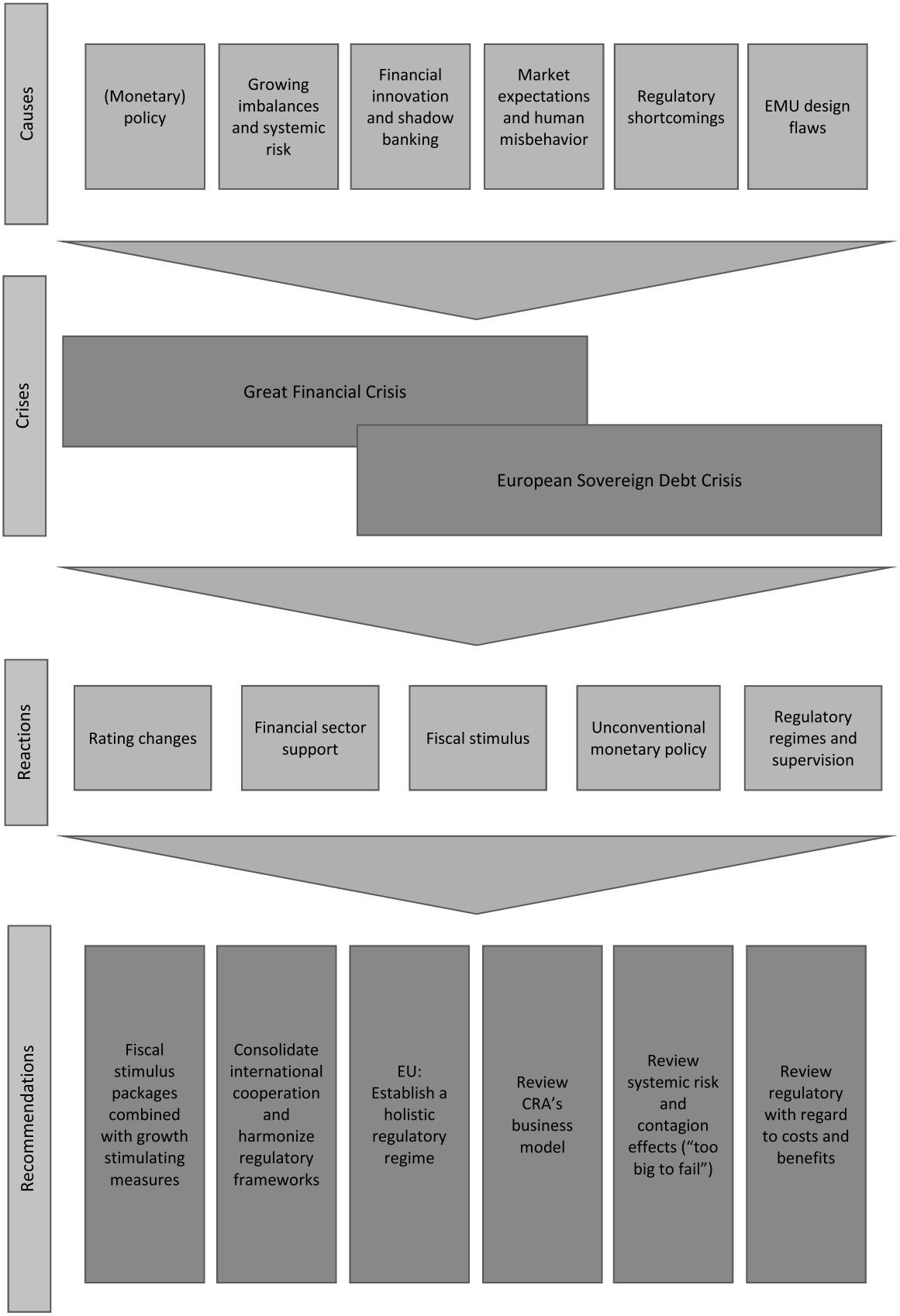


Fig. 1. The organization of the systematic literature review.

- Secondly, many studies focus on immediate policy reactions intended to mitigate crisis effects as well as reforms intending to stabilize the financial system.
- Finally, some researchers deal with the question of future development and, in this context, with the stress resilience of institutions and states as well as the danger of new crises.

However, the question arises why financial markets need to be regulated, when the literature actually assumes the existence of an at least moderately efficient market hypothesis (EMH).[1] It can be addressed in manifold ways: externalities such as bubbles and crashes, inefficient market structures, principal-agent problems, market entry/exit barriers, a lack of market integrity, or by considering financial market stability as a public good (see De Grauwe, 2011; Chaudary and Salvador-Adebayo, 2014). Since the incentives that the regulatory framework creates for decision-makers in the financial sector also play an important role, we present future potential research directions from both practical and academic perspectives. We argue in this paper that especially the concept of regulatory arbitrage may reveal that regulatory rules are often no panacea, but may even work to exacerbate crises (see Acharya and Richardson, 2009; Dagher and Fu, 2017). This view must not be taken as an opportunity to completely question the significance of regulatory and legal frameworks. Rather, a critical examination of their strengths and weaknesses is necessary in order to identify possible future Achilles' heels in the financial system in general and the Economic and Monetary Union of the European Union (EMU), and to deal with them accordingly. In doing so, we draw on the above-mentioned subdivision into the causes and effects of and reactions to the crises. Additionally, we reviewed recommendations to prevent similar crises in the future. In addition to the banking sector and the financial services industry, the insurance sector must also be included in this debate because it has been become an increasingly important actor in maintaining financial market stability (see Trichet, 2005; French et al., 2015).

Our literature survey is based on a structured and standardized search and identification process proposed by a collection of scientific publications (see Biener and Eling, 2012; Biener et al., 2015; Eling and Schnell, 2016; Eling and Lehmann, 2018). We review the English-language scholarly literature by using basic operations of Boolean algebra "TI[(financial regulation) OR (banking regulation) OR (insurance law) OR (insurance regulation) OR (regulatory authorities) OR (supervision)] AND TI[(crisis) OR (subprime) OR (sovereign debt)]"[2] in the journal databases EBSCOhost (Academic Search Ultimate, Business Source Elite, Business Source Ultimate and EconLit), ProQuest (20 databases in the social and economic sciences),[3] and the Social Science Research Network (SSRN). We then review academic articles, working papers, industry studies, and reports from January 2007 to May 2020 to cover the periods of the GFC and SDC. Moreover, we review citations in the identified papers to include further publications of interest. Additionally, we searched for supportive material via Google Scholar and regular Google searches. Based on this search and identification process a database of 455 papers is generated which main results are discussed.

The objective of this paper is to motivate further research interest in in-depth analyses of financial regulatory issues by bringing together the results of previous studies dealing with the cause-and-effect relationships of crises in a survey and, in particular, link our findings in the context of the regulatory frameworks.[4] The remainder of this paper is structured as follows. In Section 2, we review the literature on the causes of the financial and sovereign debt crises, focusing especially on the role of regulatory frameworks. In Section 3, we summarize relevant academic findings on policy reactions enacted over the course of the crises with a special focus on the interdependencies between the individual crisis sectors (i.e., sovereign debt crisis and financial crisis). Section 4 summarizes the findings from Sections 2 and 3 and formulates recommendations for regulatory action. Section 5 concludes the paper and provides recommendations for future research by focusing on the outlook and the question of the financial sector's resilience regarding future crisis events.

2. The emergence and causes of the Global Financial Crisis and the European Sovereign Debt Crisis

Undoubtedly, the economic and financial crises, starting with the burst of the housing bubble in the subprime segment of US mortgage markets in 2007, were driven by the interaction of many interdependent causes such as macroeconomic developments and (monetary) policy decisions, false expectations about innovations in financial markets, human misjudgments, and regulatory issues (see, for instance, Overbeek, 2012; Rose and Spiegel, 2012). In addition, the tremendous impact of these crises highlights the need for an appropriate and preventive regulatory framework. Although some developments of the GFC, like the globalization of markets or increasingly complex financial products, appear unique, there are indications that these structural problems have existed since the Great Depression in the 1930s (see Rötheli, 2010; Overbeek, 2012).[5] Accordingly, it seems reasonable to address the cross-country drivers of the last two major financial crises to gain valuable insights for the future. Waelti (2015) convincingly argues that the origin of a crisis is crucial to fully understanding the nexus between financial crises and reforms, and that more theoretical and empirical literature should focus on the analysis of the causes. It is therefore reasonable to address the question of the roots of financial problems (as discussed, for example, by White, 2008). For this reason, we briefly present the academic debate on the major developments leading to the GFC and SDC and elaborate on some important regulatory insights in this context. The following chapters therefore provide a structured discussion of the driving forces and triggers of the crises in the US and the EMU. As summary, Fig. 1 presents a schematic overview of these causes.

2.1. (Monetary) policy decisions

As stated above, the GFC is the consequence of the burst of the financial bubble in the US real estate market, and its severity was compounded by many factors. As Rose and Spiegel (2012) and Caprio (2009) show, over-accumulation in the financial markets occurred because of public policy decisions that were incompatible with economic fundamentals. In fact, there is evidence that the housing bubble was inter alia a result of national policy decisions like state subsidies to support home ownership in the US (see White, 2008; Rötheli, 2010; Liou, 2013).[6] As a result, spec-

[1] Ball (2009), Siegel (2009) and Malkiel (2011), for instance, discuss a possible coexistence of the EMH and crisis events.

[2] TI means that the search procedure was limited to the titles of the publications.

[3] A detailed list of the ProQuest databases is available on request from the authors.

[4] According to Amri and Kocher (2012), the most empirically analyzed databases regarding the effects of bank regulation and supervision on crisis events are *The World Bank Survey*, *Financial Reforms Database* and the *International Country Risk Guide*.

[5] For a historical reappraisal of banking regulation from the 1930s until the early 2000s, Kroszner and Strahan (2014) provide a detailed overview of causes and effects of banking regulation.

[6] Examples are the Congress' reinforcement of the Community Reinvestment Act, relaxations of down payment standards by the Federal Housing Administration, or

ulators were increasingly attracted to the US real estate market, while artificially generated demand caused property prices to rise. These risk factors were underestimated by both financial markets and regulatory authorities (Buttimer, 2011).

In addition, the emergence of macroeconomic imbalances has also been exacerbated by improper monetary policy decisions (see, for example, Mah-Hui, 2008). In fact, the Federal Reserve Bank (FED) did not return to a more restrictive monetary policy after lowering the key interest rates after the financial turmoil of the early 2000s like the Internet Bubble and the financial crash after the 9/11 attacks. Measured by the Taylor rule, the monetary policy had been too expansive, leading to an underestimation of risks (Banerjee, 2011) and an oversupply of liquididy in financial markets (Rötheli, 2010; Rose and Spiegel, 2012). The S&P/Case-Shiller home price index, an indicator of price development, almost doubled after the burst of the Internet Bubble to the beginning of the collapse of Lehman Brothers (see S&P Dow Jones Indices LLC, 2019).[7] For this reason, many investors were seeking high-yield investment opportunities, and the resulting effects are often emphasized as crucial drivers of the housing price bubble (see Mah-Hui, 2008; Taylor, 2009a; Rötheli, 2010). This trend of rising prices ultimately resulted in a financial bubble in the housing market (see Overbeek, 2012). However, as Gokhale and Van Doren (2009) argue, even if the FED would have anticipated the emergence of a bubble, there are doubts about whether it would have adapted its monetary policy, not only because of political pressure (Kantor and Holdsworth, 2010), but also because of the existing price stability in the US economy. In particular, Banerjee (2011) argues that one problem at the beginning of the crisis was a strict focus on price stability, although this was probably achieved by massive foreign (e.g., Chinese) capital flows. Nevertheless, according to Cheng et al. (2017), banks are generally an appropriate instrument to contribute significantly to ease the effects of a crisis, which has unfortunately not happened in the 1930s Great Depression (Kantor and Holdsworth, 2010).

Moreover, public financed stimulus packages were needed to weaken the effects of the economic crisis. Thus, European national governments massively supported financial institutions through capital injections (e.g., Hypo Real Estate, Fortis, Anglo-Irish, etc.). Blanchard et al. (2009), as well as Hauptmeier et al. (2011), for instance, find evidence that governmental support programs helped to effectively manage sovereign debt issues and strengthen budgetary consolidation. Moreover, Taylor (2009b) highlights the misinterpretation of problems in the bank credit market and the unclear framework of governmental state rescue packages as fundamental mistakes of political actions and interventions. Consequently, these countries' spreads on government bonds were significantly widening because of the growing default risk (Lane, 2012). However, Gajewski (2014) argues that the growing sovereign risk, predominately in Greece, Ireland, and Spain before 2009 was due to the reduction of base rates by the ECB.[8] According to Crowley and Lee (2009), Greece, Spain and the Benelux countries were most disadvantaged from a centralized monetary policy, while it was beneficial for well-positioned countries like Germany, because of a "neomercantilist accumulation strategy" (see Overbeek, 2012). Moreover, the author shows that lax fiscal policies and the application of different monetary policy measures were major drivers of the SDC. Overall, Toarna and Cojanu (2015) argue that a commonality of both crises is the lack of common rules for systemically important financial institutions (such as the FED or the ECB), and thus, the absence of an equal distribution of responsibility.

2.2. Growing imbalances and systemic risk

As previously mentioned, macroeconomic developments like cheap Chinese imports and the resulting economic disequilibrium in the balance of trade also contributed to the emergence of the crisis in the US (see, for instance, Lander et al., 2009; Miele and Sales, 2011; Rose and Spiegel, 2012). These imbalances also resulted from capital flows from less developed markets to US financial markets, which subsequently strengthened the effect of over-accumulation (Obstfeld and Rogoff, 2009; Banerjee, 2011). The bursting of the real estate bubble, the price collapse, and the bankruptcy of many companies led to a massive economic shock, and as a result, an increasing number of banks accumulated large amounts of bad debt in their accounts. The massive financial impact then caused a worldwide recession, adversely affecting other economic factors, such as private and public wealth and consumer spending (see for instance Brunnermeier, 2009; International Monetary Fund, 2010; Gorton and Metrick, 2012a), as well as economic prices and wages, as revealed by many European countries (Glod, 2018). Consequently, the GFC weakened European financial markets and simultaneously increased the national debt of many EMU members (Glod, 2018). Likewise, European banks were eventually affected by the impact of the GFC. This was mainly due to globalization in the banking sector, mainly from Europe towards the US financial markets (Welfens, 2008). Moreover, the effects on the US mortgage market also indirectly affected involved financial systems in emerging markets. This is explained, to some extent, by the "safe havens" effect and the reallocation of investments (see De Santis, 2012).

Thus, in addition to an economic and banking crisis, the situation in Europe also developed a sovereign debt crisis, starting with the debt issues of Greece in 2010 (Lane, 2012; Calabrese et al., 2017; Wegener et al., 2019). Moreover, Reinhart and Rogoff (2011), for example, provide evidence in favor of a link between banking and sovereign debt crises and even suggests that banking crises are a predictor of debt issues in developed and emerging countries. To prevent further contagion effects in the US and Europe, many states took individual rescue measures to mitigate the crisis impact (Demirgüç-Kunt and Servén, 2010; Overbeek, 2012). In this context, Demirgüç-Kunt and Servén (2010) argue that state guarantees can increase systemic risk by worsening the economic situation of a state through financial rescue measures and potential payment defaults after a financial shock. Similarly, Ureche-Rangau and Burietz (2013) confirm that, in particular, capital injections and government guarantees transmitted the GFC to the SDC. Alter and Schüler (2012) argue, that the systemic risk results from a "private-to-public risk transfer" which makes financial shocks more likely to cause national bankruptcy. Furthermore, the interdependent nature of bank bailouts and state finances reveals that one subcrisis might drive the other (see Ureche-Rangau and Burietz, 2013; De Bruyckere et al., 2013).

After the onset of this crisis and the collapse of Lehman brothers, member states' debt-to-GDP ratio rose significantly, because governments were relying on strong fiscal stimulus packages and bail-out programs to mitigate the inevitable economic recession and prevent the collapse of the financial system (Velinov, 2015; Grammatikos and Vermeulen, 2012; De Santis, 2014; Karagounis et al., 2015). Investors reacted with a loss in confidence regarding certain Eurozone member states' solvency and perceived defaults as likely outcomes (Bijlsma and Vermeulen, 2016; Alsakka et al., 2014; Arce et al., 2013). Consequently, sovereign credit default swaps (CDS) spreads widened dramatically (Aizenman et al., 2013; Alter and Schüler, 2012). CDS are common financial instru-

pressure on credit providers by the US Department of Housing and Development (HUD) to grant more mortgages.

[7] Case and Shiller (2003) are some of the few economists that had actually anticipated the house price bubble.

[8] For more detailed studies on the determinants of Eurozone sovereign bond spreads see Barrios et al. (2009), Croci Angelini et al. (2016) or Attinasi et al. (2009).

ments that function as insurance against government defaults. CDS spreads indicate the price of such insurance for a specific country. Prior to the GFC, when default risks for European member states were near zero, CDS spreads remained at low levels with little volatility. Therefore, trading activity in this segment had been low (see Arce et al., 2013). However, the financial crisis marked a caesura. German CDS spreads, for instance, remained at a relatively low level, never crossing the 100 basis points mark, whereas the Greek CDS spreads skyrocketed and even exceeded 1,100 basis points in the summer of 2010 (Bernoth and Erdogan, 2012; Grammatikos and Vermeulen, 2012; Fabozzi et al., 2016).

Systemic risk in the context of financial contagions could also have contributed to the crisis (see Liou, 2013). Following the events outlined above, a growing body of literature considers sovereign contagion effects in the EU and the transmission of sovereign risks from distressed financial markets towards the sovereign. This is because the costs of bail-out programs lead to increased sovereign credit risk (see Attinasi et al., 2009; Sgherri and Zoli, 2009; Alter and Schüler, 2012; Alter and Beyer, 2014). This impacts the financial sector, as bailout programs are funded through new issues of government bonds, which are often bought by domestic banks. Furthermore, Glod (2018) highlights the contagion in the EMU because of the interconnectedness of the member states. However, shadow banks could also have contributed to the spread of the crisis, since Bengtsson (2013) finds that there is a link between the shadow banking system and overall financial stability. However, in some EU countries, increased borrowing led to high inflation, resulting in balance of payments deficits and higher sovereign debt. Glod (2018), for instance, finds strong evidence for inflation and unemployment to explain public indebtedness. In particular, fragile economies like the PIIGS states,[9] faced severe economic impacts and sovereign debt issues (see, for example, Sklias et al., 2014; Guerreiro, 2014; Ramos-Francia et al., 2014). The disparities in associated default risk are underlined by substantially lower credit spreads of countries like Germany compared to those located in the European periphery (e.g. Greece) (Attinasi et al., 2009; Arce et al., 2013; Aizenman et al., 2013). In the following, these countries were facing higher risk premia on sovereign debt, further worsening their debt situations (Lane, 2012). Subsequently, Beirne and Fratzscher (2013) find that price changes of sovereign risk in the follow-up of the European crisis were mostly based on the respective European member states' economic fundamentals, and in the PIIGS countries, price adjustments seem to result from a "wake-up contagion". However, De Grauwe and Ji (2013) state that a large part of sovereign spreads could be explained by self-fulfilling market expectations, which then resulted in economic imbalances in the EMU. In this context, Giordano et al. (2013), for example, also find evidence for a "wake-up-call contagion" instead of a "pure contagion". In contrast, Gómez-Puig and Sosvilla-Rivero (2016) highlight the coexistence of both. However, Beirne and Fratzscher (2013) find evidence for a "herding contagion" in sovereign debt markets during the SDC.

2.3. Financial innovation and shadow banking

Besides disadvantageous economic developments and misguided policy decisions, Acosta-González et al. (2012), as well as Caruso et al. (2019) state that financial determinants were key drivers of the GFC. Before the crisis events, financial markets were changing for various reasons, such as the increasing innovative power of financial institutions and financial products, new credit transfer mechanisms, and a trend towards shadow banking (Miele and Sales, 2011).[10] In general, product innovations, such as mortgage-backed securities (MBS) or collateralized debt obligations (CDOs), have been seen as promising high-return assets with low default risks. These asset-backed securities (ABS) were then distributed by US banks, transferring the opaque risks to other financial markets.

Moreover, the securitization process, seems to have been strongly driven by incentives and regulatory flaws, both seen as major key features of the GFC (see, for instance, Pacces, 2010; Caprio, 2013). Furthermore, the dependence of the regulatory system on private rating agencies and their valuation of financial assets are heavily criticized, since credit rating agencies (CRAs) systematically underestimated the risk of securitized assets (see, for instance, Buiter, 2007; Coval et al., 2009; Rötheli, 2010; Rose and Spiegel, 2012). Therefore, banks granted highly risky loans, also in the knowledge, that they could easily transfer their risks to financial markets (Coval et al., 2009). Therefore, the combination of positive ratings for securitized assets and issuing banks underpinned the underestimation of systemic risk. However, Coval et al. (2009), for example, claim that the opaque construct of securitization was a major reason for many market participants and regulators to not anticipate the crisis. Additionally, Arezki et al. (2011), for instance, point out the announcements of CRAs are not only a driver of the GFC, but also in case of the SDC.

For the reasons mentioned above, such as the excess liquidity in the financial markets, these financial innovations were seen as promising investment opportunities. As a result, the (shadow) banking system – including so-called off-balance sheet special purpose vehicles (SPVs) – invested in these financial products (see Caprio, 2013). Noeth and Sengupta (2011) describe this shadow banking system as "a large segment of financial intermediation that is routed outside the balance sheets of regulated commercial banks and other depository institutions". Further, the SPVs issued short-term securities to raise the required capital to buy the ABS from the banking sector. Additionally, financial guarantees of other banks were provided to signal creditworthiness to their investors (Welfens, 2008). Then, after the beginning of a more restrictive monetary policy, and the first increase in the FED Funds Rate since 9/11 (see Board Of Governors Of The Federal Reserve System, 2019), higher interest rates led to financial distress of borrowers due to interest-related mortgage loans. Accordingly, the first credit defaults occurred, starting in the subprime segment. Since the issuing banks of mortgage loans were often no longer bearing the credit risks by having transferred the risk "off-balance", most importantly, the SPVs, or the banks guaranteeing the SPVs, but also best-rated investment banks (like e.g. Lehman Brothers) got into financial distress. This resulted to some extent from an economic sentiment of uncertainty, especially in the (inter)banking markets, and a "bank-run" in the shadow banking sector (Gorton and Metrick, 2012b).

2.4. Market expectations and human misbehavior

As stated above, real estate price increases, mainly driven by expectations, resulted in an artificially induced overvaluation of the US housing market[11] and large increases in household debt (Miele and Sales, 2011). Although the vulnerability of the sub-prime credit market to property price fluctuations is well known, the extent of the collapse was underestimated by both supervisors and mar-

[9] PIIGS is an acronym for the EMU member states Portugal, Ireland, Italy, Greece, and Spain.

[10] Conversely, Gokhale and Van Doren (2009) find no evidence that financial products like teaser-rate hybrid loans and credit default swaps were determinants of the SDC.

[11] See also Rose and Spiegel (2012) for a more detailed literature review of the price appreciation in real estate before the GFC.

ket participants (Buttimer, 2011). According to Rose and Spiegel (2012), the real estate bubble in the US was a result of excessive leverage and a structural underestimation of systemic risk. In the literature, there are indications that this misbehavior in the run-up to the GFC can be explained by behavioral economics in the greater part, clearly contradicting the ideal of a homo economicus. Grosse (2017), for instance, lists five different behavioral aspects of the GFC:

1. Overconfidence of creditors
2. Overconfidence of debtors
3. Underestimation of the company's own financial risk[12]
4. Misjudgments of generated risks by rating agencies and regulatory supervision
5. Breakdown of the bank refinancing market (because of e.g. fear)

As additional drivers of the crisis Toarna and Cojanu (2015) mention several aspects of information asymmetry, such as herd behavior or irrationality of market participants due to high financial incentives combined with a low responsibility for risks. As an example of the EMU, Reichlin (2014) states that information asymmetry in the banking sector caused a dependence between bank and sovereign risks. Additionally, adverse selection within banks' balance sheets might have also been a major driver of the crisis (see Nyborg, 2008; Welfens, 2008). In general, Palvia and Patro (2011) find evidence that the risk of banks can be determined by capital market data, and thus, market discipline seems to be effective in monitoring banks' risk. However, the "too big to fail" theory speaks against this approach (see Toarna and Cojanu, 2015; Rose and Spiegel, 2012).[13] The emergency bailouts of banks and other financial institutions, which are seen as systemically relevant, and the fear of contagion effects, actually carries the risk of moral hazard among the decisive market participants (Liou, 2013), but also on the side of the borrowers (Caprio, 2013). Securitization had also an incentive-reducing, and thus, behaviour-altering effect, in particular on the valuation of counterparty risk (Buiter, 2007; Caprio, 2013) or credit checks (De Michelis, 2009; Caprio, 2013). Overall, several studies describe some process of corruption in business ethics among many market participants (see, for example, Lander et al., 2009). The interbank market collapsed because of market sentiment characterized by insecurity and mistrust, which ultimately resulted in a credit crunch (Welfens, 2008; Caprio, 2013). Welfens (2008) illustrates the interdependence of various crisis factors by explaining the loss of confidence by asymmetric information in the banks' balance-sheets and the lack of transparency due to financial innovations.

2.5. Regulatory shortcomings

In light of the above findings, some reasons for the collapse of the global financial markets can clearly be found on the regulatory level.[14] Wallison (2009), for instance, emphasizes that the opaque US regulation is mainly responsible for triggering the crisis.[15] Swamy (2014) finds evidence that crisis countries were generally subject to weaker regulatory requirements than non-crisis countries. In the case of Europe, similar results can be confirmed by stating that countries with stricter regulations face lower risks of bailouts and other crisis measures. (Hoque, 2013; Maddaloni and Scopelliti, 2019). This would support the theory of risk capital flow toward regulatory arbitrage opportunities. The importance of regulating mortgage servicing is highlighted, for instance, by McNulty et al. (2019). The fact that financial institutes could do business off their balance sheets had been a regulatory shortcoming that firms used to generate regulatory arbitrage (Caprio, 2009). This led to disincentives for various market participants and regulators (Buiter, 2007; Banerjee, 2011). In addition, since regulators also relied on the risk assessments of CRAs, the effect was further intensified (Coffee, 2009; White, 2009b; Banerjee, 2011). Regulatory flaws, such as off-balance transactions, provoked less incentives for proper credit monitoring of mortgage lenders (De Michelis, 2009; Pacces, 2010; Caprio, 2013). As a consequence, mortgages did not remain on the balance sheets of the issuing banks so they could transfer risks and release equity for new businesses (Caprio, 2009). According to Banerjee (2011), a possible explanation for not adequately regulating financial innovations prior to the crisis could be a lack of awareness of these practices within the regulatory authorities' human capital stock.

However, there is still lively debate about the existence of a major period of international market liberalization in the run-up to the crisis (like stated for the US and UK by Coffee (2009), Banerjee (2011) or De Grauwe (2011)). Market liberalization was to some extent politically motivated, such as with public housing policy in the US, such as in regard with public housing policy. For example, the US mortgage business is said to not have been strictly regulated, as revealed by too-low bank capital requirements and the shortcomings in regulating off-balance business (see Lau, 2010; Mazumder and Ahmad, 2010; Kodres and Narain, 2012; Jost, 2008; Binney, 2010; Anginer et al., 2019). In comparison, Buttimer (2011) argues that the US housing market was well regulated, and that this type of regulation was intended by the federal government. According to them, the regulatory failure can be explained by incentive conflicts within the regulatory authorities since they stimulated these developments. Similarly, Pacces (2010) confirms this result through the false expectations and the acceptance of regulatory arbitrage. Equally, Calabria (2009) states that a crisis event had been a matter of regulation failure instead of a deregulation problem.

Undoubtedly, as shown by Caprio (2009), there was already much controversy regarding the Basel regulatory framework in the run-up to the crisis, but also the lowering of banks' minimum reserve standards by the US Federal Reserve and other central banks (Cabral, 2013). In accordance, Rötheli (2010) or Cabral (2013) argue that banks' capital-to-asset ratios were reduced, which in turn led to an increased systemic risk in the financial system. In particular, the capital requirements for securitized products have been too low under Basel, so the above-mentioned incentives were generated (Blundell-Wignall and Atkinson, 2009; Rose and Spiegel, 2012; Cabral, 2013). Hoque (2013) confirms similar results for Europe. According to his findings, countries with tighter Tier 1 capital requirements exhibited less risk. As an example, Kantor and Holdsworth (2010) emphasize the importance of regulating firms' capital structures.

As stated above, uneven features of regulatory frameworks can create an effect known in the literature as regulatory arbitrage (see Blundell-Wignall and Atkinson, 2009; Pacces, 2010; Kroszner and Strahan, 2011). According to Banerjee (2011), this effect leads financial companies to migrate from more strictly regulated markets (such as banks) to less-regulated markets (such as investment

[12] A more generalized view on this aspect is described by Liou (2013) as "weaknesses of corporate governance".

[13] However, in case of cross-border groups for example, Cotterli and Gualandri (2010) argues that some firms are actually "too large to save".

[14] According to Slattery and Nellis (2011), there are two approaches to explain why regulatory weaknesses in financial markets exist. The theory of market failure explains this with the economic advantages of uncontrolled markets, which should only be regulated in cases of imbalances, for example through information asymmetry. The theory of state failure explains the imperfection of regulation with the bounded rationality of regulators due to asymmetric information. There is evidence for both approaches during recent crises.

[15] For a quick view on regulation before the outburst of the crisis, see Caprio (2009).

banks or hedge funds).[16] Thus, financial liberalization, particularly in the US, also promoted weaker regulation on other financial markets to prevent these negative effects. Welfens (2008), for instance, states that about half of the US mortgage market was essentially unregulated. Furthermore, Toarna and Cojanu (2015) argue that the lack of capital control could also have had negative impact from a regulatory point of view. In general, a possible explanation for the failure of supervision is given by Welfens (2008), arguing that, for incentive reasons, there is a strong migration of highly qualified personnel from the regulatory authorities to the private sector.

2.6. EMU design flaws

Nevertheless, there are also factors that can be explained by the shortcomings of the regulatory framework of the EMU or national features in member states. Cotterli and Gualandri (2010), for instance, describe the specific problems of the EMU regarding the regulatory framework as a "problem of the fragmentation of supervision" and "the lack of a single supervisor and a single procedure for dealing with cross-border crises". According to Reichlin (2014), there are four key features of European financial markets, which also explain their sensitivity to the banking crisis. These features are "bank dominated corporate finance, dependence on wholesale funding markets, cross-border financial integration in wholesale but not in retail, and the key role of banks as intermediaries in the government bond markets". In short, Welfens (2008) describes the regulatory framework of the EMU as a loose association of different regulatory authorities.[17] Equally, Giani (2010) argues that European financial supervision and crisis management do not complement each other.

Although there had been favorable developments for certain EMU members, such as the stabilization of credit ratings in peripheral countries, De Grauwe and Ji (2014) argue, that the loss of sovereignty of the member countries made the EMU more sensitive to "self-fulfilling liquidity crises", which can possibly lead to state bankruptcies. Generally, national economies can address domestic economic imbalances through their own policy decisions, for example, by devaluating the domestic currency in case of a crisis. In the context of the EMU, this lack of action also resulted in a divergence of member countries, although because of an "internal devaluation" through wage adjustments or increasing sovereign debts (see Overbeek, 2012). However, the author also argues that the level of debt itself was not the underlying problem, but rather the risk premiums charged on the debt of peripheral countries, which worsened their financial situation even more.

Apart from this, prudential regulation aims to maintain the profitability of a company or a country after a financial shock. As stated above, bank capital requirements were not sufficient to withstand the 2007 shock, with some states even facing sovereign debt issues. Therefore, macroprudential regulation flaws can also be identified as a cause of crisis. Even though Banerjee (2011) doubts the effectiveness of macroprudential regulation because of the supervision's contribution to the emergence of the crisis, Caprio (2009), for instance, describes the negative effects that occur when market participants are qualified to generate regulatory arbitrage by "regulator shopping." As revealed for instance by Ongena et al. (2013), who found evidence for spill-over effects of regulation in the banking sector by their lending activities abroad.

[16] This can be beneficial for both the migrating firms, since they generate competitive advantages over domestic competitors, and the weakly regulated financial markets, which benefit from growth-enhancing capital flows.

[17] Such as, the Committee of European Banking Supervisors (CEBS), the European Commission, the European Banking Committee (EBC) the European Securities Committee (ESC), the European Financial Conglomerates Committee (EFCC) or the European Insurance and Occupational Pension Committee.

Table 1
Overview of policy crisis responses in the aftermath of the GFC.

Policy area	Policy reaction
Financial sector support	Ad-hoc bail-outs Ring fencing of bad assets Recapitalization Provision of lender of last resort facilities Reduced collateral requirements
Fiscal policy	Stimulus and recovery packages Tax cuts Debt haircuts
Monetary policy	Forward guidance Interest rate cuts and negative interest rates Quantitative easing and asset purchase programs
Regulatory reforms in the banking sector	Capital requirements and leverage restrictions Systemic risk Too big to fail institutions and resolution mechanisms Shadow banking Speculative financial products
Regulatory reforms in the insurance industry	Capital requirements Risk assessment Market discipline Supervision and reporting

3. Reactions to the crises

Failure to effectively regulate the financial system provoked the GFC and the SDC, which in turn have triggered different kinds of reactions to this unique period of stress (Andritzky et al., 2019; Trabelsi, 2012). Today, more than a decade later, immediate reactions to the crisis as well as regulatory changes established in the aftermath of the crisis are widely discussed in academics, politics, and popular media. Some claim that crisis induced regulatory measures did not go far enough (see Aizenman, 2009; Jones et al., 2016; Cecchetti and Schoenholtz, 2017), while others warn of over-regulation or over-reaction (see Ferran, 2011; Aizenman, 2009; Davies, 2010). Even though substantial and coordinated regulatory changes were inevitable, political leaders initially focused on crisis mitigation and crisis management following a step-by-step or trial and error approach (see Mayntz, 2013; Drew, 2010; Pavlat, 2009). As summarized and presented in Fig. 1, immediate reactions and long-term responses to the crisis can be structured as follows: rating agency reactions, emergency stabilization efforts of the financial sector, fiscal and monetary policy responses, and long-term regulatory reforms. Inspired by the overviews of Ait-Sahalia et al. (2012) and Blundell-Wignall (2012), Table 1 provides a summary of policy measures referred to in the literature.

3.1. Rating changes and rating agencies

Over the course of the SDC, increased attention was devoted to CRAs and their rating actions pointing towards limited competition in and regulation of the CRA industry, over-dependence on CRAs assessments, nontransparent methodologies, as well as conflicts of interest resulting from the clients soliciting rating-payment models (see, for example, Athavale and Chowdhury, 2015; Papaikonomou, 2010; Utzig, 2010; Bradley, 2009; Bernal et al., 2016).

Essentially, sovereign credit ratings are supposed to reflect a country's probability to default, meaning that a country is unable to meet its debt obligations. In the pre-crisis period, European countries commonly enjoyed high and stable IG credit ratings, resulting in their safe haven status for investments in European

sovereign bonds, despite known structural deficits (Alsakka et al., 2014; Haspolat, 2015; Liapis, 2012; Goodstadt, 2009). However, during the SDC, this assumption was permanently challenged when CRAs began to downgrade government ratings for countries in the European periphery as a reaction to their increasing government expenditures and growing budget deficits (Alsakka et al., 2014). Thereby, CRAs signaled a loss of confidence in these economies. These rating actions play a pivotal role as they predominantly influence borrowing costs in capital markets for states and financial institutions (see Drago and Gallo, 2017; Alsakka et al., 2014; De Bruyckere et al., 2013). Access to funding, particularly affordable funding, is of great importance to any economy as these financial resources stimulate investments and economic growth.

When considering CRA downgrades during the SDC, it becomes evident that sovereign ratings were adjusted according to the contemporary perceived political risk. Early works (see Erb et al., 1996) emphasize the interconnection between political risk, sovereign rating changes, and borrowing costs. As mentioned above, particularly countries in the European periphery faced rating changes over the course of the crisis, namely Cyprus, Greece, Ireland, Italy, Portugal, and Spain. In total, there were 63 notches of downgrades by Moody's between 2008 and 2013 for this group (Boumparis et al., 2017). Greece in particular was severely affected when the country's debt was downgraded to junk status. Although Moody's was found to be more likely to opt for multiple notch downgrades, the other two leading CRAs, S&P and Fitch, acted in a similar manner (Alsakka et al., 2014). Because of rating downgrades, government bond yields rose constantly, increasing borrowing costs for the respective countries (Afonso et al., 2012).

Negative rating changes of sovereign states do not only influence a government's cost of borrowing, but also have a significant impact on the domestic banking sector. Negative rating changes of a sovereign state result in lower capital ratios for domestic banks, hence increasing funding needs and costs (see Drago and Gallo, 2017; De Bruyckere et al., 2013). Moreover, Arezki et al. (2011) and Alsakka et al. (2014) find empirical evidence for a sovereign-bank rating channel during the crisis period. Once a state faced negative rating actions, this trend or bias was also passed on to ratings of domestic financial institutions, which then affected their funding costs as well and potentially limited their access capital markets, a phenomenon that has not been detected in the pre-crisis period. This is particularly true for domestic banks of the aforementioned countries, as these banks hold substantial debt issued by their respective domestic country (see a case study on Italy by Albertazzi et al., 2014). It was found that the debt ratio at the country level is one of the most important drivers of financial contagion between sovereign and bank risks, which is reflected in the rating channel (De Bruyckere et al., 2013). In short, through credit ratings, sovereign risk is transmitted to the domestic banking sector and the domestic economy as a whole (Drago and Gallo, 2017; Alsakka et al., 2014).

Sovereign rating changes are not only transmitted to domestic financial institutions via the rating channel, there is also a spillover effect on the CDS market (Drago and Gallo, 2016). Rating downgrades introduce new information and this so-called information discovery effect impacts CDS markets. Downgrades trigger increasing CDS spreads; however, such spillover effects have not been found in the case of rating upgrades. Through rating changes, CRAs heavily impact financial markets and influence investor decisions (Drago and Gallo, 2016).

Following the severe downgrades European countries experienced, critical voices were raised blaming CRAs for exacerbating the crisis. In this context, reforming the CRA industry has been discussed (Gärtner et al., 2011; Paudyn, 2013; Duan and Van Laere, 2012). As the three major CRAs are all located in the US, it could be argued that the CRA market is characterized by oligopolistic features. Establishing a European CRA, potentially even a public one, was proposed to promote competition (European Parliament, 2016). Duan and Van Laere (2012) question the pro-profit business model of CRA and argue that CRAs are characterized by traits of public goods. According to their empirical analysis, credit rating reform following a public good approach is practicable. Moreover, the introduction of such a business model would eventually stimulate competition in the credit rating industry, whereby competitive pressure would force the conventional for-profit CRA industry to improve their methodology and offerings (Duan and Van Laere, 2012).

Public debate forced European policy makers to take action, so the European Securities and Markets Authority (ESMA) put forward a new regulatory regime regarding CRAs which was introduced in 2012 (see European Commission, 2011; European Securities and Markets Authority, 2017). Intending to improve rating qualities, this regulatory approach requires disclosure of whether a rating analyst issues a rating from within the EU or from a jurisdiction that at least qualifies as "endorsed" (meaning similar rating regimes compared to the EU apply). Through an empirical analysis of 70 countries' sovereign rating actions assigned between 2006 and 2016 by the three major CRAs, Moody's, S&P, and Fitch, Klusak et al. (2019) provide mixed evidence with regard to the impact of a rating analysts' location on rating quality. On the one hand, quality decreases following the introduction of the disclosure rule were detected, for example, ratings by Moody's and Fitch were less informative, possibly because CRAs located in third party countries face less scrutiny compared to local ones. On the other hand, CRA offices located outside the EU aim to build a strong reputation for quality. In short, disclosing an analyst's location does not yield consistent quality improvements in ratings (Klusak et al., 2019). In summary, the close link between country risks and bank risks became evident during the SDC and was reflected in the reactions of CRA, which is especially true for peripheral Europe. In addition to the intense debate on CRAs and their business model, comprehensive regulatory novelties failed to materialize.

3.2. Financial sector support

The subprime crisis seriously weekend the financial sector and many financial institutions, commercial as well as investment banks fell into severe distress, some even went into bankruptcy, creating an elevated level of systemic risk (see White, 2009a; Benczur et al., 2017). As an initial reaction, governments began to bail-out financial institutions and provided them with large-scale capital injections. The first bail-outs took place in Germany and the UK (both 2007) (see Gerard, 2009; Forbes et al., 2013), a well-known example is the Scottish bank HBOS (see Dewing and Russell, 2016). On the other side of the Atlantic, the insurance group AIG was bailed-out in 2008. Other prominent banks affected by the crisis include Lehman Brothers (bankruptcy in 2008) and Bear Sterns (bailed-out by the Fed in 2008 and subsequently sold to JP Morgan Chase) (see Lodge and Wegrich, 2011; Harrington, 2009; Werkmeister, 2010; Davidoff and Zaring, 2009). Bail-outs of such systemically relevant institutions were largely viewed as inevitable to prevent greater disruptions and potentially a collapse of the financial system and unpredictable damage to the real economy. In this respect, the "too big to fail" expression has been popularized by referring to systemically important financial institutions that are usually large and deeply interconnected with others as well as the corporate sector (see Wigger and Buch-Hansen, 2014). Hence, should they fall into distress, they would create impacts on the real economy that are highly unpredictable but without doubt disastrous. For this reason, as an immediate response to the crisis, governments provided financial assistance to these institutions in

the form of bailouts, recapitalization, and purchases of distressed assets.

In the US, the Emergency Economic Stabilization Act of 2008 was signed into law including the Troubled Asset Relief Program containing USD 700 billions for emergency interventions intended for bail-outs and the purchase of distressed assets (see Webel and Murphy, 2008). In the EU, financial sector support in the form of capital injections and asset relief purchases amount to a similar volume. According to the European Commission, EUR 600 billions, which equals 4.6 % of the European GDP, has been spent by governments on financial sector support between 2008 and 2012 (Benczur et al., 2017).[18]

Bail-outs, however, do not come without criticism. Often, high costs for taxpayers (Benczur et al., 2017; Huertas, 2011), anti-trust (White, 2009a) and competition issues (Engel, 2020; Ojo, 2011; Mateus, 2009; Wigger and Buch-Hansen, 2014) as well as arising moral hazards (see Doyran, 2011; Kao, 2011; Avgouleas and Goodhart, 2016) are discussed in this respect. The symbolic message that globally leading institutions require lower business and risk management standards can create moral hazard (Ioannou et al., 2019). Essentially, financial institutions with insufficient risk management are bailed out at the taxpayers' expense, which means they are exempt from the main pillar of capitalism – failure (Umlauft, 2015). As a result, institutions may rely on such forms of governmental support and deliberately take risky positions in the hope of higher returns. Thus, implicit guarantees in the form of bail-outs of financial institutions may set wrong incentives undermining self-discipline and effective risk management (Crotty, 2009; Umlauft, 2015). Simultaneously, in the EU, the high costs associated with bail-outs enhanced fiscal difficulties of certain member states, such as Ireland and Cyprus, thus exemplifying the link between the financial and the sovereign debt crises (Werner, 2014). To overcome this problem, breaking up banks considered "too big to fail" (Umlauft, 2015; Basten and Sánchez Serrano, 2019) or introducing a bail-in mechanism (Avgouleas and Goodhart, 2015, 2016; Berger et al., 2019; Basten and Sánchez Serrano, 2019) were considered as potential solutions. Bail-in refers to bank creditors (i.e. the investors in their financial products) bearing the costs of failing institution's losses or the costs of the restructuring or liquidation in the event of impending insolvency (see Section 4.6.1).

3.3. Fiscal stimulus

To counteract declining consumption and decreasing economic activity, numerous governments considered the Keynesian concept of deficit spending and countercyclical spending programs as immediate responses to the ongoing crisis situation. A popular advocate of such measures has been Paul Krugman, who believes that such programs will prevent deflationary risks and a downward economic spiral (Krugman, 2009).

In Europe, the European Economic Recovery Plan (EERP) worth EUR 200 billions or 1.5 % of the EU GDP was launched in 2008 with the objective to support member states coping with the aftermath of the GFC. The instrument consisted of several different measures intended to revive the economy through short-term measures such as stimulating demand and long-term measures such as strategic investments. Precise measures have been undertaken at both the EU level and national level, which include allowing member states to break with the Stability and Growth Pact requirements, incentives for strategic investments such as energy efficient technologies, interest rate cuts, tax cuts on green technology, scrappage programs, increases in unemployment benefits amongst others (EC, 2008).

The US Congress passed the so-called Economic Stimulus Act of 2008 in the same year, which comprised USD 152 billions intended to avert recession. Measures mainly included tax rebates in the form of checks directly distributed to taxpayers (US-Congress, 2008). The American Recovery and Reinvestment Act of 2009 (more than EUR 787 billions) was launched by combining national stimulus measures, not only limited to tax rebates, but also including programs directed to support struggling homeowners (see Homeowner Affordability and Stability Plan) (US-Congress, 2009; Aubuchon, 2009; Wilson, 2012)

However, views on whether countercyclical fiscal spending managed to alleviate the effects of the 2008-2009 crisis diverge. Freedman et al. (2010) question the effectiveness in the short-run and investigate whether such policy measures yield GDP growth through multiplier effects. They conclude that multiplier effects arise more strongly if paired with supporting monetary stimulus measures and concurrently warn against dangers related to public spending getting out of hand. The above-mentioned European Economic Recovery Plan was quantitatively evaluated by Coenen and Warne (2014) prior to its implementation. It was found that such a fiscal stimulus package could increase the Eurozone GDP to a certain extent, but only for a limited time period and at the expense of further growing sovereign deficits. Fratianni and Marchionne (2009) look at fiscal policy measure announcements investigating the effects of such announcements of fiscal interventions on banks and shareholders by employing an event study methodology. They find that announcements of rescue plans directed at the banking system were associated with positive CRAs, but interventions targeting specific banks showed negative returns. This is attributed to spillover effects occurring in the former. These findings are complimented by Kollmann et al. (2013), who analyze the Eurozone's fiscal policy in the aftermath of the financial crisis from a more general perspective, including the impact of conventional fiscal stimulus measures as well as bank asset losses and government support for banks. They conclude that government support for banks stabilizes output, consumption, and physical investments, making it a promising tool for economic stabilization. Government purchases of goods and services, however, stabilized GDP while crowding out consumption and investment.

Scholars appear to agree that fiscal stimulus measures undertaken in the aftermath of the GFC only yield short term benefits. Ulrich (2011) goes further by claiming that such measures may not only be ineffective but may even encourage improper fiscal spending and endanger fiscal sustainability. Hence, he argues that the European Economic Recovery Plan encouraged member states to breach the EU's fiscal rules outlined in the Maastricht Treaty, resulting in the substantial public indebtedness of several member states. Eventually, this resulted in deteriorated public finances in the region, financial markets questioning the solvency of particularly indebted member states, and costly government bail-out programs, essentially triggering the SDC.

Thus, elevated debt levels as a consequence of fiscal policy measures puts the efficiency of such instruments into question. In particular, it is feared that governments may not be able to repay debts, which in turn would impact borrowing costs and potentially result in unsustainable debt levels and default. Addressing such concerns, Auerbach and Gorodnichenko (2017) find that an expansionary government spending shock does not persistently increase debt-to-GDP levels or borrowing costs. At the same time, the authors point towards the political risks and limits associated with disproportional, aggressive, and wasteful fiscal spending and present the case of Greece and other Southern European countries as examples. These warnings are further underpinned by Alesina et al. (2018), who undertake an empirical study using data from

[18] Wigger and Buch-Hansen (2014) cite the European Commission and mentions EUR 4.5 trillions or 37 % of the EU GDP had been mobilized between 2008 and 2010 in the form of state aid packages for the financial sector.

16 OECD nations for the time frame ranging from 1981 to 2014. They find that the composition of fiscal adjustments as well as the state of the business cycles are crucial when it comes to successfully launching fiscal stimuli programs.

It becomes evident that studies investigating impacts of fiscal policies find mixed results and tend to attribute some mostly short-term positive impacts to fiscal stimulus policies. A balanced, sustainable approach in the long run is recommended rather than haphazard and aggressive spending, which could result in excessive indebtedness.

3.4. Unconventional monetary policy

Similar to the aforementioned fiscal policy measures, extensive monetary policy measures were brought underway to mitigate the impacts of the crisis by preventing shortages of liquidity and declines in lending, thereby securing short term funding and stimulating the economy. Due to the unprecedented extent of the crisis and the limit of conventional monetary measures (i.e., interest rates reached zero), central banks reacted with hitherto unconventional monetary policy measures in order to safeguard financial and economic stability.

In the US, the so-called Term Asset-Backed Securities Loan Facility or Term Auction Facility had been launched whereby the Fed acted as "lender of last resort," supporting market liquidity with the objective to maintain the functionality of the economy. Through these facilities, a total amount of to USD 1.6 trillions in loans was provided to banks by November 2008. Moreover, credit easing measures were brought forward as the Federal Open Market Committee increased the Fed's balance sheet through extensive purchases of mortgage-backed securities. Similar measures were implemented in the European Union during the course of the GFC and the SDC, when some member states faced difficulties refinancing their government debt without third-party support. The primary objectives of monetary policy in the crisis context include lowering borrowing costs for indebted countries and avoiding insolvency of member states (see Buiter and Rahbari, 2012; Roman and Bilan, 2012). According to Dell'Ariccia et al. (2018), the ECB's monetary policy reactions can be divided into three phases: banking sector support as the lender of last resort (2008-2009), government bond purchases to restore the functioning of the market (2010-2012), and extensive asset purchases combined with forward guidance and negative interest rates (since 2013).

In short, both in the US and the EU, unconventional monetary policy measures include forward guidance, negative interest rates, and quantitative easing / credit easing in form of central bank asset purchase programs. The effectiveness of these measures has been evaluated in various studies.

3.4.1. Forward guidance

The term forward guidance refers to a central bank's process of providing market participants with clear information and transparency on intended monetary policy measures, particularly interest rate changes. In theory, clarity and commitment to the development of interest rates in the future will encourage commercial banks to lower their interest rates for an extended period of time as their future access to liquidity at low rates is secured. Consequently, the real economy should have improved access to funding, which encourages investment (See Adam and Billi, 2006; Nakov et al., 2008; Coenen et al., 2013). According to Evans et al. (2012) there are two different ways to communicate forward guidance: Either the central bank communicates its expectations regarding its economic outlook and in accordance with these expectations its monetary policy, or the central bank communicates its commitment to keeping the interest rate below a certain level, regardless of economic development.

In the EU, the ECB initially used forward guidance in July 2013, when the Governing Council informed market participants of its intention to keep the interest rate low for a longer period of time. The exact formulations have been adjusted over time, for example, it has been extended not only to provide information on interest rates, but also its asset purchase programs and general future paths (see Bletzinger and Wieland, 2016). Coenen et al. (2013) deem the approach as effective, as, according to their stochastic simulation, time-based forward guidance results in the desired stimulus. However, they also emphasize that forwarded guidance too far into the future comes with certain risks related to price stability. For this reason, they recommend incorporating a threshold condition for tolerable future inflation. To assess the case of the US and the Fed's forward guidance, Swanson (2017) considers the time period between January 2009 and October 2015, when the federal reserve rate was essentially zero and traditional monetary policy instruments were not applicable. It was found that this policy instrument was effective, particularly in moving Treasury yields and stock prices.

Naturally, forward guidance is not always effective or desirable. Additional communication by the central bank will not necessarily add transparency if market participants regard its commitment to low interest rates as not credible or if they already expect interest rates to remain below a certain level. Moreover, commitment to low interest rates may also signal market participants that the central banks may be concerned about the economic outlook, thereby weighing on sentiment and business confidence (see Dell'Ariccia et al., 2018; Issing, 2014; Gersbach and Hahn, 2008). Regarding the latter, it was shown that market participants view the ECB's forward guidance and communication more as an indication of the stance of the central bank's policy rather than negative macroeconomic outlooks of monetary policy makers (Hubert and Labondance, 2016).

3.4.2. Negative interest rates

With the aim to make borrowing less expensive, interest rates have been lowered in several steps. Moreover, central banks began to intentionally charge negative interest rates on commercial banks' reserves in order to incentivize reduced lending rates, resulting in increased credit supply and preventing liquidity shortages (see Dell'Ariccia et al., 2018; Rostagno et al., 2016; Lemke and Vladu, 2016). Negative interest rates, however, do not come without controversies: that is, they may hurt banks' profitability, which again results in restricted lending, thereby potentially outweighing the policy's benefits (see Bernanke and Reinhart, 2004; Cœuré, 2016). In this context, Cœuré (2016) argues that banks stay profitable through other income channels, such as increases in the value of their fixed income portfolio. Hutchinson and Smets (2017), who review the monetary policy measures implemented by the ECB, conclude that these unprecedented measures have proven to be exceptionally effective (see Turk, 2016; Ilgmann and Menner, 2011; Ait-Sahalia et al., 2012) and that potential side-effects of negative interest rates have been offset by positive effects in the macro-level, such as improved credit quality and intermediation activity.

3.4.3. Quantitative easing and asset purchase programs

In order to increase the pass-through of reduced borrowing costs for commercial banks to the private sector, several quantitative easing programs have been introduced by central banks. Central banks purchase extensive amounts of securities, which are often long-term government bonds. These purchases are financed through the reserve accounts that commercial banks hold at the central bank or new central bank reserves, thereby expanding the central bank's balance sheet. Thus, additional monetary stimuli encourage lending and investment. These purchases further contribute to lower interest rates as demand for fixed-income securities increases

(Dell'Ariccia et al., 2018).[19] The ECB introduced the longer-term refinancing operations (LTROs), the targeted long-term refinancing operations (TLTRO I), a third covered bond purchasing program (CSPP3) and the asset backed securities purchase program (ABSPP) (Hutchinson and Smets, 2017; Cour-Thimann and Winkler, 2012; Gibson et al., 2016). Additionally, the Securities Markets Program (SMP) was launched for sovereign and corporate bond purchases in secondary markets between 2010 and 2012 and had then been superseded by the Outright Monetary Transactions (OMT) program.[20] In the case of Italy, Albertazzi et al. (2014) support the ECB's policy measures, particularly the LTROs and the CBPP. The Euro system's 2011-2012 LTRO is further exploited by Andrade et al. (2019), who provide evidence that the central bank's liquidity injections through the commercial banks' lending channels enhanced credit supply to the real economy during the crisis. Importantly, the authors illustrate that the program did not encourage increased lending exposure to riskier firms. The impact of the ECB's asset purchases on the region's government bond yields are further quantified by De Santis (2020). It was found that the policy approach was indeed highly effective in influencing the financing conditions in the region. The program allowed the ECB to reduce the GDP-weighted 10-year Euro area sovereign yield by 72 basis points, particularly in favor of the more vulnerable member states. Pronobis (2014) compares the ECBs post-crisis non-standard monetary policy to approaches of other central banks. In this context, the ECB's measures are regarded as rather cautious and conservative, and deemed justified. One reason for this observation is the lower amount of assets purchased by the central bank. Furthermore, compared to other central banks, the ECB has been more reluctant to implement regular sovereign debt interventions (Pronobis, 2014; Gros et al., 2012). When quantifying the Fed's QE measures,[21] warrant empirical support for this policy reaction have been found as interest rates diminish, while stock prices, inflation, and economic activity increased (Swanson, 2017; Meinusch and Tillmann, 2016). Overall, because all European countries remained solvent while economic conditions improved, the ECBs' unconventional monetary policy measures were considered sufficient and justified.

3.5. Post-crisis regulatory reality

Besides immediate policy responses with direct damage containment and mitigation objectives, lasting regulatory changes and novelties were deemed indispensable in order to make financial institutions, the financial industry, and the financial system more resilient, particularly so that taxpayers will not have to bear the cost of a crisis in the future (Roncaglia, 2010). It was found that the severity of the crisis did not trigger regulatory reforms per se, but rather that strong state interventions during the crisis, amongst other factors, have been a precondition for extensive regulatory responses after the crisis (Young and Park, 2013).[22] In the EU, it was important to design appropriate but somewhat flexible rules adoptable to the transnational organization and its cross-border banking characteristics (Murgescu, 2011; De la Mata Muñoz, 2010). Therefore, laws have been adjusted, new guidelines and frameworks have been formulated, and over time, the architecture of the financial system has been redesigned (Daniela et al., 2010). At the EU level alone, more than forty pieces of legislation on the financial service sector were adopted between 2008 and 2018 (Emond and Kunertová, 2019).

In response to the economic and financial crisis, regulatory actions were discussed on a global level during the G20 summits in Washington (2008), London, and Pittsburgh (both 2009). It was decided to focus on six key policy areas (see Helleiner and Pagliari, 2009; Nolle, 2012; Véron, 2014; Negrilˇa, 2009; Avgouleas, 2009b; Davies, 2010; Sarcinelli, 2010; White, 2014; De Vincenzo et al., 2010; Duffie, 2018)

- Introduction of capital and liquidity standards to guarantee resilient financial institutions and to discourage excessive leverage
- Formulation of resolution regimes for systemically important banks to avoid the too-big-to fail view and unreasonable risk-taking
- Regulation of derivatives markets so that systematic risk related to Over-The-Counter (OTC) derivatives is eliminated
- Regulation of the shadow banking system including tax havens, money laundering, corruption etc.
- Implementation of new compensation standards that discourage excessive risk taking and instead encourage long-term value creation
- Implementation of high quality, global accounting standards

Reforms have been proposed by the Basel Committee on Banking Supervision in form of the Basel III Reform (2010) (see Peihani, 2015). In the United States, regulatory reforms were introduced in the same year through the Consumer Protection Act and the Dodd-Frank Wall Street Reform. In the European Union, comparable efforts were undertaken by the European System Risk Board and the European System of Financial Supervision in 2010. Importantly, these initiatives are consistent in their stance that imbalances between market discipline and supervisory oversight need to be overcome (see Panico et al., 2013).

3.5.1. The banking sector

To prevent costly government bail-out of distressed banks and ensure solvency of financial institutions and the financial system as a whole, this agenda has been implemented through a series of regulatory reforms (see Table 2). Therefore, policymakers, legislators, regulators, and supervisors proposed numerous measures of which the most important are listed below, mainly Basel III reforms (Baker et al., 2017; Isebor, 2014; Montalbano, 2015; Oliveira and Raposo, 2020), as well as several directives, such as the Capital Requirement Directive at the EU-level (Montalbano, 2015; Zapodeanu et al., 2010; Mihai Yiannaki, 2009) or the Dodd-Frank Act (Hoshi, 2011; Yellen, 2011; Eichengreen, 2010; Kao, 2011; Omarova, 2011; Rex, 2018; McNulty et al., 2019) and the Regulation SB SEF (Schuster, 2012) in the US. While internal control mechanisms and market discipline needed to be addressed (Couppey-Soubeyran, 2010), financial stability as a whole was of primary focus. Reforms in the banking sector and bank supervision are among the most visible following the financial crisis (Denk and Gomes, 2017).

Reviewing financial institutions' capital and liquidity requirements[23] revealed severe deficiencies in the financial system, as Basel II requirements had proven not to be expedient (see Daniela et al., 2010; Ashraf et al., 2020). For example, under Basel II, certain banks may apply internally developed risk models to determine their capital requirements. Considering that these models are often flawed, these requirements may not be sufficient

[19] Theoretical models have been proposed by: Gertler and Karadi (2011), Chen et al. (2012).

[20] An empirical analysis of the SMP's impacts is provided by Eser and Schwaab (2016) Gibson et al. (2014) and Gibson et al. (2016); the OMT programmer's impact has been reviewed by Falagiarda and Reitz (2015).

[21] Further details on the Fed's large-scale asset purchases (LSAP) and its effects in an international context are presented by Bauer and Neely (2014).

[22] Further research on the likelihood of reforms is provided by Agnello et al. (2015).

[23] Pre-crisis capital requirements have been presented by (Panico et al., 2013; Walter, 2019) for the case of the US and Heynderickx et al. (2016) for the case of the EU.

Table 2
Evolution of regulatory measures addressing the banking sector in the EU (2010–2017).

Year	Regulatory measure	Discussion in
2010	Establishment of the European System of Financial Supervision (EFSF) including: European Supervisory Authority, European Systemic Risk Board and Member States' Supervisory Authorities	Yurtsever (2011); Papadopoulos (2015)
2012	Introduction of European Market Infrastructure Regulation (EMIR) concerning derivate trading, especially so-called Over-the-Counter (OTC)	Quaglia (2013); Pagliari (2013); Gualandri et al. (2009); Ojo (2013); Gualandri et al. (2009); Murphy (2020)
2012	Establishment of the European Stability Mechanism (ESM) which replaces the European Financial Stability Facility	Bauer and Herz (2020); Howarth and Spendzharova (2019)
2013	Introduction of the Capital Requirements Regulation (CRR) and Capital Requirements Directive (CRD) IV in order to transpose the Basel III Accord into EU law	Benczur et al. (2017); Dietrich et al. (2014); Quaglia (2013); Tröger (2018)
2013	Implementation of the Single Supervisory Mechanism (SSM)	Kern (2013); Busch and Teubner (2019); Cassola et al. (2019); Babis (2014); Micossi et al. (2013)
2014	Release of the Bank Recovery and Resolution Directive (BRRD), which has to be implemented in national legislations by 2015	Benczur et al. (2017); Covi and Eydam (2018); Kern (2013); Micossi et al. (2013); Tröger (2018)
2014	Implementation of the Single Resolution Mechanism	Benczur et al. (2017); Howarth and Quaglia (2014)
2014	Introduction of the Markets in Financial Instruments Directive II (MiFID II), which became effective in 2017	Yeoh (2019), Gomber and Nassauer (2014)
2015	Specializations of the Minimum Requirement for Own Funds and Eligible Liabilities (MREL) are published	Tröger (2020); Best et al. (2017); Adolff and Häller (2019)
2017	Formulation of European Union Securitization Regulation and creation of a European framework for simple, transparent, and standardized securitization	Loukanari and Berardo (2019); Kravchuk et al. (2017); Schwarcz (2015)

(Gerding, 2009; Mihai Yiannaki, 2009). The approach of setting capital requirements laid out in Basel II depends on the proper behavior of banks and third parties like CRAs. However, this form of market-based risk assessment has proven to be insufficient as market participants have not been able to adequately manage their risk exposure (De Mendonca and Deos, 2009). Moreover, when comparing countries hit by the crisis to those impacted to a lesser extent, it becomes evident that the former group had much more stringent and lower capital ratios in place (Cihak et al., 2012). Imposing minimum capital requirements for financial institutions is believed to reduce their leverage and thus their risks of bankruptcies. Overall, stronger capital requirements are associated with greater stability in the banking sector (Lee and Lu, 2015). In this context, Basel III was introduced with the objective of imposing stricter capital requirements set by the regulator (Anagnostopoulos and Kabeega, 2019).

The costly bail-out and the lack of orderly resolution processes during the financial crisis made it clear to legislators that such processes needed to be formulated specifically for systemically important banks, which were considered "too big to fail" during the crisis. Improved resolution authority was especially demanded for the US, where the crisis originated and where some of the largest banks were based (Vaughan, 2009). One of the primary concerns was to shield taxpayer money from future crises (Panico et al., 2013; Carstensen, 2013; Sironi, 2018). Regulatory solutions on how to establish orderly resolution mechanisms were proposed in the so-called Squam Lake report and were later addressed in the Dodd Frank Act (Hoshi, 2011). In the EU, bank resolution policies were introduced through the establishment of the total loss absorbing capacity (TLAC) and Minimum Requirements for Own Funds and Eligible Assets (MREL) (Sironi, 2018; Quaglia and Spendzharova, 2018).

OTC derivatives do not just fulfill a useful role in capital markets to transfer risks, they were also used as speculative instrument and allowed for significantly increased leverages, thereby contributing to financial turmoil during the GFC. Because OTC derivatives in the pre-crisis period were commonly traded in the absence of clearing houses in the unregulated market, there was a great degree of opacity (Murphy, 2020). Comprehensive regulations of the derivatives market, as proposed during the G20 summit, were viewed as key points for reforms in the US and the EU (Mateus, 2009). For example, the use of central counterparties and the clearing of some OTC derivatives were established in an initial attempt to regulate the market. This reduced dealers' exposure to each other, but at the same time their exposure to the central counterparties was even greater, making this first regulatory approach insufficient (Murphy, 2020).

It was not only encouraged that regulatory reforms target the formal financial system, but also to touch upon the shadow banking system. Considering that financial intermediaries in the shadow banking system largely contributed to the expansion of housing credits prior to the crisis, it seems inevitable to regulate hitherto unregulated market participants such as hedge funds, as well as unregulated products like unlisted derivatives. However, the Dodd Frank Wall Street Reform and the Consumer Protection Act did not sufficiently address this problem (Tarullo, 2019; Tropeano, 2011).

Besides lax regulation and increased trading of derivatives, fair value accounting standards used in the US contributed to the turmoil of the crisis and consequently needed to be addressed by legislators (Masood et al., 2010). Additionally, executive compensation schemes have been reviewed with no less than seven different initiatives being discussed in the US (Verret, 2009) even though the sheer amount of salaries and bonuses played a subordinate role (Ashby, 2011; Simoneti, 2010; Ruppel, 2009). Compensation schemes were viewed critically, in particular regarding the incentives set by the system (Ellis et al., 2014). While both topics are widely recognized as crucial to efficient regulatory legislation, the literature in this respect is rather scarce.

Intending to publish a holistic assessment on the evolution of banking regulation in the post-financial crisis era, Sironi (2018) and Panico et al. (2013) provide a detailed analysis and discussion of the Basel III and the newly established bank resolution policies (TLAC and MREL).[24] According to the authors, these measures resulted in a significant increase in the amount and quality of equity capital for banks due to new liquidity and leverage requirements. Moreover, the methodology and instruments that calculate these requirements have been improved. Through the introduction of a bail-in mechanism for banks' liabilities, it is less likely that taxpayers will face the burden of a government bail-out. Threats to the stability of the financial system have not yet been fully eliminated. According to Sironi (2018), shortcomings are interlinked with the long-term sustainability of the financial industry, meaning that the overall profitability of banks is not sustainable. In this context, the author identifies the so-called sovereign-banks doom-loop describing the close connection between the two. A future recession threatening the well-being of the sovereign and the domestic economy could

[24] Overviews on the evolution of financial regulation covering both, the pre- and post-crisis period have been published by Oreiro (2013) and Forsyth (2015).

Table 3
The evolutionary stages in the transition from Solvency I to II (2001–2018).

Year	Regulatory measure	Discussion in
1970s	Introduction of Solvency I – insurance regulation across European member states	Ellis (1990); Finsinger and Schmid (1994); Konrath (1996)
2001	Solvency II process is launched by the European Commission with the aim to introduce a single solvency system applicable for European insurers across all member states and to incorporate new methods of risk assessment	Beckmann et al. (2003); Eling et al. (2007)
2002	Publication of the Sharma Report on various regulatory tools available to the regulator	London Working Group (2002); Eling et al. (2007); Doff (2008)
2007	Solvency II proposal is adopted by the European and is supposed to come into force in 2012	Doff (2008); Elderfield (2009); Schuckmann (2007)
2009	Report "Lessons learned from the crisis" is published suggesting that Solvency II must be adjusted due to recent developments	CEIOPS (2009)
2009	Official publication of a compromised Solvency II framework Directive text	EU (2009); Huerta De Soto (2009); Gatzert and Wesker (2012)
2011	The European Insurance and Occupational Pensions Authority (EIOPA) is established	Gal and Gründl (2017); Van Hulle (2011); Nouy (2012)
2011	Omnibus II Directive amending the Solvency II Framework Directive is adopted by the European Commission with the objective to align the Framework with the Lisbon Treaty and the new supervisory structure of the EU; the target date is revised to January 2013	Peleckienė and Peleckisa (2014)
2014	Omnibus II is approved by the European Parliament	Doff (2016); Rae et al. (2018)
2016	Solvency II is implemented	Doff (2016); Rae et al. (2018); Pradier and Chneiweiss (2017); Swain and Swallow (2015)
2018	EIOPA proposes a review of Solvency II	EC (2019); Pelkiewicz et al. (2020)

still lead to a widespread banking crisis because bank profitability depends upon the well-being of the economy and its lending policy is aligned with economic cycles. Overall, the newly established regulatory requirements do not manage to curb this kind of procyclicality.

Despite numerous legislative changes, many critics argued at the time that the reforms were not strong enough. Generally, regulatory efforts are still ongoing, and certain topics have not been addressed yet, such as, shadow banking (see also Tarullo, 2019; Tropeano, 2011; Thiemann et al., 2018; Rixen, 2013), financial transaction tax (see Page, 2010), and the European deposit guarantee scheme. Whether the implementation of these newly established regulatory provisions is sufficient to prevent a financial crisis naturally depends on regulatory effectiveness and is thus up to debate.

3.5.2. The insurance industry

Even though the financial crisis is generally regarded as a banking crisis caused by flawed compensation schemes and weak banking regulations (see Ashby, 2011), the insurance industry and their clients were deeply affected by the crisis through their large investment portfolios (particularly portfolios of life insurances), rating downgrades, as well as credit, market and systemic risks (Schich, 2010). For this reason, the aim was to improve the regulatory frameworks of the insurance industry and protect the sector from systemic risks (Eling and Schmeiser, 2010). In view of the recent crises, it must be noted that the extremely low long-term interest rates that are also a result of the monetary policy measures to combat the problems have created some problems for the life insurance industry in Europe (Basse et al., 2014; Berdin and Gründl, 2015). However, these developments also seem to show that Solvency II is a huge step in the right direction (at least in comparison to Solvency I) (see Table 3).

Prior the establishment of Solvency II, the framework in place was Solvency I (enforced in the 1970s), which was largely criticized for not properly accounting for different types of risks, such as market, operational, or credit risks in capital requirements. This resulted in inaccurately assessed risks and, consequently, problems related to optimal capital allocation in relation to risks taken by insurers. Moreover, there is no harmonized methodology among EU member states on how to adequately assess such risks (Rae et al., 2018). Therefore, the EU renewed its legal frameworks with the Solvency II directive superseding Solvency I. Solvency II was initially passed in 2009 by the European Parliament, but changes were made in 2016 after some of the program's shortcomings became evident. In 2014, the Omnibus II Directive was passed by the European Parliament as an amendment to Solvency II, which defined the role of the European Insurance and Occupational Pension Authority (EIOPA) to guarantee law enforcement as well as accounting and valuation technicalities. Details on the evolution of the Solvency II Framework Directive have been presented by Eling et al. (2007), Jones (2014), and Rae et al. (2018). In short, Solvency II seeks four main objectives: the establishment of a greater degree of integration and harmonization in the European insurance market, the improvement the protection of policyholders and beneficiaries, effective general risk management, and a greater degree of financial stability (Doff, 2016; Rae et al., 2018; Hopt, 2013).

4. Recommendation to prevent future crisis

In order to reduce the risk of similar crisis scenarios, it is necessary to consider what changes in existing regulations are needed. Otherwise, confidence in the stability of financial markets is threatened. When considering the present economic situation, this appears to be of utmost importance: high indebtedness and rising government budget deficits due to increased public spending as a response to the COVID-19 pandemic (see Hale et al., 2020; Fornaro and Wolf, 2020), the technical recession in Italy, the contracting economy in Germany since the second quarter of 2019, and stagnating growth in other parts of Europe are warning signals for an upcoming economic downturn. An economic environment with low inflation, low growth rates, and ultra-low interest rates intensifies these risks and pose serious difficulties to the banking and financial service industry. Thus, a robust regulatory framework for the financial and insurance industries is crucial. This article showed that the pre-crisis financial market architecture, immediate market movements, and market participants' reactions to a crisis impact regulators' agendas and inspire new regulatory frameworks. Academic literature addresses the remaining regulatory shortcomings, which urgently need to be addressed to prevent crisis in the future. Fig. 1 clusters these regulatory shortcomings and presents an overview of fields of research in this context while linking recommendations to causes of the crisis and policy reactions. In the following, important policy recommendations to overcome these shortcomings are presented.

4.1. International cooperation

Undoubtedly, the outlined crisis is of global scope, even though it originated in the US subprime market. Through contagion effects,

severe economic harm hit foreign financial institutions, insurers, investors, and economies. However, despite the cross-border effects of the crisis, consolidated trans-national actions during the crisis were rare. For example, the resolution of Lehman Brothers and Fortis as well as the bailouts of Bear Stearns and RBS were all carried out by the home country of the respective institutions (Avgouleas et al., 2013; Davidoff and Zaring, 2009). Even at the EU level, rescue operations were initially driven by national efforts, as the EU did not have sufficient financial resources (Dabrowski, 2010; Posner and Véron, 2010). Owing to its unprecedented scale, a joint and coordinated international response as well as expanded international cooperation to regulate financial markets, including the banking and the insurance sector, were proposed (Langevoort, 2010; Leong, 2010; Masciandaro and Quintyn, 2010). The G20 emerged as a key body of discussion among heads of state, making the forum stronger than before (Moshirian, 2011). Addressing the financial architecture jointly and setting transnational regulatory frameworks became apparent and essential to impede loopholes and regulatory arbitrage (Masera, 2010). This is important since most regulatory novelties introduced in the preceding century followed a national approach. Additionally, a greater degree of globally integrated financial markets, including internationally ratified agreements and a sufficient international exchange of information, is desirable to achieve transnational financial stability (Moshirian, 2011; Von Bomhard, 2010).

Aiming to unify banking supervision at EU level, the Banking Union was created and included the establishment of the Single Supervisory Mechanism (SSM) (Laguna De Paz, 2019). Still, not all supervisory tasks have been transferred to the European level; instead, national authorities also supervise parts of the financial sector, adding a great degree of complexity to the new system (Laguna De Paz, 2019). With a focus on integration and through its single rulebook, the SSM's design intends to limit national supervisors' tendencies to favor their domestic banks. Self-interest of member states and their domestic banks is viewed as problematic when aspiring an effective and legitimate European financial and economic system based on shared interests (Groenleer et al., 2014). However, the single rulebook consists of different directives, still allowing room for national legislation and essentially different level playing fields (Laguna De Paz, 2019). Therefore, creating fairer competition in a single market is desirable (Monnet et al., 2019).

An important step in the direction of harmonized financial markets in the EU was achieved through the European passport system, which allows dually licensed financial intermediaries of one member state to operate in another member state without the need to obtain additional regulatory approval. Therefore, market access within the region is made easier and the regulatory burden on companies is reduced (Pistor, 2010). Granting similar privileges to non-EU countries, however, bears the risk of importing instabilities in the case of less stringent regulatory standards in the foreign country. For this reason, many of the EU's post-crisis financial regulations contain so-called equivalence clauses guaranteeing that foreign companies providing services in the EU or working with EU counterparts will be subject to EU regulation in addition to their domestic regulatory requirements. As EU legislation may be more comprehensive, equivalence clauses were drafted to promote equal competition and to shield the region from foreign financial instability (Quaglia, 2015). Clearly, with financial institutions and intermediaries operating transnationally, these risk patterns need to be addressed (Pistor, 2010).

At the international level, there is a lack of incentives for deep and binding international financial regulation. Insufficient commitments toward institution building or enforcement mechanisms at the international level as well as dominant domestic political positions, in the US for example, prevent the passing of genuine reforms (Leong, 2010). Similarly, the UK and the City of London prevented several strategic reforms, and the EU was not willing to actively expend its political control in international finance (Bieling, 2014). Moreover, the sheer mass of the existing complex and diverse legal structures that control bank solvency hinder harmonization (Avgouleas et al., 2013). As full-fledged integration appears to be unattainable, softer and more flexible efforts may still advance transnational financial regulation (Leong, 2010). Pistor (2010) proposes cooperative regulation of international financial markets with emphasis on effect-based jurisdiction. Certain risks are unique to specific markets and are thus unlikely to be regulated in internationally operating financial institutions' domestic laws. Through effect-based regulation, the jurisdiction where foreign financial intermediaries operate would have the power to regulate their activities, particularly if these activities have systemic effects on the local financial system.

Calls for global solvency standards have also been proposed with respect to the insurance sector, because like financial institutions, these companies provide their services across several jurisdictions. For this reason, domestically driven regulatory reforms may not be sufficient to adequately protect against the contagion effects of a future crisis on the scale of the 2008 great financial crisis. The European Solvency II approach may function as a starting point for a potential global solvency standard (Von Bomhard, 2010).

4.2. EMU governance and supervisory architecture

The incomplete governance architecture of the EU and EMU became especially apparent over the course of the financial crisis initially when member states could not bail-out distressed domestic institutions due to insolvency risks. Holding on to the idea of a single currency, economic integration was gradually deepened through sequentially adopted incremental reforms (see Jones et al., 2016). To meet expectations for extensive architectural and governance reform in the EMU, great efforts have been made to align regulatory frameworks of member states and strengthen a centralized institutional set-up for banking regulation, thereby progressing towards deeper financial integration in the region (see Masciandaro, 2010; Lannoo, 2011).

Considering that supervisory failure has been identified as one of the prime factors contributing to the crisis and that supervisory unification, amongst other factors, bolsters the soundness of financial institutions (Doumpos et al., 2015), the importance of a financial system's architecture is an important factor of safeguarding financial stability (Allen et al., 2012b). Admittedly, views on the optimal supervisory set-up and especially the role of central banks are divided (Masciandaro and Quintyn, 2016). While De Grauwe et al. (2017) argues for the involvement of central banks in bank supervision, Brunnermeier et al. (2009) and Sohn and Vyshnevskyi (2017) advocate for a so-called "twin peak model" thus essentially entrusting central banks with macroprudential regulation. Masciandaro et al. (2013) conclude that consolidation in supervision is negatively correlated with economic resilience, while central bank involvement in supervision has no significant impact on such. In this respect, the crisis triggered reforms in the EMU architecture because of shortcomings in microprudential regulation (Harnay and Scialom, 2016). To ensure microprudential regulation at the EU level, three supranational bodies were created: the European Banking Authority (EBA) (formed in 2011), the European Securities and Markets Authority (ESMA), and the European Insurance and Occupational Pensions Authority (EIOPA). The European Systemic Risk Board (ESRB) has been entrusted with macroprudential supervision (Curcio et al., 2017). Creating such an institutional triangle is sometimes viewed as a simple upgrade of the existing supervisory system, missing the opportunity to move to a truly holistic regulatory regime at the EU level. Cross-sectoral risk may remain undetected (Ringe et al., 2019). Moreover, due to multilevel

complexity, banks tend to engage more closely with national regulators instead of the European Banking Authority, which may limit the efficacy of agency governance for banks in the EU and hamper the development of appropriate EU regulatory standards (Coen and Salter, 2020). For this reason, a greater degree of collaboration at the EU level between different national and regional bodies is recommended to ensure smooth and efficient operation of the supervisory system (Lener, 2013).

Besides the integration efforts taken in the aftermath of both crisis, reforms remain largely incomplete and comprehensive as far reaching solutions have not been established in many areas. Jones et al. (2016) explains that even though flaws of the EMU governance architecture became evident during the crisis period, diverse preferences of member states and intergovernmental bargaining often only resulted in a lowest common denominator agreement resulting in partial solutions and a still incomplete EMU. European integration may have advanced during the crisis, but it clearly did not use it to its fullest potential.

Effective regulatory governance ensuring enforcement of compliance with regulatory requirements presents a challenge, particularly considering the growing number and complexity of applicable regulations which evolved after the great financial crisis. It should be noted that compliance and effective enforcement of regulatory frameworks are just as important as how the frameworks work to maintain financial stability; otherwise, the stability of the banking system is at stake (Chaikovska, 2019a,b).

4.3. Fiscal discipline

Debates surrounding the resolution of the sovereign debt crises repeatedly centered around the topic of whether austerity policies offer the solution or aggravate the problem (Begg, 2013; Bergman and Hutchison, 2015). Clearly, in the EMU, the importance of a sustainable growth model, sufficient fiscal rules combined with fiscal discipline as well as fiscal consolidation is recommended to prevent spikes in public debt levels (Anderson et al., 2014; Bergman et al., 2016). However, putting too much pressure on countries facing deficits bears risks, such as the creation of a downward spiral and lack of focus on the injection of structural reforms targeting the causes of imbalances (Begg, 2013). There is a fine line between encouraging fiscal consolidation of public finances designed in a growth-friendly manner and creating an overly harsh disciplinary force (De Grauwe and Ji, 2014; De Grauwe and Foresti, 2016). While some find that nations' debt-to-GDP levels exceeding 90 per cent are affected by impeded growth rates (see Reinhart and Rogoff, 2010), recent works suggest that higher debt levels do not automatically reduce economic activity (see Amann and Middleditch, 2020). Essentially, considering the nature of budget cuts and fiscal consolidation measures seems crucial. For example, it was found that cuts in public sector salaries as well as increased public investments had expansionary effects (Maşca et al., 2015) Examples of appropriate policy recommendations include the use of VAT taxes, transfers, and government absorptions, all of which combined with growth-oriented structural reforms in all member states (Anderson et al., 2014; Maşca et al., 2015). As Catrina (2012) highlights, uncoordinated budget cuts could do more harm than good. It is recommended to opt for a more stabilized and balanced structure of public expenditure instead of a maintaining the public debt level at zero at all costs. This means finding a way of sustainably managing public expenditure over the economic cycle with targeted fiscal stimulus packages. Any abrupt adjustment would undermine the catching-up process, that especially newer European member states are still going through. Similarly, Freedman et al. (2010) cautiously selected fiscal stimulus packages combined with supporting monetary measures in times of acute stress. In the medium-term, budget deficits and public debt should not get out of hand, so short-term benefits are in line with the long-term costs of these measures. It was even found that the importance of fiscal discipline may have been overstated during the debate on the SDC. Empirical evidence on a negative causal link between sovereign debt levels and economic growth is mixed.

Due to the severity of the SDC and the unprecedented circumstances, solutions discussed also go beyond the suggestion to combine well-balanced public finances with greater fiscal discipline and sustainable growth measures. Following the concept of unconventional monetary policy, Werner (2014) calls for unconventional fiscal measures to be considered in sovereign debt management. In contrast to the lending approach taken by the Troika, the so-called enhanced debt management accounts for demand simulation components through alternative funding tools, such as issuing non-tradable debt, which in essence is equivalent a bank loan contract. Using such an instrument could offer a number of advantages, among them being the ability to raise borrowed funds at cheaper interest rates compared to regular sovereign bonds. It would also not have to be marked by the market, and such an instrument would not require a rating from a CRA. In addition to stimulating domestic demand, it is proposed to issue such a debt instrument solely domestically to exclude foreign investors. Consequently, when governments borrow through these kinds of domestic bank loans, lending banks earn returns so that credit creation may boost nominal GDP growth, which is then associated with improving debt-to-GDP ratios. If such a mechanism could be successfully implemented and used by EU member states' debt management offices, it may solve the funding problems of crisis-affected countries while stimulating demand and stabilizing banking.

4.4. Credit rating agencies

Even though CRAs are considered an essential element of regulatory frameworks in the banking sector (Liapis, 2012), they and ratings themselves played a role in the development of the crisis, resulting in criticism towards their business models and methodology (as discussed in Duan and Van Laere, 2012; Eijffinger, 2012; Papaikonomou, 2010). However, besides criticism, CRAs still do not disclose their methodology or explain how they reach their conclusions (Thalassinos and Thalassinos, 2018). It is argued that CRAs may be more lenient before markets become distressed but become more severe afterwards. For instance, with regard to the SDC, it is argued that CRAs did not appropriately account for fundamentals such as public finance imbalances, and that assigned rating downgrades were arbitrary and did not properly reflect reality (Gärtner and Griesbach, 2017). Hence, downgrades assigned during crises have not been transparent (Eijffinger, 2012). Avoiding another financial crisis clearly requires transparent, reliable, and sustainable rating assignments (Papaikonomou, 2010). For this reason, CRAs business models, transparency regarding their methodology, and their objectivity is deemed necessary. Based on this argument, policy recommendations target increased competition in the CRA industry (Utzig, 2010), which could be achieved through the establishment of a greater number of smaller CRAs, an internationally competitive European rating agency, or delegating sovereign credit ratings to the ECB. Each of these options has their pros and cons, but according to Thalassinos and Thalassinos (2018), establishing a European rating agency is the only feasible option that could improve both transparency and rating quality. In this context, Drago and Gallo (2016) emphasize the importance of accounting for rating changes from a public finance view and with regard to overall financial stability, which also supports the argument outlined above.

Similar recommendations are provided by Rötheli (2010), who points out that CRA initially conveyed a false sense of security prior

to the crisis. They also recommend that CRA should be required to provide investors with more transparency, for example, by publishing measures of accuracy of individual estimates. This would allow investors to improve their own risk evaluation of increasingly more complex financial products.[25]

4.5. Contagions effects and systemic risk

The GFC and the SDC made market participants even more aware of the internationally interconnected financial systems (Yadav, 2010) and systemic risk spillovers between financial institutions (see Pino and Sharma, 2019; Echevarria Icaza, 2017; Omarova, 2012), financial intermediaries (see Begg, 2009), insurers (Düll et al., 2017; Bernal et al., 2014) as well as sovereigns (see Fasiangova and Haiss, 2009) and vice versa. Consequently, policymakers urged regulators to focus on systemic risk and contagion effect mitigation, including both the financial and insurance industries (Vaughan, 2009; Avgouleas, 2009a; Abolo, 2008). This is of predominant importance for the member states of the Eurozone, which are highly interconnected through their common currency and monetary policy. However, this should not discourage regional integration in the European financial sector. Policy makers should still be aware of risks related to financial contagions (Drago and Gallo, 2017; Masciandaro et al., 2013). Relevant measures and tools to address systemic risk include sufficient liquidity buffers, as well as macroprudential supervision.

Policy recommendations aiming to reduce contagion effects and system risk spillovers advocate sufficient liquidity buffers of high-quality assets. However, the results of whether the provisions implemented under Basel III are sufficient vary. Additionally, the regulatory set up and supervisory architecture is reviewed, with scholars pointing out that the transnational character of financial markets should be reflected here (see sections 4.2 and 4.3 of this article).

De Bruyckere et al. (2013) outline three areas of action to alleviate contagion effects between financial institutions and sovereign states. First, banks should be more robust. Second, public finances should be more durable. Finally, action should be taken to weaken the links between financial institutions and sovereign states. Essentially, the Basel III directive has been formulated with these points in mind, which is why the authors support the directive as well as stricter capital requirements in general. Moreover, they advocate the establishment of a Banking Union in the EMU (for example, joint bank supervision, deposit insurance, a bank resolution mechanism, and burden sharing arrangements (see Goodhart, 2014; Honkapohja, 2014; Howarth and Quaglia, 2015; Lannoo, 2013; Prisecaru, 2014; Véron and Wolff, 2013; Constâncio, 2014; Kudrna, 2016). Paltalidis et al. (2015) partly disagree. According to their empirical analysis, the new capital requirements did not achieve the intended reduction of systemic risk contagion effects. For this reason, it is suggested to introduce additional policies that make the financial sector more resilient, particularly in southern Europe. Similarly, Reichlin (2014) emphasizes that the Eurozone is characterized by an especially strong correlation between sovereign states and banks risks due to its supranational set up, making member states particularly vulnerable to contagion effects. Thus, it is recommended to develop tools that address solvency problems and safe assets more efficiently.

Simultaneously, as outlined in parts 4.2 and 4.3 of this article, scholars also recommend addressing the institutional set-up and design of regulatory agencies and financial institutions. With systemic failure of financial regulation and sweeping contagion effects contributing to the crisis, a review of the institutional set-up and design of regulatory supervision seems feasible (Avgouleas, 2009a; Masciandaro et al., 2011). Levine (2012) finds that a fundamental weakness lies in the absence of checks and balances for elected representatives and the public. Consequently, there is no mechanism to induce reforms and no incentive for regulators to act in the best interest of the public. While defining an effective supervisory system ex-ante is difficult, the importance of transparency and accountability of an independent supervisory body is crucial (Amri and Kocher, 2012; Sohn and Vyshnevskyi, 2017). In addition, more than 10 years after the crisis, the "too big to fail" predicament has not been properly addressed for banks, resulting in large interconnected banks still being able to trigger the same avalanche effects as in 2008, although governments are now aware of these increasing systemic risks (Ioannou et al., 2019; Quaglia, 2015; Gordon and Ringe, 2015).

In the pre-crisis period, banking supervision did not explicitly account for these above mentioned form of interconnected financial markets and instead focused on the supervision of individual institutions, thus neglecting macroprudential supervision (Den Butter, 2010). Following the financial crisis, preventive measures in the form of macroprudential policies, however, became much more prominent compared to the prevailing view of the pre-crisis period favoring ex-ante crisis interventions (Jeanne and Korinek, 2020). However, Stellinga (2020) emphasizes that macroprudential and countercyclical policy measures, which have been widely viewed as solutions to boom-bust patterns in financial markets (see Baker, 2015; Yellen, 2011; Di Iasio, 2013; Eidenberger et al., 2014; Suarez, 2010; Lothian, 2012; Ojo, 2016; Zamorski and Lee, 2015; Galati and Moessner, 2013; Staikouras and Triantopoulos, 2016; Pooran, 2009; Mertzanis, 2010; Garicano and Lastra, 2010; Ruščáková and Semančíková, 2016), are an improvement, but have not been sufficiently incorporated in regulatory reforms. Partly because there are no criteria on when to activate or deactivate specific instruments and partly because policy makers have failed to clearly delegate responsibilities to supervisors and firms. In the case of the US Financial Stability Oversight Council, it was found that its macroprudential regimes are not sufficiently equipped to prevent a crisis similar to the GFC because of its limited ability to react to fast paced financial sector developments (Aikman et al., 2019). Ultimately, macroprudential policy, in its current position, is unlikely to fully mitigate systemic risk and thus prevent a crisis meltdown. For this reason, a combination of coherent policies, including macroprudential, microprudential, and monetary measures as well as socioeconomic policies, is advised (Stellinga, 2020). Newly developed and reliable forecasts of economic crises (see Papadopoulos et al., 2019) may help to adequately deploy sufficient macroprudential policies as a precautionary measure. Furthermore, the institutional set-up of microprudential (i.e., supervision of banks) and macroprudential supervision may be crucial, including providing the relevant institutions with sufficient power and a clear mandate, while also making them accountable for their use of policy tools (Stellinga, 2020; Aikman et al., 2019; Begg, 2009). In this context, centralization of regulatory power is viewed as a possible solution (Lupo-Pasini and Buckley, 2015). In particular, countries with deeper financial markets may benefit from delegating macroprudential supervision to central banks. Thereby, policy makers will gain a deeper understanding of the financial system's microstructure, allowing them to better safeguard financial stability (Melecky and Podpiera, 2015).

4.6. Regulatory frameworks

Corresponding to Section 3.5 of this article, recommendations to prevent a financial crisis in the future are intricately

[25] Such recommendations are also made by Papaikonomou (2010) who additionally advises to establish alternative models to the "issuer pays" concept and reducing regulatory reliance on external ratings.

connected to regulatory regimes of the financial sector and the insurance industry. For this reason, the literature discussing shortcomings and weaknesses of the current regulatory environment will be presented in the following sections. These works often consider regulatory novelties introduced in the light of the crisis, their implementation, and provide valuable indications on existing weaknesses legislation, which should be addressed in order to prevent and mitigate a crisis in the future (see White, 2014). One central challenge when redesigning regulatory reforms is safeguarding against reforms which may create additional problems, either because they are too complex or too costly (see Weber, 2010).

4.6.1. The banking sector

Regulatory novelties have been diligently developed as response to the financial crisis, thereby following the objective of establishing a more resilient, solvent and stable financial system, preventing costly bail-outs and in particular offsetting Basel II's shortcomings (see Table 2; Adrian et al., 2018). Insufficient capital requirements were identified as a major deficiency in the post-crisis regulatory framework, which was then addressed in the Third Basel Accord. As the successor of Basel I and II, Basel III predominantly aimed at strengthening capital requirements for financial institutions as new liquidity and leverage rules were introduced. Therefore, speculative bank investments and excessive risk exposure may be prevented (Benhabib et al., 2016). For example, when examining regulatory capital ratios of banks in Europe and Central Asia, it was found that these banks are much better capitalized today, 10 years after the GFC (Anginer et al., 2020). Moreover, better capitalized banks manage to maneuver financial turmoil better (Hoque et al., 2015). A quantitative analysis of the cumulative effects of the safety measures implemented at the EU level finds that these measures should reduce potential costs for public finances if another financial crisis of similar magnitude hit the region again. In fact, if all safety-net measures (including increased capitalization, capital conservation buffers, and bail-in) are applied, financing needs could be reduced by 90 per cent compared to a scenario with no new measures in place (see Tanasie et al., 2015). However, some scholars argue that the newly introduced capital requirements may be too harsh and may limit economic activity, thereby hurting the real economy (see Philipponnat, 2019; Næss-Schmidt et al., 2019; Caprio et al., 2014; Dermine, 2013; Buck and Schliephake, 2013). Empirical evidence, however, suggests that this is not necessarily the case. Higher capital buffers, in combination with strengthened supervisory independence, did not have inimical effects on credit provision (see Fratzscher et al., 2016). Similarly, Barth et al. (2013) find that greater capital regulations as well as stronger supervision, at least in countries with independent supervisory authorities, are positively associated with bank efficiency. Capital requirements and regulations, as laid out in Basel III, are not the only factors determining financial institutions' capital structure, but macroeconomic prospects on GDP growth or inflation also play a vital role (Teixeira et al., 2014). In short, defining sufficient capital requirements and ensuring adequate capital buffers while preventing overly tight regulation is crucial, prove that Basel III followed the right intentions (see Riccetti et al., 2018).

Allen et al. (2012a) analyze the economic impact of the reform and argue that a higher capital requirement does not pose a danger to economic activity, but rather that an inconsistent and uncoordinated transition and implementation process does. Basel III requires complex and costly operational changes in banks' business models and governance systems, which need to be managed cautiously. Otherwise, smaller institutions may face funding shortages resulting in reduced credit supply to the real economy, and consequently decreased economic activity. Hence, the difficulty is not so much in higher capital requirements, but rather the implementation process of these requirements. Depending on the underlying risk model, the minimum capital requirements under Basel III may not be significantly higher than those under Basel II (Kinateder, 2016).

The newly introduced capital requirements are widely viewed as a step towards a more resilient financial system (see Rubio and Carrasco-Gallego, 2016; Krug et al., 2015). Therefore, it can be concluded that Basel III introduced several stabilizing mechanisms. On the other hand, not all shortcomings of Basel II were properly addressed in the new directive, and the Basel III standards made an already complex structure even more so (Balseven, 2016). Schwerter (2011) and Caprio (2013) point out that the new accord still does not adequately dampen systemic risk or interconnectedness of the global financial system. Hence, among other aspects, it is suggested to selectively adjust risked-weighted leverage ratios and opt for a more in-depth treatment of procyclicality. Dermine (2013) proposes a privately based mechanism to share risk among all creditors, including short-term interbank creditors, as these other banks can best assess counterparty risks and process information on potential insolvencies. It is argued that banks will intentionally monitor and diversify their risk exposure in the interbank market. In short, Basel III generally contributed towards a more stable financial system, but the Directive's ability to mitigate systemic risk is questioned in academic literature, which is why regulators and policy makers are well advised to take up this topic.

Not only Basel III itself is reviewed critically; a vast amount of literature focuses on the translation of Basel III into national legislations. For instance, Ayadi et al. (2012) argue that the Capital Requirements Directive and Regulation (CRD IV-CRR), which is supposed to translate Basel III into European law, is not as far-reaching as claimed. According to their analysis, there is a lack of commitment regarding strict and binding leverage ratios and long-term liquidity requirements. Hence, systemic risk mitigation may not be properly addressed under the regulatory rules alleviating the effectiveness of the EU's macroprudential policy. For a sample of 921 western European banks, Dietrich et al. (2014) analyze the implementation of the new liquidity rules, aiming to provide insights on how new regulatory requirements are realized. Historically, most banks have not fulfilled the NSFR minimum requirements, and at the time of the study (2014), about 60 % still did not meet the criteria. Consequently, they would have to improve their funding profile and maintain higher liquid assets and improve their management of liquidity risk. These arguments support the findings of Quaglia (2013), who compares the new legislation to the pre-crisis setup, and concludes that there were no substantial differences between the two.

Another important element of the post-financial crisis regulatory regime in the EU is the Bank Recovery and Resolution (BRRD) Directive EU (2014a), which established arrangements on how to deal with failing financial institutions at the European level. One prime motivation behind this directive was the reduction of bail-out costs for taxpayers, as public funds had been previously used to bailout distressed banks. Benczur et al. (2017) reviews the effectiveness of the newly established CRR and CRD IV directive, the BRRD directive as well as the Single Resolution Mechanism (SRM). They quantify the effect of the adoption of these measures and find that the new regulatory framework can significantly decrease bailout costs. Similarly, the study by Covi and Eydam (2018) evaluates the effectiveness of the BRRD directive and comes to a supportive conclusion. Looking at the period 2012-2014 prior its implementation, and 2015-2016 after its implementation, they investigate whether a transfer of risk from sovereign states to banks or from banks to sovereign states has taken place. They identify a feedback loop between banks and sovereign states for the period between 2012-2014, but this effect decreased significantly for the 2015-2016 period, when the BRRD was effective. Based on their results,

they confirm the effectiveness of the BRRD in tackling spillover effects between financial institutions and sovereign states.

As part of the BRRD/SRM, a bail-in tool has been developed according to which bank creditors bear the costs of failing institutions and tax payers are not hold accountable. To realize this concept, banks must fulfill the so-called MREL quotas, which are supposed to function as a solvency buffer so that there are sufficient liabilities to absorb a bank's losses when the institution falls into difficulties and enters resolution. While this concept has been extensively praised, practical implementation at the EU level does not come without criticism (Tröger, 2018). Importantly, Avgouleas and Goodhart (2015) presents the advantages and disadvantages of bail-in tools and stress that the implementation of such does not completely eliminate the possibility that capital injections from public funds may be needed in the future, particularly in case of a systemic collapse. For the sake of wide financial stability, bail-outs shall not be ruled out per se; instead, they should be seen as a complementary tool to bail-in mechanisms, which particularly become relevant in times of extreme economic stress (Dewatripont, 2014). Tröger (2020) finds substantial shortcomings the EU level bail-in tool and argues that MREL specifications are too complex with too many rules and exceptions to effectively prevent taxpayer and public fund involvement (Table 3).

The GFC triggered the revision of another regulatory directive, which entered into force just one year prior the outbreak of the crisis: the Markets in Financial Instruments Directive (MiFID I) had been revised and came into effect as MiFID II (EU, 2014b) on January 3, 2018. Targeting investor and consumer protection, MiFID II is supposed to increase market transparency, to guarantee that potentially harmful financial products do not come to the market, and to ensure adequate investor protection, for example, complex products can only be marketed to professional investors (Busch, 2017; Prorokowski, 2015; Inderst, 2009). Considering that the directive itself comprises 148 pages and the framework package more than 20,000 pages, it is unsurprising that this regulatory novelty is regarded as far too complex. The criticism by Yeoh (2019) targets this complexity[26] and finds that only half of the EU's member states were able to implement MiFID II provisions when it became effective. Moreover, at the practical level, Schaeken Willemaers (2014) observes that the complicated disclosure obligations required under MiFID II may not fulfill their purpose, as many consumers do not understand them. Colaert (2016) finds that the comprehensive MiFID II framework is inconsistent with other pieces of EU legislation on investor protection. In addition to the complexity of MiFID II, the costs of implementation pose a challenge, particularly for smaller institutions (Prorokowski, 2015). Consequently, in order to ensure straightforward investor protection, it might be worth reviewing the MiFID II framework even after its implementation to reconsider how it could be designed in a more straightforward manner without sacrificing the intended consumer protection. Following the analysis by Colaert (2016), harmonization of EU legislation on consumer protection appears to be advisable.

Overall, it becomes evident that the GFC triggered and inspired the establishment of a complex regulatory framework. However, whether these novelties will manage to prevent a crisis in the future remains to be seen. It becomes evident that academic studies on the implementation and effectiveness of the new regulatory framework cover many diverse and detailed aspects, often coming to mixed results. However, critiques are often directed towards the tendency to draft extremely detailed and intricate directives, which are too complex and hence difficult to effectively transpose into practice.

4.6.2. The insurance industry

As outlined above, the financial crisis triggered the adoption of Solvency II, the EU's harmonized insurance industry regulatory framework. Generally, Solvency II and its risk-based approach are regarded as critical steps in the right direction and an important advancement compared to Solvency I (Gatzert and Wesker, 2012; Rae et al., 2018; Doff, 2016). The European Commission reviewed Solvency II ("2018 Interim Review") regarding methods and standard parameters when calculating the Solvency Capital Requirements (SCR) under the standard formula in 2018. Moreover, by the end of 2020, Solvency II is to be further reviewed ("2020 Full Review") and EIOPA is supposed to deliver in-depth input to guarantee a "holistic and thorough assessment of the framework" (EC, 2019). Revision of the interest rate risk sub-module is expected, potentially including increases in capital requirements in case stress scenarios are adjusted. Moreover, simplification and proportionate application of rules are reviewed.

After it came into effect in 2016, the majority of academic works on this topic confirm that the Solvency II framework through its rules and requirements, notably the newly introduced capital requirements, make the European insurance industry as a whole more resilient, hence the main goal of the framework has been achieved (see Section 3.5, as well as Doff, 2016). The new framework has since been critically reviewed, with most works focusing on the entire framework, while others concentrate on individual aspects. A holistic analysis of the effectiveness of Solvency II is provided by Doff (2016). Using 12 different criteria to systematically test the effectiveness of Solvency II, the author finds that the new framework sets the right incentives for insurers to fulfill the above-mentioned objectives of Solvency II. Hence, Solvency II was found to be effective overall. Only a few works (Huerta De Soto, 2009) question legislative reform in its entirety, most works address specific aspects of the framework while at the same time providing approaches for improvement. With an extensive review of Solvency II coming up in 2020, these aspects may function as inspiration to further enhance the framework and ensure regulatory objectives are met while guaranteeing applicability across EU member states. After consulting literature published on this topic, two main areas of criticism can be identified:

Firstly, as a general point of criticism, the sheer complexity and costs of the framework are mentioned. To ensure consumer protection, the cost appropriateness of regulation needs to be guaranteed. Otherwise, if insurers are required to hold more capital reserves than is efficient for their risk level, these costs will be passed on to consumers, who will face unnecessarily high insurance costs (Eling et al., 2007). While the first frameworks on insurance industry solvency published in the 1970s amounted to as little as 30 pages, the current Solvency II framework comprises 155 pages, plus another 50 pages for the Omnibus amendment. Moreover, the implantation mechanism is outlined in the writing of roughly another 1,000 pages. Hence, the pure length of the framework depicts its complexity, which also functions as an indicator for the compliance cost the insurance industry faces (see Monkiewicz, 2013). The direct costs related to the implementation of Solvency II were estimated at around EUR 25 millions for each large European insurance company (Accenture, 2010). In addition, it was estimated that IT spending of EUR 700-900 millions across the industry was necessary to comply with the directive (Monkiewicz, 2013). Hence, criticizing the costs of implementation based on absolute numbers seems feasible, but essentially, the balance between the cost of implementation, regulatory benefits, and policy makers' willingness to pay for higher safety levels is decisive. In their analysis, Lorson et al. (2012) addressed this aspect and concluded that this is not necessarily the

[26] Further studies suggesting that regulatory novelties may have limited effects due to their complexity, inconsistency, and in-transparency include Anagnostopoulos and Kabeega (2019), Bradley (2011a,b), Morais and Feteira (2018), Blair (2017), Baber (2013), Peretz and Schroedel (2009), Ruppel (2009), Turk (2014).

case. With regard to Solvency II, Gatzert and Wesker (2012), and Pradier and Chneiweiss (2017) conclude that the new framework incentivizes insurers to better assess and evaluate their risk picture, but at the same time, the authors underline the great complexity of the framework and regulatory bureaucracy.

One aspect that could potentially reduce costs for insurers is the integration of an illiquidity premium on the liability side of the balance, which was already suggested by representatives of the insurance industry when Solvency II was initially underway. The argument was based on the claim that long-term assets, due to their illiquid characteristics, have a predictable cash flow profile. However, as outlined by Danielsson et al. (2011) and Wüthrich (2011), there is no inherently scientific basis for the determination of these illiquidity premiums as uncertain gains in the future are shifted to the starting point. Furthermore, including such would contradict the market-consistence actuarial valuation in the insurance industry. The debate on whether theoretical considerations are sufficient to include a discount rate for illiquid long-term liabilities is still ongoing, and this topic is likely to also be discussed during the Solvency II 2020 review (Bulpitt and Fulcher, 2019). All in all, policy makers are well-advised to reconsider the cost and complexity of the framework when reviewing Solvency II.

Secondly, arguments pointing to shortcomings of Solvency II often concern specifics, for example, aspects concerning the standard formula and asset requirements. Applying a standard formula aims at establishing a systemic procedure to measure insurance companies' risks. Developing an appropriate, universal formula is of great importance, so it adequately reflects the solvency requirements and objectives outlined in the underlying regulatory framework. Regarding Solvency II, the underlying standard formula has been a point of debate. For example, Arias et al. (2010) point out that, even though Solvency II's risk-based approach is a step in the right direction, developing and implementing a standard formula is a delicate and sensitive operation. According to their research, equity classes are inappropriately represented. Detailed criticism has also been raised by Mittnik (2016), who argues that the two-step calibration of the standard formula for the assessment of equity risk gives rise to spurious correlations. The calibration of the equity-risk model, which is the most significant component of the formula, is flawed, and implantation poses significant risk. For this reason, the author advises to reconsider the calibration for equity risk to prevent volatile capital requirements.

The Value-at-Risk (VaR)-based capital requirements are criticized by Floreani (2013) who concludes that contrary to the intent, these requirements could even increase fragility in the insurance industry. It is argued that the VaR capital requirement seeks to incentivize better risk management through a "more risk/more capital"- risk management approach. While this approach is valid, VaR is considered the wrong risk measure because it simply measures risk and does not account for the different kinds of risk, namely systemic risk and diversifiable risk. However, highly diversified insurance companies are more exposed to systemic risk and, in turn, will be hit harder in times of global crisis. Hence, as Solvency II encourages diversification, growth in size, and systemic risk assumption, it is argued that larger and more diversified insurance companies are potentially hit harder in the case of market shortfalls. Based on this argument, suggestions on how to improve the Solvency II framework are outlined, such as introducing a quota for diversifiable risk. Scholars like Floreani (2013) question the VaR-based approach, while others find that the approach would be practical if subjected to some adjustments. With a more practical focus on Solvency II's impact on insurance companies' investment strategies, Höring (2013) compares the capital requirements for market risk under Solvency II with the S&P rating model's requirements. It is shown that the S&P model requires more capital than the Solvency II model for the same market risks and comparable levels of confidence. This leads to the conclusion that the Solvency II capital requirements would not bind additional capital and, consequently, are unlikely to cause significant restructuring of investment portfolios. Against this background, the author does not see the impact of Solvency II requirements on insurance companies' investment strategies. In short, disruptions in capital markets due to alterations of insurances' investment strategies because of Solvency II are not expected.

To summarize, in order to make the existing Solvency II framework more resilient for future crises, academic literature provides the following germane starting points: reconsideration of the balance between cost and complexity on the one hand and appropriateness of regulation on the other hand, the impact of private rating agencies on regulation and lastly, technical aspects related to solvency capital requirements.

5. Conclusion

A lot has happened with respect to regulatory novelties triggered by the GFC and SDC, but not all aspects addressed in this survey have been put into practice yet. Of course, the risk of a financial crisis can probably never be completely excluded by regulatory authorities, and thus some authors, such as Grosse (2017), for instance, argue that the occurrence of financial shocks has to be accepted. However, to improve the safety and robustness of the global financial system and to reduce systemic risk, numerous policy measures, regulatory directives, and frameworks have been proposed. Simultaneously, numerous academic works critically reviewed these developments. Therefore, this article intends to structure the multitude of publications and provide a comprehensive overview of post-crisis regulatory research publications. First, we examined the causes for the emergence of the US subprime mortgage crisis and the EMU sovereign debt crisis as the two most important crisis events in recent years. Both discussed events resulted from a combination of different factors - precipitating as well as more fundamental, or deep-rooted causes (see, for instance, Park, 2015). Second, policy responses as well as regulatory reforms triggered by crisis events have been clustered and presented. The initial responses to the crisis were intended to stabilize the situation. Thereafter, a series of regulatory reforms has been gradually launched to make the financial sector more resilient, some targeting individual institutions' stability, while others were directed to stabilize the whole financial system. Third, the literature critically reviewing these developments investigates whether these reforms fit their purpose and present recommendations to prevent a crisis in the future. To summarize, while many works find that the reforms adopted have been effective in many ways and thus contributed to make the financial system more resilient, essential recommendations found in the literature include:

1. Fiscal stimulus packages combined with proven growth stimulating measures need to correspond to the given economic situation. This means that in economically prosperous times, adequate fiscal discipline is advisable. This applies particularly to the EU to foster fiscal consolidation.
2. Due to the global interconnectedness of financial markets, a greater degree of consolidated international cooperation and harmonization of regulatory frameworks would be desirable. This applies for both the banking and insurance sectors.
3. Flaws in the EMU architecture should be actively addressed to move away from the present regulatory hodgepodge by gradually establishing a harmonized, holistic regulatory regime.[27]

[27] For instance by forming an European state or harmonizing wage and labor markets or tax systems in Europe (Ruščáková and Semančíková, 2016).

4. Considering that CRA played a dominant role in the debate surrounding the causes of the GFC and the SDC, little has happened since. It may be time to rethink the CRAs' business models, the issuer pays principal, how to add a great degree of transparency to the methodology as well as competition in the industry.
5. It is also recommended to critically address the "too big to fail" difficulties as large, internationally operating financial institutions are still likely to trigger similar avalanche effects to those experienced in 2008.
6. For both regulatory frameworks in the financial and insurance industries, it is suggested to asses simplification potential and whether the complexity of regimes are adequate with respect to implementation potential, practicability, as well as costs and benefits. In short, it is recommended to review whether regulatory compliance costs could be partially reduced without compromising on stability.
7. Ultimately, rationale-based economic theory failed to address the important aspects of human behavior. Therefore, many studies recommend more focus on a behavioral economic perspective, in both academic theory and regulatory practice.[28]

Even though strengthened prudential measures, higher liquidity, and capital standards as well as new resolution mechanisms have been enacted in the aftermath of the GFC and SDC, it is still important for policy makers and regulatory and supervisory authorities to scrutinize the impact of regulatory innovations in the current market environment as well as in stress scenarios. Without claiming to have covered all aspects of the topic, this literature review has demonstrated the importance of a holistic approach to financial regulatory discussions. However, because regulatory frameworks are always a work-in-progress, it is of utmost importance to continuously question the status quo.

This work provides a first effort to review the large body of literature in a structured approach. Further work for a better understanding of crisis management could be based on this overview. Other factors for further analyses could be the empirical analysis of the long-term effects of measures in fiscal and monetary policy and on regulatory changes. Further research in the field "smart regulation" could also be very promising. This theory is based on the idea of flexible regulatory standards that depend on economic indicators, the so-called "financial automatic stabilizers"' (see Gokhale and Van Doren, 2009).

References

Abolo, E.M., 2008. Banking Regulation and Global Financial Crisis: Issues. Implications & Way Forward, Available at SSRN 1321483.
Accenture, 2010. Most European Insurers Say Compliance With Solvency II Will Cost More Than Originally Expected.
Acharya, V.V., Richardson, M., 2009. Causes of the financial crisis. Crit. Rev. 21, 195–210.
Acosta-González, E., Fernández-Rodíguez, F., Sosvilla-Rivero, S., 2012. On factors explaining the 2008 financial crisis. Econ. Lett. 115, 215–217.
Adam, K., Billi, R.M., 2006. Optimal monetary policy under commitment with a zero bound on nominal interest rates. J. Money Credit Bank., 1877–1905.
Adolff, J., Häller, J., 2019. Bail-In Im Lichte Des EU-Bankenpakets: Das Zusammenspiel Von MREL, TLAC und TLOF. Zeitschrift für Bankrecht und Bankwirtschaft 31, 369–378.
Adrian, T., Kiff, J., Shin, H.S., 2018. Liquidity, leverage, and regulation 10 years after the global financial crisis. Annu. Rev. Financ. Econ. 10, 1–24.
Afonso, A., Furceri, D., Gomes, P., 2012. Sovereign credit ratings and financial markets linkages: application to European data. J. Int. Money Finance 31, 606–638.
Agnello, L., Castro, V., Jalles, J.T., Sousa, R.M., 2015. What determines the likelihood of structural reforms? Eur. J. Polit. Econ. 37, 129–145.
Aikman, D., Bridges, J., Kashyap, A., Siegert, C., 2019. Would macroprudential regulation have prevented the last crisis? J. Econ. Perspect. 33, 107–130.
Ait-Sahalia, Y., Andritzky, J., Jobst, A., Nowak, S., Tamirisa, N., 2012. Market response to policy initiatives during the global financial crisis. J. Int. Econ. 87, 162–177.
Aizenman, J., 2009. Financial Crisis and the Paradox of Under-And Over-Regulation, NBER Working Paper No. 15018.
Aizenman, J., Hutchison, M., Jinjarak, Y., 2013. What is the risk of European sovereign debt defaults? Fiscal space, CDS spreads and market pricing of risk. J. Int. Money Finance 34, 37–59.
Albertazzi, U., Ropele, T., Sene, G., Signoretti, F.M., 2014. The impact of the Sovereign debt crisis on the activity of Italian banks. J. Bank. Finance 46, 387–402.
Alesina, A., Azzalini, G., Favero, C., Giavazzi, F., Miano, A., 2018. Is it the "how" or the "when" that matters in fiscal adjustments? IMF Econ. Rev. 66, 144–188.
Allen, B., Chan, K.K., Milne, A., Thomas, S., 2012a. Basel III: is the cure worse than the disease? Int. Rev. Financ. Anal. 25, 159–166.
Allen, F., Gu, X., Kowalewski, O., 2012b. Financial crisis, structure and reform. J. Bank. Finance 36, 2960–2973.
Alsakka, R., Ap Gwilym, O., Vu, T.N., 2014. The Sovereign-bank rating channel and rating agencies' downgrades during the European debt crisis. J. Int. Money Finance 49, 235–257.
Alter, A., Beyer, A., 2014. The dynamics of spillover effects during the European sovereign debt turmoil. J. Bank. Finance 42, 134–153.
Alter, A., Schüler, Y.S., 2012. Credit spread interdependencies of European states and banks during the financial crisis. J. Bank. Finance 36, 3444–3468.
Amann, J., Middleditch, P., 2020. Revisiting reinhart and rogoff after the crisis: a time series perspective. Camb. J. Econ. 44, 343–370.
Amri, P.D., Kocher, B.M., 2012. The political economy of financial sector supervision and banking crises: a cross-country analysis. Eur. Law J. 18, 24–43.
Anagnostopoulos, Y., Kabeega, J., 2019. Insider perspectives on European banking challenges in the post-crisis regulation environment. J. Bank. Regul. 20, 136–158.
Anderson, D., Hunt, B., Snudden, S., 2014. Fiscal consolidation in the euro area: how much pain can structural reforms ease? J. Policy Model. 36, 785–799.
Andrade, P., Cahn, C., Fraisse, H., Mésonnier, J.-S., 2019. Can the provision of long-term liquidity help to avoid a credit crunch? Evidence from the eurosystem's LTRO. J. Eur. Econ. Assoc. 17, 1070–1106.
Andritzky, J., Christofzik, D.I., Feld, L.P., Scheuering, U., 2019. A mechanism to regulate sovereign debt restructuring in the euro area. Int. Finance 22, 20–34.
Anginer, D., Bertay, A.C., Cull, R., Demirgüç-Kunt, A., Mare, D.S., 2019. Bank Regulation and Supervision Ten Years After the Global Financial Crisis. The World Bank.
Anginer, D., Demirgüç-Kunt, A., Mare, D.S., 2020. Bank Capital and Risk in Europe and Central Asia Ten Years After the Crisis. The World Bank.
Arce, O., Mayordomo, S., Peña, J.I., 2013. Credit-risk valuation in the sovereign CDS and bonds markets: evidence from the euro area crisis. J. Int. Money Finance 35, 124–145.
Arezki, R., Candelon, B., Sy, A., 2011. Sovereign Rating News and Financial Markets Spillovers: Evidence from the European Debt Crisis. CESifo Working Paper: Monetary Policy and International Finance.
Arias, L., El Hedi Arouri, M., Foulquier, P., Gregoir, S., 2010. On the Suitability of the Calibration of Private Equity Risk in the Solvency II Standard Formula. Publication of the EDHEC Financial Analysis and Accounting Research Centre.
Ashby, S., 2011. Risk management and the global banking crisis: lessons for insurance solvency regulation. Geneva Papers Risk Insur. – Issues Pract. 36, 330–347.
Ashraf, B.N., Zheng, C., Jiang, C., Qian, N., 2020. Capital regulation, deposit insurance and bank risk: international evidence from normal and crisis periods. Res. Int. Bus. Finance 52.
Athavale, S., Chowdhury, A.K., 2015. Global financial crisis and the regulation of credit rating business. Vinimaya 36, 17–44.
Attinasi, M.G., Checherita-Westphal, C.D., Nickel, C., 2009. What Explains the Surge in Euro Area Sovereign Spreads During the Financial Crisis of 2007–09?, ECB Working Paper.
Aubuchon, C.P., 2009. What's under the TARP? Econ. Synop., 2009.
Auerbach, A.J., Gorodnichenko, Y., 2017. Fiscal Stimulus and Fiscal Sustainability. National Bureau of Economic Research.
Avgouleas, E., 2009a. The global financial crisis and the disclosure paradigm in European financial regulation: the case for reform. Eur. Co. Financ. Law Rev. 6, 440–475.
Avgouleas, E., 2009b. The global financial crisis, behavioural finance and financial regulation: in search of a new orthodoxy. J. Corp. Law Stud. 9, 23–59.
Avgouleas, E., Goodhart, C., 2015. Critical reflections on bank bail-ins. J. Financ. Regul. 1, 3–29.
Avgouleas, E., Goodhart, C., 2016. An anatomy of bank bail-ins – why the eurozone needs a fiscal backstop for the banking sector. Eur. Econ. 2, 75–90.
Avgouleas, E., Goodhart, C., Schoenmaker, D., 2013. Bank resolution plans as a catalyst for global financial reform. J. Financ. Stab. 9, 210–218.
Ayadi, R., Arbak, E., Pieter De Groen, W., 2012. Implementing Basel III in Europe: Diagnosis and Avenues for Improvement, CEPS Policy Brief.
Baber, G., 2013. A critical examination of the legislative response in banking and financial regulation to issues related to misconduct in the context of the crisis of 2007–2009. J. Financ. Crime 20, 237–252.
Babis, V.S., 2014. European bank recovery and resolution directive: ecovery proceedings for cross-border banking groups. Eur. Bus. Law Rev. 25, 459–480.

[28] See, for instance, Rannou (2010), Buttimer (2011) or Avgouleas and Goodhart (2015).

Baker, A., 2015. Varieties of economic crisis, varieties of ideational change: how and why financial regulation and macroeconomic policy differ. New Polit. Econ. 20, 342–366.
Baker, C., Cummings, C., Jagtiani, J., 2017. The impacts of financial regulations: solvency and liquidity in the post-crisis period. J. Financ. Regul. Compliance 25, 253–270.
Ball, R., 2009. The global financial crisis and the efficient market hypothesis: what have we learned? J. Appl. Corp. Finance 21, 8–16.
Balseven, H., 2016. The political economy of financial regulation policies following the global crisis. Int. J. Econ. Financ. Issues 6, 607–616.
Banerjee, S., 2011. Macro Prudential Supervision and the Financial Crisis of 2007: the Aegis of the Central Banks, Available at SSRN 1827088.
Barrios, S., Iversen, P., Lewandowska, M., Setzer, R., et al., 2009. Determinants of Intra-Euro Area Government Bond Spreads During the Financial Crisis. Directorate General Economic and Financial Affairs (DG ECFIN), European Commission.
Barth, J.R., Lin, C., Ma, Y., J. Seade, J., Song, F.M., 2013. Do bank regulation, supervision and monitoring enhance or impede bank efficiency? J. Bank. Finance 37, 2879–3289.
Basse, T., Friedrich, M., Kleffner, A., Graf von der Schulenburg, J.-M., 2014. Are interest rates too low? Empirical evidence and implications for German life insurers. Zeitschrift für die gesamte Versicherungswissenschaft 103, 31–43.
Basten, M., Sánchez Serrano, A., 2019. European banks after the global financial crisis: a new landscape. J. Bank. Regul. 20, 51–73.
Bauer, C., Herz, B., 2020. Reforming the European stability mechanism. J. Common Market Stud. 58, 636–653.
Bauer, M.D., Neely, C.J., 2014. International channels of the feds unconventional monetary policy. J. Int. Money Finance 44, 24–46.
Beckmann, R., Eppendorfer, C., Neimke, M., 2003. Financial integration within the European union: towards a single market for insurance. In: The Incomplete European Market for Financial Services. Springer, pp. 1–29.
Begg, I., 2009. Regulation and supervision of financial intermediaries in the EU: the aftermath of the financial crisis. J. Common Market Stud. 47, 1107–1128.
Begg, I., 2013. Are better defined rules enough? An assessment of the post-crisis reforms of the governance of EMU. Transf.: Eur. Rev. Labour Res. 19, 49–62.
Beirne, J., Fratzscher, M., 2013. The pricing of Sovereign risk and contagion during the European sovereign debt crisis. J. Int. Money Finance 34, 60–82.
Benczur, P., Cannas, G., Cariboni, J., Di Girolamo, F., Maccaferri, S., Giudici, M.P., 2017. Evaluating the effectiveness of the new Eu bank regulatory framework: a farewell to bail-out? J. Financ. Stab. 33, 207–223.
Bengtsson, E., 2013. Shadow banking and financial stability: European money market funds in the global financial crisis. J. Int. Money Finance 32, 579–594.
Benhabib, J., Miao, J., Wang, P., 2016. Chaotic banking crises and regulations. Econ. Theory 61, 393–422.
Berdin, E., Gründl, H., 2015. The effects of a low interest rate environment on life insurers. Geneva Papers on Risk and Insurance-Issues and Practice 40, 385–415.
Berger, A.N., Himmelberg, C.P., Roman, R.A., Tsyplakov, S., 2019. Bank Bailouts, Bail-Ins, or No Regulatory Intervention? A Dynamic Model and Empirical Tests of Optimal Regulation, Available at SSRN 3179226.
Bergman, U.M., Hutchison, M., 2015. Economic stabilization in the post-crisis world: are fiscal rules the answer? J. Int. Money Finance 52, 82–101.
Bergman, U.M., Hutchison, M.M., Hougaard Jensen, S.E., 2016. Promoting sustainable public finances in the European union: the role of fiscal rules and government efficiency. Eur. J. Polit. Econ. 44, 1–19.
Bernal, O., Girard, A., Gnabo, J.-Y., 2016. The importance of conflicts of interest in attributing sovereign credit ratings. Int. Rev. Law Econ. 47, 48–66.
Bernal, O., Gnabo, J.-Y., Guilmin, G., 2014. Assessing the contribution of banks, insurance and other financial services to systemic risk. J. Bank. Finance 47, 270–287.
Bernanke, B.S., Reinhart, V.R., 2004. Conducting monetary policy at very low short-term interest rates. Am. Econ. Rev. 94, 85–90.
Bernoth, K., Erdogan, B., 2012. Sovereign bond yield spreads: a time-varying coefficient approach. J. Int. Money Finance 31, 639–656.
Best, S., Read, O., et al., 2017. MREL and TLAC: the path from bail-out to bail-in for banks creditors in the European union. Credit Cap. Mark. 50, 337–362.
Bieling, H.-J., 2014. Shattered expectations: the defeat of European ambitions of global financial reform. J. Eur. Public Policy 21, 346–366.
Biener, C., Eling, M., 2012. Insurability in microinsurance markets: an analysis of problems and potential solutions. Geneva Papers Risk Insur. – Issues Pract. 37, 77–107.
Biener, C., Eling, M., Wirfs, J.H., 2015. Insurability of cyber risk: an empirical analysis. Geneva Papers Risk Insur.-Issues Pract. 40, 131–158.
Bijlsma, M., Vermeulen, R., 2016. Insurance companies' trading behaviour during the european sovereign debt crisis: flight home or flight to quality? J. Financ. Stabil. 27, 137–154.
Binney, M.F., 2010. A Brief Look at the Sub-Prime Crisis: Was It a Regular Business Cycle, the Result of Lax Supervision and/or a Regulatory Failure?, Available at SSRN 1669051.
Blair, M.M., 2017. A simple fix for a complex problem? Comments on morgan ricks, the money problem: rethinking financial regulation. Account. Econ. Law: Conviv. 8.
Blanchard, O.J., Cottarelli, C., Spilimbergo, A., Symansky, S., 2009. Fiscal Policy for the Crisis, CEPR Discussion Paper No. DP7130.
Bletzinger, T., Wieland, V., 2016. Forward Guidance and "Lower for Longer": the Case of the ECB, IMFS Working Paper Series No. 102.
Blundell-Wignall, A., 2012. Solving the financial and sovereign debt crisis in Europe. OECD J.: Financ. Market Trends 2011, 201–224.
Blundell-Wignall, A., Atkinson, P., 2009. Origins of the financial crisis and requirements for reform. J. Asian Econ. 20, 536–548.
Board Of Governors Of The Federal Reserve System (US), 2019. Effective Federal Funds Rate [FEDFUNDS]. https://fred.stlouisfed.org/series/FEDFUNDS.
Boumparis, P., Milas, C., Panagiotidis, T., 2017. Economic policy uncertainty and sovereign credit rating decisions: panel quantile evidence for the eurozone. J. Int. Money Finance 79, 39–71.
Bradley, C., 2011a. Transparency and financial regulation in the European union: crisis and complexity. Fordham Int. Law J. 35, 1171–1206.
Bradley, C., 2011b. Transparency is the new opacity: constructing financial regulation after the crisis. Am. Univ. Bus. Law Rev. 1, 7–32.
Bradley, C.M., 2009. Rhetoric and the Regulation of the Global Financial Markets in a Time of Crisis: the Regulation of Credit Ratings, University of Miami Legal Studies Research Paper No. 2009-24.
Brunnermeier, M., Crocket, A., Goodhart, C., Persaud, A.D., Shin, H., 2009. The Fundamental Principles of Financial Regulation, vol. 11. ICMB, Internat. Center for Monetary and Banking Studies.
Brunnermeier, M.K., 2009. Deciphering the Liquidity and Credit Crunch 2007–2008. J. Econ. Perspect. 23, 77–100.
Buck, F., Schliephake, E., 2013. The regulator's trade-off: bank supervision vs. minimum capital. J. Bank. Finance 37, 4584–4598.
Buiter, W.H., 2007. Lessons from the 2007 Financial Crisis, CEPR Discussion Paper No. DP6596.
Buiter, W.H., Rahbari, E., 2012. The ECB as Lender of Last Resort for Sovereigns. The Euro Area, CEPR Discussion Paper No. DP8974.
Bulpitt, T., Fulcher, P., 2019. Illiquid Liabilities: A Myth or a reality?
Busch, D., 2017. Product Governance and Product Intervention Under MiFID II/MiFIR. Oxford University Press, Oxford, pp. 123–146.
Busch, D., Teubner, A., 2019. Fit and Proper Assessments Within the Single Supervisory Mechanism, EBI Working Paper Series 2019/34.
Buttimer Jr., R.J., 2011. The financial crisis: imperfect markets and imperfect regulation. J. Financ. Econ. Policy 3, 12–32.
Cabral, R., 2013. A perspective on the symptoms and causes of the financial crisis. J. Bank. Finance 37, 103–117.
Calabrese, R., Elkink, J.A., Giudici, P.S., 2017. Measuring bank contagion in Europe using binary spatial regression models. J. Operat. Res. Soc. 68, 1503–1511.
Calabria, M.A., 2009. Did deregulation cause the financial crisis. Cato Policy Rep. 31, 1–8.
Caprio Jr., G., 2009. Financial Regulation in a Changing World. Center for Development Economics, Working Papers Series.
Caprio Jr., G., 2013. Financial Regulation After the Crisis: How Did we Get Here, and How do we Get Out?, Available at SSRN 2350564.
Caprio Jr., G., D'Apice, V., Ferri, G., Puopolo, G.W., 2014. Macro-financial determinants of the great financial crisis: implications for financial regulation. J. Bank. Finance 44, 114–129.
Carstensen, M.B., 2013. The role of special resolution regimes in post-crisis nancial regulation: four Danish lessons. Politik 16.
Caruso, A., Reichlin, L., Ricco, G., 2019. Financial and fiscal interaction in the Euro area crisis: this time was different. Eur. Econ. Rev. 119, 333–355.
Case, K.E., Shiller, R.J., 2003. Is There A Bubble In The Housing Market? Brookings Papers On Economic Activity., pp. 299–362.
Cassola, N., Kok, C., Mongelli, F.P., 2019. The ECB After the Crisis: Existing Synergies Among Monetary Policy, Macroprudential Policies and Banking Supervision, ECB Occasional Paper.
Catrina, I.L., 2012. The failure of fiscal consolidation through "budget cuts". Proc. Econ. Finance 3, 367–374.
Cecchetti, S.G., Schoenholtz, K.L., 2017. Regulatory Reform: A Scorecard, CEPR Discussion Paper No. DP12465.
CEIOPS, 2009. Lessons to Be Learned from the Crisis – Solvency II and Beyond.
Chaikovska, I., 2019a. Enforcement actions of banking supervision authorities in European union: non-compliance with post-crisis banking regulations. Int. J. Arts Sci. 12, 107–112.
Chaikovska, I., 2019b. The role of post-crisis banking regulations in maintaining the security of the banking system. Int. J. Arts Sci. 12, 165–175.
Chaudary, S., Salvador-Adebayo, D., 2014. Why regulate financial markets? The underlying rationale for financial regulation in the wake of the current crisis. J. Eur. Stud. 30.
Chen, H., Cúrdia, V., Ferrero, A., 2012. The macroeconomic effects of large-scale asset purchase programmes. Econ. J. 122, 289–315.
Cheng, J., Dai, M., Dufourt, F., 2017. Banking and sovereign debt crises in a monetary union without central bank intervention. J. Math. Econ. 68, 142–151.
Cihak, M., Demirgüç-Kunt, A., Martinez Peria, M.S., Mohseni-Cheraghlou, A., 2012. Bank Regulation and Supervision Around the World: A Crisis Update. The World Bank.
Coen, D., Salter, J.-P., 2020. Multilevel regulatory governance: establishing bank-regulator relationships at the European banking authority. Bus. Polit. 22, 113–134.
Coenen, G., Straub, R., Trabandt, M., 2013. Gauging the effects of fiscal stimulus packages in the euro area. J. Econ. Dyn. Control 37, 367–386.
Coenen, G., Warne, A., 2014. Risks to price stability, the zero lower bound, and forward guidance: a real-time assessment. Int. J. Central Bank.
Cœuré, B., 2016. Assessing the implications of negative interest rates. Speech at the Yale Financial Crisis Forum, vol. 28. Yale School of Management, New Haven, pp. 2016.

Coffee Jr., J.C., 2009. What went wrong? An initial inquiry into the causes of the 2008 financial crisis. J. Corpor. Law Stud. 9, 1–22.
Colaert, V., 2016. MiFID II in relation to other investor protection regulation: picking up the crumbs of a piecemeal approach. In: Busch, D., Ferrarini, G. (Eds.), Regulation of the EU Financial Markets: MiFID II and MiFIR.
Constâncio, V., 2014. The European crisis and the role of the financial system. J. Macroecon. 39, 250–259.
Cotterli, S., Gualandri, E., 2010. Financial Crisis and Supervision of Cross-Border Groups in the EU.
Couppey-Soubeyran, J., 2010. Financial regulation in the crisis regulation, market discipline, internal control: the big three in turmoil. Int. Econ. 123, 13–29.
Cour-Thimann, P., Winkler, B., 2012. The ECB's non-standard monetary policy measures: the role of institutional factors and financial structure. Oxf. Rev. Econ. Policy 28, 765–803.
Coval, J., Jurek, J., Stafford, E., 2009. The economics of structured finance. J. Econ. Perspect. 23, 3–25.
Covi, G., Eydam, U., 2018. End of the sovereign-bank doom loop in The European union? The bank recovery and resolution directive. J. Evol. Econ., 1–26.
Croci Angelini, E., Farina, F., Valentini, E., 2016. Contagion across eurozone's sovereign spreads and the core-periphery divide. Empirica 43, 197–213.
Crotty, J., 2009. Structural causes of the global financial crisis: a critical assessment of the 'new financial architecture'. Camb. J. Econ. 33, 563–580.
Crowley, P.M., Lee, J., 2009. Evaluating the Stresses from ECB Monetary Policy in the Euro Area, Bank of Finland Research Discussion Paper.
Curcio, D., De Simone, A., Gallo, A., 2017. Financial crisis and international supervision: new evidence on the discretionary use of loan loss provisions at euro area commercial banks. Br. Account. Rev. 49, 181–193.
Dabrowski, M., 2010. The global financial crisis: lessons for European integration. Econ. Syst. 34, 38–54.
Dagher, J., Fu, N., 2017. What fuels the boom drives the bust: regulation and the mortgage crisis. Econ. J. 127, 996–1024.
Daniela, Z., Mihail-Ioan, C., Anatol, C., Sebastian, M.D., 2010. New international financial regulation: necessity or required by crisis. Annals of the university of Oradea. Econ. Sci. Ser. 19, 456–461.
Danielsson, J., De Jong, F., Laeven, R., Laux, C., Perotti, E., Wüthrich, M., 2011. A Prudential Regulatory Issue at the Heart of Solvency II, VOX Policy Note, March.
Davidoff, S.M., Zaring, D., 2009. Regulation by deal: the government'S response to the financial crisis. Adm. Law Rev. 61, 463–542.
Davies, H., 2010. Global financial regulation after the credit crisis. Global Policy 1, 185–190.
De Bruyckere, V., Gerhardt, M., Schepens, G., Vander Vennet, R., 2013. Bank/sovereign risk spillovers in the European debt crisis. J. Bank. Finance 37, 4793–4809.
De Grauwe, P., 2011. The banking crisis: causes, consequences and remedies. In: Systemic Implications of Transatlantic Regulatory Cooperation and Competition. World Scientific, pp. 23–46.
De Grauwe, P., Foresti, P., 2016. Fiscal rules, financial stability and optimal currency areas. Econ. Lett. 145, 278–281.
De Grauwe, P., Ji, Y., 2013. Self-fulfilling crises in the eurozone: an empirical test. J. Int. Money Finance 34, 15–36.
De Grauwe, P., Ji, Y., 2014. How much fiscal discipline in a monetary union? J. Macroecon. 39, 348–360.
De Grauwe, P., Ji, Y., Steinbach, A., 2017. The EU debt crisis: testing and revisiting conventional legal doctrine. Int. Rev. Law Econ. 51, 29–37.
De la Mata Muñoz, A., 2010. The future of cross-border banking after the crisis: facing the challenges through regulation and supervision. Eur. Bus. Organ. Law Rev. 11, 575–607.
De Mendonca, A.R., Deos, S., 2009. Crises in the financial regulation of finance-led capitalism: a Minskyan analysis. Rev. Regul. 6.
De Michelis, A., 2009. Overcoming the Financial Crisis in the United States, OECD Economics Department Working Papers.
De Santis, R.A., 2012. The Euro Area Sovereign Debt Crisis: Safe Haven, Credit Rating Agencies and the Spread of the Fever from Greece, Ireland and Portugal, ECB Working Paper.
De Santis, R.A., 2014. The euro area sovereign debt crisis: identifying flight-to-liquidity and the spillover mechanisms. J. Empir. Finance 26, 150–170.
De Santis, R.A., 2020. Impact of the asset purchase programme on euro area government bond yields using market news. Econ. Model. 86, 192–209.
De Vincenzo, A., Freni, M.A., Generale, A., Nicoletti-Altimari, S., Quagliariello, M., 2010. Lessons Learned From the Financial Crisis for Financial Stability and Banking Supervision, Bank of Italy Occasional Paper.
Dell'Ariccia, G., Rabanal, P., Sandri, D., 2018. Unconventional monetary policies in the euro area, Japan, and the United Kingdom. J. Econ. Perspect. 32, 147–172.
Demirgüç-Kunt, A., Servén, L., 2010. Are all the sacred cows dead? Implications of the financial crisis for macro and financial policies. World Bank Res. Obs. 25.
Den Butter, F.A., 2010. The Macroeconomics of the Credit Crisis: In Search of Externalities for Macro-Prudential Supervision, Tinbergen Institute Discussion Paper 2010-052/3.
Denk, O., Gomes, G., 2017. Financial Re-Regulation Since the Global Crisis?: An Index-Based Assessment, OECD Economic Department Working Papers 1396.
Dermine, J., 2013. Bank regulations after the global financial crisis: good intentions and unintended evil. Eur. Financ. Manag. 19, 658–674.
Dewatripont, M., 2014. European banking: bailout, bail-in and state aid control. Int. J. Ind. Organ. 34, 37–43.
Dewing, I.P., Russell, P.O., 2016. Whistleblowing, governance and regulation before the financial crisis: the case of HBOS. J. Bus. Ethics 134, 155–169.
Di Iasio, G., 2013. Incentives and financial crises: microfounded macroprudential regulation. J. Financ. Intermed. 22, 627–638.
Dietrich, A., Hess, K., Wanzenried, G., 2014. The good and bad news about the new liquidity rules of basel Iii in western European countries. J. Bank. Finance 44, 13–25.
Doff, R., 2008. A critical analysis of the solvency II proposals. Geneva Papers Risk Insur. – Issues Pract. 33, 193–206.
Doff, R., 2016. The final solvency II framework: will it be effective? Geneva Papers Risk Insur. – Issues Pract. 41, 587–607.
Doumpos, M., Gaganis, C., Pasiouras, F., 2015. Central bank independence, financial supervision structure and bank soundness: an empirical analysis around the crisis. J. Bank. Finance 61, 69–83.
Doyran, M.A., 2011. The contradictions of state regulation of the banking sector: the challenge of moral hazard during the sub-prime mortgage crisis. Int. J. Econ. Bus. Res. 3, 72–92.
Drago, D., Gallo, R., 2016. The impact and the spillover effect of a sovereign rating announcement on the euro area CDS market. J. Int. Money Finance 67, 264–286.
Drago, D., Gallo, R., 2017. The impact of sovereign rating changes on the activity of European banks. J. Bank. Finance 85, 99–112.
Drew, M.E., 2010. The future of financial regulation: lessons from the global financial crisis. Griffith Law Rev. 19, 1–5.
Duan, J.-C., Van Laere, E., 2012. A public good approach to credit ratings – from concept to reality. J. Bank. Finance 36, 3239–3247.
Duffie, D., 2018. Financial regulatory reform after the crisis: an assessment. Manag. Sci. 64, 4835–4857.
Düll, R., König, F., Ohls, J., 2017. On the exposure of insurance companies to sovereign risk-portfolio investments and market forces. J. Financ. Stabil. 31, 93–106.
EC, 2008. Communication From the Commission to The European Council. A European Economic Recovery Plan.
EC, 2019. Formal Request to EIOPA for Technical Advice on the Review of the Solvency II Directive.
Echevarria Icaza, V., 2017. The literature on the interaction of fiscal risk and financial stability – a survey. Cuadernos De Economía 40, 177–190.
Eichengreen, B., 2010. International financial regulation after the crisis. Daedalus 139, 107–114.
Eidenberger, J., Liebeg, D., Schmitz, S.W., Seliger, R., Sigmund, M., Steiner, K., Strobl, P., Ubl, E., et al., 2014. Macroprudential supervision: a key lesson from the financial crisis. Financ. Stabil. Rep. 27, 83–94.
Eijffinger, S.C., 2012. Rating agencies: role and influence of their sovereign credit risk assessment in the eurozone. J. Common Market Stud. 50, 912–921.
Elderfield, M., 2009. Solvency II: setting the pace for regulatory change. Geneva Papers Risk Insur. – Issues Pract. 34, 35–41.
Eling, M., Lehmann, M., 2018. The impact of digitalization on the insurance value chain and the insurability of risks. Geneva Papers Risk Insur. – Issues Pract. 43, 359–396.
Eling, M., Schmeiser, H., 2010. Insurance and the credit crisis: impact and ten consequences for risk management and supervision. Geneva Papers Risk Insur. – Issues Pract. 35, 9–34.
Eling, M., Schmeiser, H., Schmit, J.T., 2007. The solvency II process: overview and critical analysis. Risk Manag. Insur. Rev. 10, 69–85.
Eling, M., Schnell, W., 2016. What do we know about cyber risk and cyber risk insurance? J. Risk Finance 17.
Ellis, H., 1990. Government regulation of insurance companies. In: A Guide to Insurance Management. Springer, pp. 277–289.
Ellis, L., Haldane, A., Moshirian, F., 2014. Systemic risk, governance and global financial stability. J. Bank. Finance 45, 175–181.
Emond, I., Kunertová, T., 2019. European union regulation of insurance industry in the aftermath of the financial crisis. Lawyer Q. 9.
Engel, J., 2020. Regulation, financialization and fraud in Chinese commodity markets after the global financial crisis. Reg. Stud. 54, 219–228.
Erb, C.B., Harvey, C.R., Viskanta, T.E., 1996. Political risk, economic risk, and financial risk. Financ. Anal. J. 52, 29–46.
Eser, F., Schwaab, B., 2016. Evaluating the impact of unconventional monetary policy measures: empirical evidence from the ECB's securities markets programme. J. Financ. Econ. 119, 147–167.
EU, 2009. Directive 2009/136/EC of the European parliament and of the council. Off. J. Eur. Union 337, 11.
EU, 2014a. Directive 2014/59/EU of the European Parliament and of the Council of 15 May 2014 Establishing a Framework for the Recovery and Resolution of Credit Institutions and Investment Firms.
EU, 2014b. Directive 2014/65/EU Of The European Parliament and the Council of 15 May 2014 on Markets in Financial Instruments.
European Commission, 2011. Proposal for a Regulation of the European Parliament and of the Council Amending Regulation (EC) no 1060/2009 on Credit Rating Agencies.
European Parliament, 2016. The Case for a European Public Credit Rating Agency. http://www.europarl.europa.eu/RegData/etudes/BRIE/2016/589865/EPRS_BRI(2016)589865_EN.pdf.
European Securities and Markets Authority, 2017. Guidelines On The Application Of The Endorsement Regime Under Article 4(3) Of The Credit Rating Regulation 1060/2009. https://www.esma.europa.eu/sites/default/files/library/esma33-9-205_final_report_on_the_application_of_the_cra_endorsement_regime_1.pdf.
Evans, J.R., Campbell, C.L., Justiniano, J.D., Fisher, A., 2012. Macroeconomic effects of FOMC forward guidance. Brook. Papers Econ. Act., 1–80.

Fabozzi, F.J., Giacometti, R., Tsuchida, N., 2016. Factor decomposition of the eurozone sovereign CDS spreads. J. Int. Money Finance 65, 1–23.
Falagiarda, M., Reitz, S., 2015. Announcements of ECB unconventional programs: implications for the sovereign spreads of stressed euro area countries. J. Int. Money Finance 53, 276–295.
Fasiangova, L., Haiss, P.R., 2009. Lessons from the financial crisis: is national supervision of international markets to blame? Wirtschaftspolitische Blätter 3, 389–405.
Ferran, E., 2011. The Regulation of Hedge Funds and Private Equity: A Case Study in the Development of the EU's Regulatory Response to the Financial Crisis, University of Cambridge Faculty of Law Research Paper.
Finsinger, J., Schmid, F.A., 1994. Prices, distribution channels and regulatory intervention in European insurance markets. Geneva Papers Risk Insur. – Issues Pract., 22–36.
Floreani, A., 2013. Risk measures and capital requirements: a critique of the solvency II approach. Geneva Papers Risk Insur. – Issues Pract. 38, 189–212.
Forbes, W., O'Donohoe, S., Prokop, J., 2013. Financial Regulation and Nation State Crisis Management: Evidence from Germany, Ireland and The UK, ZenTra Working Paper in Transnational Studies No. 18/2013.
Fornaro, L., Wolf, M., 2020. Covid-19 Coronavirus and Macroeconomic Policy, CEPR Discussion Paper No. DP14529.
Forsyth, D.J., 2015. Financial Innovation, Regulation and Crises in History. Enterp. Soc. 16, 716–719.
Fratianni, M.U., Marchionne, F., 2009. Rescuing Banks From the Effects of the Financial Crisis, Available at SSRN 1476786.
Fratzscher, M., Konig, P.J., Lambert, C., 2016. Credit provision and banking stability after the great financial crisis: the role of bank regulation and the quality of governance. J. Int. Money Finance 66, 113–135.
Freedman, C., Kumhof, M., Laxton, D., Muir, D., Mursula, S., 2010. Global effects of fiscal stimulus during the crisis. J. Monet. Econ. 57, 506–526.
French, A., Vital, M., Minot, D., 2015. Insurance and financial stability. Bank Engl. Q. Bull. Q3.
Gajewski, P., 2014. Monetary Policy Stress in Emu During the Moderation and the Global Crisis. Faculty of Economics and Sociology of the University of Lodz.
Gal, J., Gründl, H., 2017. The Recalibration of the European System of Financial Supervision in Regard of the Insurance Sector: from Dreary to Dreamy or Vice Versa?, SAFE Policy Letter.
Galati, G., Moessner, R., 2013. Macroprudential policy – a literature review. J. Econ. Surv. 27, 846–878.
Garicano, L., Lastra, R.M., 2010. Towards a new architecture for financial stability: seven principles. J. Int. Econ. Law 13, 597–621.
Gärtner, M., Griesbach, B., 2017. Rating agencies, self-fulfilling prophecy and multiple equilibria? An empirical model of the European sovereign debt crisis 2009–2011. Bus. Econ. Res. 7, 199–226.
Gärtner, M., Griesbach, B., Jung, F., 2011. PIGS or lambs? The European sovereign debt crisis and the role of rating agencies. Int. Adv. Econ. Res. 17, 288.
Gatzert, N., Wesker, H., 2012. A comparative assessment of basel II/III and solvency II. Geneva Papers Risk Insur. – Issues Pract. 37, 539–570.
Gerard, D., 2009. Financial crisis remedies in the European union: balancing competition and regulation in the conditionality of bailout plans. The future of retail banking in Europe: competition and regulatory challenges. In: Jentzsch, N., Wey, Ch. (Eds.), ECRI/CEPS.
Gerding, E.F., 2009. Code, crash, and open source: the outsourcing of financial regulation to risk models and the global financial crisis. Wash. Law Rev. 84, 127–198.
Gersbach, H., Hahn, V., 2008. Forward Guidance for Monetary Policy: Is It Desirable?, Economics Working Paper Series 8.
Gertler, M., Karadi, P., 2011. A model of unconventional monetary policy. J. Monet. Econ. 58, 17–34.
Giani, L., 2010. The complementarity between financial supervision and crisis resolution: a gap in the EU framework at the time of the crisis. Law Financ. Mark. Rev. 4, 421–427.
Gibson, H.D., Hall, S.G., Tavlas, G.S., 2014. Fundamentally wrong: market pricing of sovereigns and the Greek financial crisis. J. Macroecon. 39, 405–419.
Gibson, H.D., Hall, S.G., Tavlas, G.S., 2016. The effectiveness of the ECB's asset purchase programs of 2009 to 2012. J. Macroecon. 47, 45–57.
Giordano, R., Pericoli, M., Tommasino, P., 2013. Pure or wake-up-call contagion? Another look at the emu sovereign debt crisis. Int. Finance 16, 131–160.
Glod, A., 2018. European sovereign and private debt crisis what should we learn? Acta Univ. Danubius. Œconomica 14.
Gokhale, J., Van Doren, P., 2009. Would a stricter fed policy and financial regulation have averted the financial crisis? Cato Policy Anal. Ser. 648.
Gomber, P., Nassauer, F., 2014. Neuordnung Der Finanzmärkte In Europa Durch MiFID II/MiFIR, SAFE White Paper.
Gómez-Puig, M., Sosvilla-Rivero, S., 2016. Causes and hazards of the euro area sovereign debt crisis: pure and fundamentals-based contagion. Econ. Model. 56, 133–147.
Goodhart, C.A., 2014. Lessons for monetary policy from the euro-area crisis. J. Macroecon. 39, 378–382.
Goodstadt, L.F., 2009. The Global Crisis: Fatal Decisions – Four Case Studies in Financial Regulation, HKIMR Working Paper No. 33/2009.
Gordon, J.N., Ringe, G., 2015. Bank Resolution in Europe: The Unfinished Agenda of Structural Reform. Oxford University Press, United Kingdom, pp. 500–523.
Gorton, G., Metrick, A., 2012a. Getting up to speed on the financial crisis: a one-weekend-reader's guide. J. Econ. Lit. 50, 128–150.
Gorton, G., Metrick, A., 2012b. Securitized banking and the run on repo. J. Financ. Econ. 104, 425–451.
Grammatikos, T., Vermeulen, R., 2012. Transmission of the financial and sovereign debt crises to the EMU: stock prices, CDS spreads and exchange rates. J. Int. Money Finance 31, 517–533.
Groenleer, M.L., Mijs, A., Ten Heuvelhof, E., Van Meeuwen, B., Van der Puil, J., 2014. Strategic Behaviour and Crisis-Driven Change in Regulation and Governance of the European Financial and Economic System: From Networks to Hybrids, Jerusalem Papers in Regulation & Governance Working Paper 63.
Gros, D., Alcidi, C., Giovannini, A., 2012. Central Banks in Times of Crisis: The FED Vs. The ECB, CEPS Policy Briefs.
Grosse, R., 2017. The global financial crisis – market misconduct and regulation from a behavioral view. Res. Int. Bus. Finance 41, 387–398.
Gualandri, E., Landi, A., Venturelli, V., 2009. Financial crisis and new dimensions of liquidity risk: rethinking prudential regulation and supervision. J. Money Invest. Bank., 25–42.
Guerreiro, D., 2014. Is the European debt crisis a mere balance of payments crisis? Econ. Model. 44, 50–56.
Hale, T., Petherick, A., Phillips, T., Webster, S., 2020. Variation in Government Responses to COVID-19. Blavatnik School Of Government, Working Paper 31.
Harnay, S., Scialom, L., 2016. The influence of the economic approaches to regulation on banking regulations: a short history of banking regulations. Camb. J. Econ. 40, 401–426.
Harrington, S.E., 2009. The financial crisis, systemic risk, and the future of insurance regulation. J. Risk Insur. 76, 785–819.
Haspolat, F.B., 2015. Analysis of moody's sovereign credit ratings: criticisms towards rating agencies are still valid? Proc. Econ. Finance 30, 283–293.
Hauptmeier, S., Sanchez-Fuentes, A.J., Schuknecht, L., 2011. Towards expenditure rules and fiscal sanity in the euro area. J. Policy Model. 33, 597–617.
Helleiner, E., Pagliari, S., 2009. Towards a new bretton woods? The first G20 leader summit and the regulation of global finance. New Polit. Econ. 14, 275–287.
Heynderickx, W., Cariboni, J., Petracco Giudici, M., 2016. Drivers Behind the Changes in European Banks' Capital Ratios: A Descriptive Analysis, JRC Working Papers in Economics and Finance.
Honkapohja, S., 2014. The euro area crisis: a view from the North. J. Macroecon. 39, 260–271.
Hopt, K.J., 2013. Corporate governance of banks and other financial institutions after the financial crisis. J. Corp. Law Stud. 13, 219–253.
Hoque, H., 2013. From the credit crisis to the sovereign debt crisis: determinants of share price performance of global banks. Int. Rev. Financ. Anal. 30, 334–350.
Hoque, H., Andriosopoulos, D., Andriosopoulos, K., Douady, R., 2015. Bank regulation, risk and return: evidence from the credit and sovereign debt crises. J. Bank. Finance 50, 455–474.
Höring, D., 2013. Will solvency II market risk requirements bite? The impact of solvency II on insurers' asset allocation. Geneva Papers Risk Insur. – Issues Pract. 38, 250–273.
Hoshi, T., 2011. Financial regulation: lessons from the recent financial crises. J. Econ. Lit. 49, 120–128.
Howarth, D., Quaglia, L., 2014. The steep road to European banking union: constructing the single resolution mechanism. J. Common Market Stud. 52, 125.
Howarth, D., Quaglia, L., 2015. The New Intergovernmentalism in Financial Regulation and European Banking Union, The New Intergovernmentalism: States and Supranational Actors in the Post-Maastricht Era 146.
Howarth, D., Spendzharova, A., 2019. Accountability in post-crisis eurozone governance: the tricky case of the European stability mechanism. J. Common Market Stud. 57, 894–911.
Hubert, P., Labondance, F., 2016. The Effect of Ecb Forward Guidance on Policy Expectations.
Huerta De Soto, J., 2009. The fatal error of solvency II. Econ. Aff. 29, 74–77.
Huertas, T.F., 2011. The Road to Better Resolution: From Bail-Out to Bail-in. The Euro Area and the Financial Crisis, pp. 243.
Hutchinson, J., Smets, F., 2017. Monetary policy in uncertain times: ECB monetary policy since June 2014. Manch. School 85, 1–15.
Ilgmann, C., Menner, M., 2011. Negative nominal interest rates: history and current proposals. Int. Econ. Econ. Policy 8, 383–405.
Inderst, R., 2009. Retail finance: thoughts on reshaping regulation and consumer protection after the financial crisis. Eur. Bus. Organ. Law Rev. 10, 455–464.
International Monetary Fund, 2010. Global Financial Stability Report: Sovereigns, Funding, and Systemic Liquidity.
Ioannou, S., Wójcik, D., Dymski, G., 2019. Too-Big-To-Fail: why megabanks have not become smaller since the global financial crisis? Rev. Polit. Econ. 31, 356–381.
Isebor, J.E., 2014. The future of international banking regulations in response to the financial crisis of 2007/2009: after basel III then what next? Risk Gov. Control: Financ. Mark. Inst. 4, 27–52.
Issing, O., 2014. Communication and transparency – the example of the ECB. J. Econ. Dyn. Control 49, 70–73.
Jeanne, O., Korinek, A., 2020. Macroprudential regulation versus mopping up after the crash. Rev. Econ. Stud. 87, 1470–1497.
Jones, E., Kelemen, R.D., Meunier, S., 2016. Failing forward? The euro crisis and the incomplete nature of European integration. Comparat. Polit. Stud. 49, 1010–1034.
Jones, O., 2014. Solvency II: the journey so far. In: Doff, R. (Ed.), Solvency II Handbook: Practical Approaches to Implementation. , pp. 7–26.
Jost, K., 2008. Financial Crisis: Did Lax Regulation Cause a Credit Meltdown?, vol. 18. Congressional Quarterly.

Kantor, B., Holdsworth, C., 2010. Lessons from the global financial crisis (or why capital structure is too important to be left to regulation). J. Appl. Corp. Finance 22, 112–122.
Kao, E.S., 2011. Moral hazard during the savings and loan crisis and the financial crisis of 2008–09: implications for reform and the regulation of systemic risk through disincentive structures to manage firm size and interconnectedness. N. Y. Univ. Annu. Surv. Am. Law 67, 817–862.
Karagounis, K., Syrrakos, D., Simister, J., 2015. The stability and growth pact, and balanced budget fiscal stimulus: evidence from Germany and Italy. Intereconomics 50, 32–39.
Kern, A., 2013. Bank Resolution and Recovery in the EU: Enhancing Banking Union? In: ERA Forum, vol. 14. Springer, pp. 81–93.
Kinateder, H., 2016. Basel II versus III: a comparative assessment of minimum capital requirements for internal model approaches. J. Risk 18.
Klusak, P., Alsakka, R., Ap Gwilym, O., 2019. The impact of ESMA regulatory identifiers on the quality of ratings. Int. Rev. Financ. Anal. 66.
Kodres, L., Narain, A., 2012. Fixing the system-after a burst of effort to reform financial regulation widely perceived as contributing to the global crisis, pace has slowed. Finance Dev. 49, 14.
Kollmann, R., Ratto, M., Roeger, W., et al., 2013. Fiscal policy, banks and the financial crisis. J. Econ. Dyn. Control 37, 387–403.
Konrath, N., 1996. Solvency of insurance undertakings and financial groups. Geneva Papers Risk Insur. – Issues Pract., 22–35.
Kravchuk, I., et al., 2017. Assets securitization in European financial scope. Account. Finance, 91–98.
Kroszner, R.S., Strahan, P.E., 2011. Financial regulatory reform: challenges ahead. Am. Econ. Rev. 101, 242–246.
Kroszner, R.S., Strahan, P.E., 2014. Regulation and Deregulation of the U.S. Banking Industry: Causes, Consequences, and Implications for the Future. University of Chicago Press, pp. 485–543.
Krug, S., Lengnick, M., Wohltmann, H.-W., 2015. The impact of basel III on financial (In) stability: an agent-based credit network approach. Quant. Finance 15, 1917–1932.
Krugman, P., 2009. How did economists get it so wrong? New York Times 2, 2009.
Kudrna, Z., 2016. Financial market regulation: crisis-induced supranationalization. J. Eur. Integr. 38, 251–264.
Laguna De Paz, J.C., 2019. Administrative and judicial review of Eu supervisory decisions in the banking sector. J. Bank. Regul. 20, 159–173.
Lander, G.H., Barker, K., Zabelina, M., Williams, T.A., 2009. Subprime mortgage tremors: an international issue. Int. Adv. Econ. Res. 15, 1–16.
Lane, P.R., 2012. The European sovereign debt crisis. J. Econ. Perspect. 26, 49–68.
Langevoort, D.C., 2010. Global securities regulation after the financial crisis. J. Int. Econ. Law 13, 799–815.
Lannoo, K., 2011. The EU's Response to the Financial Crisis: A Mid-Term Review, CEPS Policy Brief.
Lannoo, K., 2013. The New Financial Regulatory Paradigm: A Transatlantic Perspective, CEPS Policy Briefs.
Lau, L.J., 2010. Financial Regulation and Supervision Post the Global Financial Crisis, IGEF Working Paper No. 2.
Lee, K., Lu, W., 2015. Do bank regulation and supervision matter? International evidence from the recent financial crisis. J. Financ. Econ. Policy 7, 275–288.
Lemke, W., Vladu, A.L., 2016. Below the Zero Lower Bound: A Shadow-Rate Term Structure Model for the Euro Area, Deutsche Bundesbank Discussion Paper No. 32/2016.
Lener, R., 2013. The revision of the supervision of professionals operating in the banking, financial and insurance sector in the context of the financial market crisis. Rivista Bancaria-Minerva Bancaria 69, 63–84.
Leong, J., 2010. Combating Financial Crisis: Building Super-Structures of International Financial Regulation, Available at SSRN 1690537.
Levine, R., 2012. The governance of financial regulation: reform lessons from the recent crisis. Int. Rev. Finance 12, 39–56.
Liapis, K., 2012. The regulation framework for the banking sector: the EMU, European banks and rating agencies before and during the recent financial and debt crisis. Int. J. Discl. Gov. 9, 301–330.
Liou, K.T., 2013. The financial crisis and the challenge of government regulation. Public Perform. Manag. Rev. 37, 208–221.
Lodge, M., Wegrich, K., 2011. Arguing about financial regulation: comparing national discourses on the global financial crisis. PS: Polit. Sci. Polit. 44, 726–730.
London Working Group, 2002. Prudential supervision of insurance undertakings (Sharma Report). Conference Of Insurance Supervisory Services Of The Member States Of The EU.
Lorson, J., Schmeiser, H., Wagner, J., 2012. J. Insur. Regul. 31, 125–156.
Lothian, T., 2012. Beyond macroprudential regulation: three ways of thinking about financial crisis. Regul. Reform. Global Policy 3, 410–420.
Loukanari, A., Berardo, C., 2019. LIBOR and EU securitization changes. J. Struct. Finance 25, 40–46.
Lupo-Pasini, F., Buckley, R.P., 2015. Global systemic risk and international regulatory coordination: squaring sovereignty and financial stability. Am. Univ. Int. Law Rev. 30, 665.
Maddaloni, A., Scopelliti, A., 2019. Rules and Discretion(s) in Prudential Regulation and Supervision: Evidence From EU Banks in the Run-Up to the Crisis, ECB Working Paper.
Mah-Hui, M.L., 2008. Old wine in new bottles: subprime mortgage crisis-causes and consequences. J. Appl. Res. Account. Finance 3, 3–13.
Malkiel, B.G., 2011. The efficient-market hypothesis and the financial crisis. Rethinking Finance: Perspectives on the Crisis (Proceedings of a Conference).
Maşca, S.G., Cuceu, I.C., Văidean, V.L., 2015. The fiscal policy as growth engine in Eu countries. Proc. Econ. Finance 32, 1628–1637.
Masciandaro, D., 2010. Reforming regulation and supervision in Europe: five missing lessons from the financial crisis. Intereconomics 45, 293–296.
Masciandaro, D., Pansini, R.V., Quintyn, M., 2013. The economic crisis: did supervision architecture and governance matter? J. Financ. Stabil. 9, 578–596.
Masciandaro, D., Quintyn, M., 2010. The Architecture of Insurance Supervision Before and After the Financial Crisis, PaoloBaffi Centre Research Paper.
Masciandaro, D., Quintyn, M., 2016. The governance of financial supervision: recent developments. J. Econ. Surv. 30, 982–1006.
Masciandaro, D., Vega Pansini, R., Quintyn, M., 2011. The Economic Crisis: Did Financial Supervision Matter?, pp. 1–47, IMF Working Papers.
Masera, R., 2010. Reforming financial systems after the crisis: a comparison of EU and USA. PSL Q. Rev. 63, 297–360.
Masood, O., Aktan, B., Pariente, G., 2010. A discussion of financial regulations' impact on the subprime crisis: implications for financial markets. Int. J. Bus. 15, 51–69.
Mateus, A.M., 2009. After the Crisis: Reforming Financial Regulation, Revista Finanças Publicas e Direito Fiscal.
Mayntz, R., 2013. Financial Market Regulation in the Shadow of the Sovereign Debt Crisis, MPIfG Discussion Paper.
Mazumder, M.I., Ahmad, N., 2010. Greed, financial innovation or laxity of regulation? A close look into the 2007–2009 financial crisis and stock market volatility. Stud. Econ. Finance 27, 110–134.
McNulty, J.E., Garcia-Feijoo, L., Viale, A., 2019. The regulation of mortgage servicing: lessons from the financial crisis. Contemp. Econ. Policy 37, 170–180.
Meinusch, A., Tillmann, P., 2016. The macroeconomic impact of unconventional monetary policy shocks. J. Macroecon. 47, 58–67.
Melecky, M., Podpiera, A.M., 2015. Placing Bank Supervision in the Central Bank: Implications for Financial Stability Based on Evidence from the Global Crisis. The World Bank.
Mertzanis, H., 2010. The financial crisis and the future of European financial supervision structures. J. Financ. Transform., 137–148.
Micossi, S., Bruzzone, G., Carmassi, J., 2013. The New European Framework for Managing Bank Crises, CEPS Policy Briefs.
Miele, M.G., Sales, E., 2011. The financial crisis and regulation reform. J. Bank. Regul. 12, 277–307.
Mihai Yiannaki, S., 2009. Regulatory failure and the subprime credit crunch-the importance of Basel Ii regulation/supervision. Icfai Univ. J. Bank. Law 2.
Mittnik, S., 2016. Solvency II Calibrations: Where Curiosity Meets Spuriosity, Preprints.
Monkiewicz, J., 2013. Dialectics of the current regulatory and supervisory developments in insurance. Geneva Papers Risk Insur. 38, 183.
Monnet, É., Pagliari, S., Vallée, S., 2019. Beyond Financial Repression and Regulatory Capture: The Recomposition of European Financial Ecosystems After the Crisis, LEQS Paper No. 147/2019.
Montalbano, G., 2015. Geopolitical economy and competing capitalist blocs in the EU post-crisis financial regulation: two cases from the reform of the banking sector. World Rev. Polit. Econ. 6, 498–521.
Morais, L.S., Feteira, L.T., 2018. All's well that ends well? Abuse regulation in the wake of the financial crisis: the interplay between regulation and the application of competition law to the financial sector. In: Abusive Practices in Competition Law. Edward Elgar Publishing, pp. 109–128.
Moshirian, F., 2011. The global financial crisis and the evolution of Mark. Inst. Regul. J. Bank. Finance 35, 502–511.
Murgescu, D.M., 2011. The influence of the economic crisis on EU financial regulations changes. Ann. 'Dunarea De Jos' Univ. Galati: Fascicle 1: Econ. Appl. Inform. 17, 91–94.
Murphy, D., 2020. Our Lessons Have Returned: Insights into Post-Crisis Financial Regulation from Mandatory OTC Derivatives Clearing Policy, LSE Legal Studies Working Paper No. 6/2020.
Næss-Schmidt, S., Bjarke, J., Ehmann, H., Christiansen, B., 2019. EU Implementation of the Final Basel Iii Framework – Impact on the Naking Market and the Real Economy. Copenhagen Economics.
Nakov, A., et al., 2008. Optimal and simple monetary policy rules with zero floor on the nominal interest rate. Int. J. Central Bank. 4, 73–127.
Negrilˇa, A., 2009. The implementation of systemic risk management and the reinforcing of macro-prudential supervision – vital elements in avoiding the future occurrence of a financial crisis similar to the present one. Theor. Appl. Econ. 16, 17–30.
Noeth, B.J., Sengupta, R., 2011. Is shadow banking really banking? Reg. Econ. 10, 8–13.
Nolle, D.E., 2012. Global financial system reform: the dodd-frank act and the G20 agenda. J. Financ. Econ. Policy 4, 160–197.
Nouy, D., 2012. Is sovereign risk properly addressed by financial regulation? Banque France Financ. Stabil. Rev. 16, 95–106.
Nyborg, K.G., 2008. Bank Supervision After the Financial Crisis: Signals from the Market for Liquidity, NHH Department of Business and Management Science Discussion Paper 2015/14.
Obstfeld, M., Rogoff, K., 2009. Global Imbalances and the Financial Crisis: Products of Common Causes, CEPR Discussion Paper No. DP7606.
Ojo, M., 2011. The changing role of central banks and the role of competition in financial regulation during (And in the aftermath of) the financial crisis. Eur. Law J. 17, 513–533.

Ojo, M., 2013. Capital, Liquidity Standards and Macro Prudential Policy Tools in Financial Supervision: Addressing Sovereign Debt Problems, MPRA Paper.
Ojo, M., 2016. Redefining a Role for Central Banks: The Increased Importance of Central Banks' Roles in the Management of Liquidity Risks and Macro Prudential Supervision in the Aftermath of the Financial Crisis, Munich Personal RePEc Archive Paper No. 70905.
Oliveira, V.B., Raposo, C., 2020. How did regulation and market discipline influence banking distress in Europe? Lessons from the global financial crisis. Stud. Econ. Finance 37, 160–198.
Omarova, S.T., 2011. The dodd-frank act: a new deal for a new age. N. C. Bank. Inst. 15, 83.
Omarova, S.T., 2012. Bankers, bureaucrats, and guardians: toward tripartism in financial services regulation. J. Corp. Law 37.
Ongena, S., Popov, A., Udell, G.F., 2013. "When the cat's away the mice will play": does regulation at home affect bank risk-taking abroad? J. Financ. Econ. 108, 727–750.
Oreiro, J.L., 2013. Some notes on "The evolution of financial regulation before and after the crisis". Rev. Econ. 15, 51–54.
Overbeek, H., 2012. Sovereign debt crisis in euroland: root causes and implications for European integration. Int. Spect. 47, 30–48.
Pacces, A.M., 2010. Consequences of uncertainty for regulation: law and economics of the financial crisis. Eur. Company Financ. Law Rev. 7, 479–511.
Page, R.T., 2010. Foolish revenge or shrewd regulation? Financial-industry tax law reforms proposed in the wake of the financial crisis. Tulane Law Rev. 85, 191–214.
Pagliari, S., 2013. A wall around Europe? The European regulatory response to the global financial crisis and the turn in transatlantic relations. J. Eur. Integr. 35, 391–408.
Paltalidis, N., Gounopoulos, D., Kizys, R., Koutelidakis, Y., 2015. Transmission channels of systemic risk and contagion in The European financial network. J. Bank. Finance 61, 36–52.
Palvia, A.A., Patro, D.K., 2011. Re-Examining the Role of Market Discipline for Bank Supervision: Evidence From the Subprime Crisis, Available at SSRN 1593031.
Panico, C., Pinto, A., Puchet Anyul, M., Vazquez Suarez, M., 2013. The evolution of financial regulation before and after the crisis. Rev. Econ. 15, 9–40.
Papadopoulos, S., Stavroulias, P., Sager, T., 2019. Systemic early warning systems for EU14 based on the 2008 crisis: proposed estimation and model assessment for classification forecasting. J. Bank. Regul. 20, 226–244.
Papadopoulos, T., 2015. European System of Financial Supervision. Max Planck Encyclopedia of Public International Law.
Papaikonomou, V.L., 2010. Credit rating agencies and global financial crisis: need for a paradigm shift in financial market regulation. Stud. Econ. Finance 27, 161–174.
Park, K.H., 2015. Lessons and implications from the European sovereign debt crisis. J. Finance Econ. 3, 72–88.
Paudyn, B., 2013. Credit rating agencies and the sovereign debt crisis: performing the politics of creditworthiness through risk and uncertainty. Rev. Int. Polit. Econ. 20, 788–818.
Pavlat, V., 2009. Financial stability, world financial crisis and financial markets' regulation: some new issues. Econ. Stud. Anal./Acta VSFS 3, 48–61.
Peihani, M., 2015. The basel committee on banking supervision: a post-crisis assessment of governance and accountability. Can. Foreign Policy J. 21, 146–163.
Peleckienėa, V., Peleckisa, K., 2014. Omnibus II effective measures in adjusting the current solvency II framework. Proc. – Soc. Behav. Sci. 110, 156–163.
Pelkiewicz, A.J., Ahmed, S.W., Fulcher, P., Johnson, K.L., Reynolds, S.M., Schneider, R.J., Scott, A.J., 2020. A review of the risk margin – solvency II and beyond. Br. Actuar. J. 25.
Peretz, P., Schroedel, J.R., 2009. PAR symposium on the financial crisis: financial regulation in the United States: lessons from history. Public Adm. Rev. 69, 603–612.
Philipponnat, T., 2019. How Can Safer Banks Hurt the Eu Economy? A Critical Analysis of the Report on the EU Implementation of the Final Basel III Framework by Copenhagen Economics for the European Banking Federation, Finance Watch.
Pino, G., Sharma, S.C., 2019. On the contagion effect in the US banking sector. J. Money Credit Bank. 51, 261–280.
Pistor, K., 2010. Host's Dilemma: Rethinking Eu Banking Regulation in Light of the Global Crisis. Columbia Law and Economics, Working Paper No. 378.
Pooran, P.N., 2009. Macro-prudential supervision – a panacea for the global financial crisis? Law Financ. Mark. Rev. 3, 534–538.
Posner, E., Véron, N., 2010. The EU and financial regulation: power without purpose? J. Eur. Public Policy 17, 400–415.
Pradier, P.C., Chneiweiss, A., 2017. The evolution of insurance regulation in the Eu since 2005. In: Financial Regulation in the EU. Springer, pp. 199–251.
Prisecaru, P., 2014. Banking union – an European project with certain success prospects. Proc. Econ. Finance 8, 582–589.
Pronobis, M., 2014. Is monetary policy of ECB the right response to the eurozone crisis? Proc. – Soc. Behav. Sci. 156, 398–403.
Prorokowski, L., 2015. MiFID II Compliance – are we ready? J. Financ. Regul. Compliance 23.
Quaglia, L., 2013. Financial regulation and supervision in the European union after the crisis. J. Econ. Policy Reform 16, 17–30.
Quaglia, L., 2015. The politics of 'Third country equivalence' in post-crisis financial services regulation in the European union. West Eur. Polit. 38, 167–184.
Quaglia, L., Spendzharova, A., 2018. The Challenges of Multi-Level Coordination In Post-Crisis Banking Regulation, CERiM Online Paper.
Rae, R.A., Barrett, A., Brooks, D., Chotai, M.A., Pelkiewicz, A.J., Wang, C., 2018. A review of solvency II: has it met its objectives? Br. Actuar. J. 23.
Ramos-Francia, M., Aguilar-Argaez, A.M., García-Verdú, S., Cuadra, G., 2014. Heading Into Trouble: A Comparison Of The Latin American Crises And The Euro Area's Current Crisis, Working Papers.
Rannou, Y., 2010. Banking regulation, behavioural finance and the financial crisis in Europe: looking to the kindleberger-minsky paradigm. J. Risk Manag. Financ. Inst. 3, 278–295.
Reichlin, L., 2014. Monetary policy and banks in the euro area: the tale of two crises. J. Macroecon. 39, 387–400.
Reinhart, C.M., Rogoff, K.S., 2010. Growth in a time of debt. Am. Econ. Rev. 100, 573–578.
Reinhart, C.M., Rogoff, K.S., 2011. From financial crash to debt crisis. Am. Econ. Rev. 101, 1676–1706.
Rex, J., 2018. Scoundrel or scapegoat? A reassessment of the office of thrift supervision's performance before the 2008 financial crisis. Adm. Soc. 50, 1396–1421.
Riccetti, L., Russo, A., Gallegati, M., 2018. Financial regulation and endogenous macroeconomic crises. Macroecon. Dyn. 22, 896–930.
Ringe, W.-G., Morais, L.S., Ramos Muñoz, D., 2019. A Holistic Approach To The Institutional Architecture Of Financial Supervision And Regulation In The EU. European Banking Institute, Working Paper Series.
Rixen, T., 2013. Why reregulation after the crisis is feeble: shadow banking. Offshore Financ. Centers Jurisd. Compet. Regul. Gov. 7, 435–459.
Roman, A., Bilan, I., 2012. The euro area sovereign debt crisis and the role of ECB's monetary policy. Proc. Econ. Finance 3, 763–768.
Roncaglia, A., 2010. Confronting the financial crisis: surveillance and regulation. PSL Q. Rev. 63, 293–296.
Rose, A.K., Spiegel, M.M., 2012. Cross-country causes and consequences of the 2008 crisis: early warning. Jpn. World Econ. 24, 1–16.
Rostagno, M., Bindseil, U., Kamps, A., Lemke, W., Sugo, T., Vlassopoulos, T., 2016. Breaking Through The Zero Line: The Ecb'S Negative Interest Rate Policy, Presentation at Brookings.
Rötheli, T.F., 2010. Causes of the financial crisis: risk misperception, policy mistakes, and banks' bounded rationality. J. Socio-Econ. 39, 119–126.
Rubio, M., Carrasco-Gallego, J.A., 2016. The new financial regulation in basel III and monetary policy: a macroprudential approach. J. Financ. Stabil. 26, 294–305.
Ruppel, C.C., 2009. Dimensions of the global financial crisis: the future of corporate governance and regulation. Int. J. Regul. Gov. 9, 71–98.
Ruščáková, A., Semančíková, J., 2016. The European debt crisis: a brief discussion of its causes and possible solutions. Proc. – Soc. Behav. Sci. 220, 399–406.
Sarcinelli, M., 2010. Past and future regulation to prevent a systemic financial crisis. PSL Q. Rev. 63, 101–127.
Schaeken Willemaers, G., 2014. Client Protection On European Financial Markets-From Inform Your Client To Know Your Product And Beyond: An Assessment Of The PRIIPs Regulation, MiFID II/MiFIR And IMD 2, Revue Trimestrielle De Droit Financier.
Schich, S., 2010. Insurance companies and the financial crisis. OECD J.: Financ. Market Trends 2009, 123–151.
Schuckmann, S., 2007. The Impact Of Solvency II On Insurance Market Competition – An Economic Assessment. Universidad De St. Gallen, St. Gallen, Suiza, 58.
Schuster, R.T., 2012. Sacrificing functionality for transparency: the regulation of swap agreements in the wake of the financial crisis. Syracuse Law Rev. 62, 385–404.
Schwarcz, S.L., 2015. Securitization and post-crisis financial regulation. Cornell Law Rev. 101, 115–139.
Schwerter, S., 2011. Basel III's ability to mitigate systemic risk. J. Financ. Regul. Compliance 19.
Sgherri, S., Zoli, E., 2009. Euro Area Sovereign Risk During The Crisis: "European Department". International Monetary Fund, European Department.
Siegel, J.J., 2009. Efficient market theory and the recent financial crisis. Wall Street J., A23.
Simoneti, M., 2010. Bankers' pay and the financial crisis: policy debate and new regulation. Bančni Vestnik 59, 55–65.
Sironi, A., 2018. The Evolution Of Banking Regulation Since The Financial Crisis: A Critical Assessment. Baffi Carefin Centre, Research Paper.
Sklias, P., Roukanas, S., Maris, G., 2014. Keynes and the Eurozone's crisis: towards a fiscal union? Proc. Econ. Finance 9, 66–73.
Slattery, D., Nellis, J.G., 2011. Rethinking the role of regulation in the aftermath of the global financial crisis: the case of the UK. Panoeconomicus 58, 407–423.
Sohn, W., Vyshnevskyi, I., 2017. The 'Twin Peaks' model of post-crisis banking supervision. Appl. Econ. Lett. 24, 571–574.
S&P Dow Jones Indices LLC, 2019. S&P/Case-Shiller U.S. National Home Price Index [CSUSHPINSA]. https://fred.stlouisfed.org/series/CSUSHPINSA.
Staikouras, P., Triantopoulos, C., 2016. Financial supervision after the crisis: the structures, the lessons, and the way forward. Eur. Bus. Law Rev. 27, 85–135.
Stellinga, B., 2020. The open-endedness of macroprudential policy. Endogenous risks as an obstacle to countercyclical financial regulation. Bus. Polit. 22, 224–251.
Suarez, J., 2010. The pending challenges in global financial regulation reform: liquidity insurance for systemic crises. Margin: J. Appl. Econ. Res. 4, 241–253.
Swain, R., Swallow, D., 2015. The Prudential Regulation Of Insurers Under Solvency II. Bank of England Quarterly Bulletin Q2.

Swamy, V., 2014. Bank Regulation, Supervision And Efficiency During The Global Financial Crisis, Available at SSRN: 2491413.
Swanson, E.T., 2017. Measuring The Effects Of Federal Reserve Forward Guidance And Asset Purchases On Financial Markets, National Bureau of Economic Research No. 23311.
Tanasie, A., Netoiu, L., Cîrciumaru, D., Netoiu, T., 2015. European Union's post crisis financial regulatory system – a brief analysis of existing options. Proc. Econ. Finance 22, 552–559.
Tarullo, D.K., 2019. Financial regulation: still unsettled a decade after the crisis. J. Econ. Perspect. 33, 61–80.
Taskinsoy, J., 2019. Higher Capital And Liquidity Regulations Of Basel Standards Have Made Banks And Banking Systems Become More Prone To Financial And Economic Crises, Available at SSRN 3401378.
Taylor, J.B., 2009a. Economic policy and the financial crisis: an empirical analysis of what went wrong. Crit. Rev. 21, 341–364.
Taylor, J.B., 2009b. How government created the financial crisis. Wall Street J. 9, A19.
Teixeira, J.C., Silva, F.J., Fernandes, A.V., Alves, A.C., 2014. Banks' capital, regulation and the financial crisis. N. Am. J. Econ. Finance 28, 33–58.
Thalassinos, E., Thalassinos, Y., 2018. How To Avoid Financial Crises. In: Al-Sharhan, S.A., Simintiras, A.C., Dwivedi, Y.K., Janssen, M., Mäntymäki, M., Tahat, L., Moughrabi, I., Ali, T.M., Rana, N.P. (Eds.), Challenges And Opportunities In The Digital Era. Springer International Publishing, Cham, pp. 232–243.
Thiemann, M., Birk, M., Friedrich, J., 2018. Much ado about nothing? Macro-prudential ideas and the post-crisis regulation of shadow banking. KZfSS Kölner Zeitschrift für Soziologie und Sozialpsychologie 70, 259–286.
Toarna, A., Cojanu, V., 2015. The 2008 crisis: causes and future direction for the academic research. Proc. Econ. Finance 27, 385–393.
Trabelsi, M.A., 2012. The impact of the sovereign debt crisis on the eurozone countries. Proc. – Soc. Behav. Sci. 62, 424–430.
Trichet, J.-C., 2005. Financial stability and the insurance sector. Geneva Papers Risk Insur. – Issues Pract. 30, 65–71.
Tröger, T.H., 2018. Too complex to work: a critical assessment of the bail-in tool under the european bank recovery and resolution regime. J. Financ. Regul. 4, 35–72.
Tröger, T.H., 2020. Why MREL won't help much: minimum requirements for bail-in capital as an insufficient remedy for defunct private sector involvement under the european bank resolution framework. J. Bank. Regul. 21, 64–81.
Tropeano, D., 2011. Financial regulation after the crisis: where do we stand? Int. J. Polit. Econ. 40, 45–60.
Turk, M.C., 2014. Reframing international financial regulation after the global financial crisis: regional states and interdependence, not regulatory networks and soft law. Michigan J. Int. Law 36, 59–128.
Turk, R., 2016. Negative Interest Rates: How Big A Challenge For Large Danish And Swedish Banks? International Monetary Fund.
Ulrich, F., 2011. Fiscal Stimulus, Financial Ruin. Institutions In Crisis: European Perspectives On The Recession., pp. 142–163.
Umlauft, T.S., 2015. Regulators' irrational rationality and bankers' rational irrationality: too big to fail, self-regulation, moral hazard and the global financial crisis, 2007–2009. Aust. J. Hist. Stud. 26, 21–45.
Ureche-Rangau, L., Burietz, A., 2013. One crisis, two cris. The subprime crisis and the European sovereign debt problems. Econ. Model. 35, 35–44.
US-Congress, 2008. H.R. 5149 (110th): Economic Stimulus Act Of 2008.
US-Congress, 2009. H.R. 1 (111th): American Recovery And Reinvestment Act Of 2009.
Utzig, S., 2010. The Financial Crisis And The Regulation Of Credit Rating Agencies: A European Banking Perspective, ADBI Working Paper No. 188.
Van Hulle, K., 2011. Solvency II: state of play and perspectives. Zeitschrift für die gesamte Versicherungswissenschaft 100, 177–192.
Vaughan, T.M., 2009. The economic crisis and lessons from (and for) US insurance regulation. J. Insur. Regul. 28, 3–18.
Velinov, A., 2015. Assessing fiscal-policy sustainability: on the different states of the Debt-To-GDP process. Finanz-Archiv: Zeitschrift für das Gesamte Finanzwesen 71, 415.
Véron, N., 2014. The G20 Financial Reform Agenda After Five Years. Bruegel Policy Contribution.
Véron, N., Wolff, G.B., 2013. From Supervision To Resolution: Next Steps On The Road To European Banking Union. Bruegel Policy Contribution.
Verret, J.W., 2009. Unintended Consequences Of Executive Compensation Regulation Threatens To Worsen The Financial Crisis, George Mason Law & Economics Research Paper 09-34.
Von Bomhard, N., 2010. The advantages of a global solvency standard. Geneva Papers Risk Insur. – Issues Pract. 35, 79–91.
Waelti, S., 2015. Financial crisis begets financial reform? The origin of the crisis matters. Eur. J. Polit. Econ. 40, 1–15.
Wallison, P.J., 2009. Cause and effect: government policies and the financial crisis. Crit. Rev. 21, 365–376.
Walter, J.R., 2019. US bank capital regulation: history and changes since the financial crisis. Econ. Q., 1–40.
Webel, B., Murphy, E.V., 2008. The Emergency Economic Stabilization Act And Current Financial Turmoil: Issues And Analysis, CRS Report for Congress.
Weber, R.F., 2010. New governance, financial regulation, and challenges to legitimacy: the example of the internal models approach to capital adequacy regulation. Adm. Law Rev., 783–869.
Wegener, C., Kruse, R., Basse, T., 2019. The walking debt crisis. J. Econ. Behav. Organ. 157, 382–402.
Welfens, P.J., 2008. Banking crisis and prudential supervision: a european perspective. Int. Econ. Econ. Policy 4, 347–356.
Werkmeister, W., 2010. Financial crisis 101: a beginner's guide to structured finance, the financial crisis, and capital market regulation. Harv. Kennedy School Rev. 10, 92–98.
Werner, R.A., 2014. Enhanced debt management: solving the eurozone crisis by linking debt management with fiscal and monetary policy. J. Int. Money Finance 49, 443–469.
White, L.H., 2008. How Did We Get Into This Financial Mess?, Cato Institute Briefing Papers No. 110.
White, L.J., 2009a. Financial Regulation And The Current Crisis: A Guide For The Antitrust Community, Available at SSRN 1426188.
White, L.J., 2009b. The credit-rating agencies and the subprime debacle. Crit. Rev. 21, 389–399.
White, W.R., 2014. The Prudential Regulation Of Financial Institutions: Why Regulatory Responses To The Crisis Might Not Prove Sufficient, OECD Economics Department Working Papers 1108.
Wigger, A., Buch-Hansen, H., 2014. Explaining (missing) regulatory paradigm shifts: eu competition regulation in times of economic crisis. New Polit. Econ. 19, 113–137.
Wilson, D.J., 2012. Fiscal spending jobs multipliers: evidence from the 2009 American recovery and reinvestment act. Am. Econ. J.: Econ. Policy 4, 251–282.
Wüthrich, M.V., 2011. An academic view on the illiquidity premium and market-consistent valuation in insurance. Eur. Actuar. J. 1, 93–105.
Yadav, Y., 2010. Specter of sisyphus: re-making international financial regulation after the global financial crisis. Emory Int. Law Rev. 24, 83–118.
Yellen, J.L., 2011. Macroprudential supervision and monetary policy in the post-crisis world. Bus. Econ. 46, 3–12.
Yeoh, P., 2019. MiFID II key concerns. J. Financ. Regul. Compliance 27, 110–123.
Young, K.L., Park, S.H., 2013. Regulatory opportunism: cross-national patterns in national banking regulatory responses following the global financial crisis. Public Adm. 91, 561–581.
Yurtsever, Ş., 2011. Investigating the recovery strategies of European union from the global financial crisis. Proc. – Soc. Behav. Sci. 24, 687–695.
Zamorski, M.J., Lee, M., 2015. Enhancing Bank Supervision in Asia: Lessons Learned from the Financial Crisis. Asian Development Bank Economics, Working Paper Series 443.
Zapodeanu, D., Ioan, C., Cojocari, A., Sebastian, M., 2010. New international financial regulation: necessity or required by crisis. Ann. Univ. Oradea: Econ. Sci. Ser. 19, 456–461.

Module 4

Early Warning Indicator Systems for Real Estate Investments: Empirical Evidence and some Thoughts from the Perspective of Financial Risk Management

Rodriguez Gonzalez, M. / Basse, T. / Kunze, F. / Vornholz, G. (2018)

Published in:
Zeitschrift für die gesamte Versicherungswissenschaft, Vol. 107, No. 4, pp. 387–403. DOI: https://doi.org/10.1007/s12297-018-0426-1.

ZVersWiss (2018) 107:387–403
https://doi.org/10.1007/s12297-018-0426-1

ABHANDLUNG

Early warning indicator systems for real estate investments: Empirical evidence and some thoughts from the perspective of financial risk management

Miguel Rodriguez Gonzalez · Tobias Basse · Frederik Kunze · Günter Vornholz

Published online: 2 January 2019

Abstract In recent years, early warning indicators and real estate—as an increasingly relevant asset class—have received more and more attention in German insurers' investment strategies. Therefore, this paper examines the relationship of real estate sentiment data as leading indicators for housing activity and house price indices. However, we focus on empirical evidence from the US due to the quite limited data availability in Germany. The National Association of Home Builders (NAHB) housing market index is used as an indicator for US real estate prices and other variables related to housing activity and the S&P/Case-Shiller 20 city home price index for house prices in the US. In order to test for Granger causality among US house prices and the NAHB sentiment indictor we employ a modified Wald test based on Toda and Yamamoto (1995) examining an augmented vector autoregressive (VAR) model in levels. The results of our empirical investigations do show that there are clear signs for unidirectional Granger causality running from the NAHB housing market index to the S&P/Case-Shiller index. Therefore, the NAHB data seem to be quite helpful predicting US house prices. This empirical finding is of high relevance with regard to the construction of early warning indicator systems for real estate prices.

M. Rodriguez Gonzalez (✉)
Insitute for Risk & Insurance, Gottfried Wilhelm Leibniz University,
Otto-Brenner-Straße 1, 30159 Hannover, Germany
E-Mail: mr@ivbl.uni-hannover.de

T. Basse · F. Kunze
Norddeutsche Landesbank Girozentrale, Friedrichswall 10, 30159 Hannover, Germany

T. Basse
Touro College Berlin, Am Rupenhorn 5, 14055 Berlin, Germany

G. Vornholz
Deutsche Hypothekenbank, Osterstraße 31, 30159 Hannover, Germany

EBZ Business School, Springorumallee 20, 44795 Bochum, Germany

Zusammenfassung Frühwarnindikatoren und Immobilien — als zunehmend relevantere Anlageklasse — haben in den letzten Jahren immer mehr Beachtung in den Anlagestrategien deutscher Versicherer gefunden. Daher untersucht dieser Artikel die Beziehung zwischen Immobilienmarktstimmungsdaten als Frühindikator für Immobilienaktivität und Immobilienpreisindizes. Aufgrund der eingeschränkten Datenverfügbarkeit in Deutschland beschränkt sich diese Analyse dabei auf eine empirische Untersuchung der USA: Der Immobilienmarktindex der National Association of Home Builders (NAHB) wird als Indikator für US-Immobilienpreise und andere mit der Wohnaktivität zusammenhängende Variablen verwendet, sowie der S&P/Case-Shiller Home Price Index für Preisentwicklungen am US-Immobilienmarkt. Um die Granger-Kausalität zwischen den US-amerikanischen Hauspreisen und dem NAHB-Sentimentindikator zu testen, verwenden wir einen modifizierten Wald-Test, basierend auf Toda und Yamamoto (1995), und untersuchen ein erweitertes vektorautoregressives Modell (VAR) in Levels. Die Ergebnisse unserer empirischen Untersuchungen finden eindeutige Hinweise auf unidirektional verlaufende Granger-Kausalität vom NAHB-Immobilienmarktindex zum S&P/Case-Shiller-Index. Daher scheinen die NAHB-Daten bei der Vorhersage der US-Immobilienpreise recht hilfreich zu sein. Diese empirische Feststellung ist somit für die Konstruktion von Frühwarnindikatorsystemen für Immobilienpreise von großer Bedeutung.

1 Introduction

The new Solvency II rules have fundamentally changed the regulatory framework and the supervisory structure of the insurance industry in the European Union (see, for example, Eling et al. 2007 and Doff 2008). Without any doubt, the implementation of Solvency II has had major consequences in the risk management processes in the European insurance industry (see, for example, Eling and Schmeiser 2010 and Gatzert and Martin 2012). Most importantly, Eling and Schmeiser (2010) have stressed that Solvency I I focuses on an enterprise risk management approach that is guided by a principle-based regulatory framework. The implementation of Solvency I I especially has had important consequences for the risk management processes in the asset allocation context, which forces insurers to focus more strongly on asset liability management issues (see, for example, Basse et al. 2007; Basse and Friedrich 2008 and Heinrich and Wurstbauer 2018). This has been a very important development. In fact, the current macroeconomic environment, which has led to low interest rates, has been a challenge for the European insurance industry (see, for example, Linderkamp et al. 2013 and Basse et al. 2014). Without the stronger focus on interest rate risk, that has been a direct consequence of the implementation of Solvency II, German life insurers for example, would now have to cope with even more difficulties. Eling and Schmeiser (2010) have discussed new challenges for insurance regulation and risk management that have surfaced after the global financial crisis. They have argued convincingly that risk managers in insurance companies have to be proactive. In recent years, early warning indicators have received more and more attention in the insurance industry (most importantly, see Romeike 2003). This paper tries to focus on one specific asset class that is of some importance for

the European insurers (namely real estate). As will be discussed below, real estate investments are relevant for the life insurance industry. Or, put somewhat differently, as institutional investors German life insurers belong to the most important players in this segment.

The paper is structured as follows: The 2nd paragraph discusses the role of early warning indicators in modern risk management systems. In the 3rd paragraph the asset allocation approaches of insurers in the Solvency II environment are examined focusing on real estate investment. The 4th paragraph briefly analyzes the development of real estate prices in Germany. Before concluding in the 6th paragraph, the 5th paragraph discusses practical aspects of the construction of an early warning indicator system for real estate investments that is based on survey results examining data from the US.

2 The role of early warning indicators in modern risk management systems

Dealing with the uncertainty of future outcomes belongs to the most challenging tasks of managerial decision makers. More specifically, risk managers have to combine different disciplines (e. g. probability theory, decision theory or behavioral science) to manage this inter temporal uncertainty (see Bannister and Bawcutt 1981). Bromiley et al. (2015) more recently, explicitly emphasized the temporal dynamics of risk. Hence, economic institutions with a strong risk culture are forward-looking (see Rochette 2009). Due to the business model inherent risk taking of financial institutions risk management is of very high importance in the financial services industry (see, for example, Carey 2001).

Following this line of thought, with regards to the inter-temporal component of risk as well as the statements above focusing on the insurance industry it has to be argued, that together with forecasting leading indicators as well as early warning indicators are highly relevant risk management tools in the life insurance industry. As a matter of fact, within the Solvency II's second pillar regulatory authorities demand a forward-looking self-assessment with regards to the own risks (see, for example, Lindberg and Seifert 2015). The global financial crisis did demonstrate quite impressively the negative impact of crisis events of financial institutions. Furthermore, as regards to European banks, financial institutions may also become a source of risk for global financial markets in general (see, for example, Black et al. 2016). In this regard, potential interdependencies between the banking and the insurance sector have to also be considered by risk managers (see, for example, Bernoth and Pick 2011, who mentioned the necessity to investigate linkages between banks and insurance companies). This is only one reason, why risk managers in the insurance sector should focus on financial crisis events in general and on downturn in the real estate cycle in particular and potential early warning indicators in this regard.

Foresight regarding economic respectively financial events especially in a crisis context has received attention from academic researchers, financial market practitioners as well as policy decision makers for decades (see for example Frankel and Rose 1996; Kaminsky et al. 1998; Demirguc-Kunt and Detragiache 1998 and Man-

asse et al. 2003). Recent studies did focus on the foresight regarding the banking crises. For example, Betz et al. (2014) investigated the vulnerabilities which may lead to a distress in European banks. Lainà et al. (2015) examined leading indicators of systemic banking crises. As a matter of fact, literature explicitly focusing on the insurance sector is rather scarce. Having said that, the insurance sector has to also be seen as a source of systemic risk (see, for example, Harrington 2009 as well Cummins and Weiss 2014). At an early stage, Heathcotte and Apilado (1974) investigated the predictive content of economic leading indicators for stock prices. In addition to that, the effort has been put into research dealing with leading indicators as well as early warning signals seems to be higher just after a crisis struck. For example, following the Mexican crisis in December 1994 and the Asian Crisis 1997/98 early warning systems gained much attention (see for example Berg et al. 2005). The same holds for the global financial crisis. As, for example, Frankel and Saravelos (2012) stressed the fact that the global financial crisis 2008/09 did lead to a renewed interest in early warning indicators. Given the severe economic consequences of the global financial crisis 2008/09 and the following European Debt crisis functioning early warning signals respectively lead indicators might have reduced the economic welfare cost substantially (see for example Ghosh et al. 2009). In addition to that, Dawood et al. (2017) have mentioned recently, that the global financial crisis forced governments especially in the major advanced economies to bail out and recapitalize financial institutions, which inter alia resulted in large fiscal deficits. Hence, providing decision makers with some kind of early warning sign could in fact be seen as beneficiary. Following Dawood et al. (2017) early warning indicators could have helped to avert or at least mitigate the costs resulting from economic respectively financial crises.

Within the literature there exists a huge variety of applied leading and early warning indicators. For early warning models three main ingredients are needed. Firstly, a crisis definition is needed. For example, Frankel and Saravelos (2012) focused on currency movements, equity returns and real economic indicators (i. e. GDP growth and industrial production). Secondly, and most important to the context of this paper, potential explanatory indicator variables must be identified and tested for predictive content. Not surprisingly, the indicators investigated are numerous as well. Frankel and Saravelos (2012) also gave a comprehensive overview regarding early warning indicators. Finally, the methodology through which those indicators are modeled has to be defined and applied (see for example, Chamon and Crowe 2013 as well as Hermansen and Röhn 2015).

In the context of early warning systems financial variables and their relationship to real economic variables have gained much attention by researchers (see for example Coudert and Gex 2008; Hatzius et al. 2010; Aizenman et al. 2013, and more recently Bleaney et al. 2016). Following for example Estrella and Mishkin (1998), one clear advantage of financial time series stems from the fact that a quick look at financial variable might already be an indication for looming economic or financial challenges. Estrella and Mishkin (1998) mentioned inter alia spreads between interest rates of different maturities. In addition to that, following the authors, stock prices are useful indicators since they incorporate both views regarding future profits and interest rates. As macroeconomic time series, monetary aggregates (see for example Edison

2003 as well as Kliesen et al. 2012) do also have predictive content. Not surprisingly, interest rate spreads (i. e. term spreads as well as sovereign spreads) have gained much attention in the context of recession forecasting (see for example Ahrens 2002 as well as Ang et al. 2006). Stock markets and volatility of stock prices have also been extensively investigated regarding the predictive content for financial and economic crisis (see or example, Kim et al. 2009). In the context of the global financial crisis which may be clearly seen as a result of the US subprime crisis, house price booms and their economic or, to be more precise, crisis impact is of high relevance (see, e. g. Barrell et al. 2010). Furthermore, the interdependencies of real-estate prices and the stability of financial institutions, and banks in particular have been investigated. For example, Koetter and Poghosyan (2010) mentioned the "real estate-financial fragility nexus".

Having said that, in the context of early warning systems and leading indicators the focus of decision makers and market participants seem to have changed decisively in the last years. Firstly, the vulnerability of advanced economies came into the fore. And secondly, already much more relevant for the focus of this paper, financial market variables gained much more attention. Furthermore, and also as an obvious consequence of the global financial crisis, researchers recently focused on asset price or real-estate related banking crisis (see, especially, Ferrari et al. 2015 and more recently Clayes et al. 2017). Focusing on the real estate sector in the United States Tsolacos et al. (2014) investigated the forerunning properties of well-known economic leading indicators (e. g. Conference Board Leading Indicators, CBLI) with regards to the development of future rental growth in the US. The authors were able to show that these leading indicators for the real economic activity have predictive content in this context. Furthermore, Marcato and Nanda (2016) inter alia utilized sentiment indicators to model changes in real estate returns. The author discovered significant statistical evidence for a quantifiable relationship between sentiment and residential real estate. More recently, Bengtsson et al. (2018) investigated the vulnerabilities in the residential real estate sector. While focusing on potential foresight for decision makers in regards to crisis events in the residential real estate sector the authors utilized within their approach a set of indicators related to the early warning literature.

3 Some facts about the investment policies of German insurers

The general economic situation, the turmoil on the capital markets, the sovereign debt crisis as well as changing legal and regulatory conditions affect the capital policy of financial intermediaries to a great extent. German Insurers are the biggest institutional investors with an investment portfolio amounting to 1509 billion Euro in 2015 compared to a total GDP of 3043 billion Euro in Germany (see GDV 2017). Hence, the insurance industry is an important capital provider for the financing of real estate, companies, banks and the public sector. Institutional investors are among the most important players in the German real estate market, representing large portfolio holders of directly held real estate portfolios and, depending on the legal framework conditions, they can choose from different real estate investment

Table 1 Share of real estate investments by German Insurance companies and pension funds. Source: Own representation based on EY (2017)

Real Estate Investments	%
Direct Real Estate Investment used by	
Owner	15
Third party	70
Open Special Real Estate Funds	
German Law	4.4
Foreign Law	22
Open Real Estate Funds	15
Closed Real Estate Funds	48
Real Estate Private Equity Companies	22
Real Estate Investment Funds (REIT)	15
Project Developments	37
Alternative Real Estate Investments	30

segments in Germany and abroad. In order to better understand the investment policy of German insurance companies and the role of real estate investments, firstly some fundamentals of asset management in insurance companies will be explained.

Insurance companies operate in a highly regulated environment. At the national level, the Insurance Supervision Act (Versicherungsaufsichtsgesetz, VAG) and the German Ordinance on the Investment of Restricted Assets of Insurance Undertakings (Anlageverordnung, AnlV) are important regulatory frameworks, as well as the Solvency I I Directive at European level. Especially the latter affects the investment behavior of the insurance industry. For instance, Solvency I I stipulates demands on the required economic capital, risk management, and reporting standards of insurance companies. These capital requirements are based on the risk of the asset classes and thus impact insurers' investment strategy. Real estate risk is the risk that the value of basic own funds will change negatively due to a negative overall real estate shock of 25% in property prices or their volatility. In addition, there is no distinction in regulatory treatment whether the real estate is a direct investment or part of a funds. However, investments in real estate private equity companies are not part of the real estate risk module but the equity risk module. Other asset classes, such as equities, must be backed by 39% percent or even more equity. Nevertheless, even though, there are supervisory advantages of property investments, the solvent capital requirements of real estate investments are criticized to be too high (see IPD 2011). Table 1 shows that direct real estate investments used by third parties are the most frequent (70%) real estate investments for German insurers and pension funds.

Furthermore, the European debt crisis has been a cause of major concern for European insurers. Especially the fears about increased sovereign credit risk in some Southern European member states (like e. g. Italy) and the resulting higher risk premiums may have resulted in major difficulties for highly invested insurers (see Basse et al. 2012). Moreover, insurance business, in particular the life insurance sector, is a long-term oriented business. Consequently, the insurer's investment horizon spans many years up to even decades. Because of the long-term guarantees of life insurance policies e. g., the insurers are likewise interested in long-term investments in the context of their asset-liability management (see Basse and Friedrich 2008).

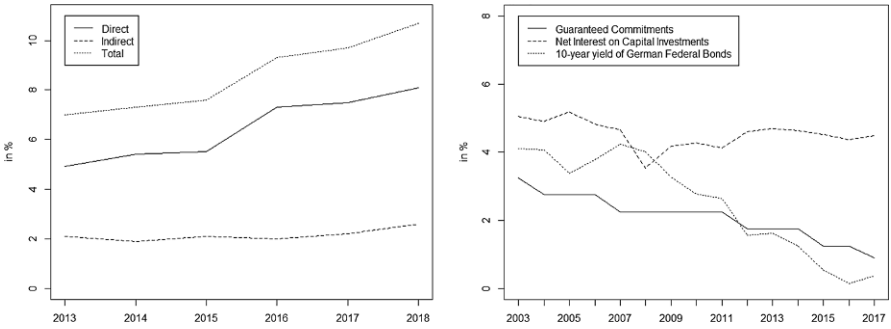


Fig. 1 Development of real estate investments and interest rates. Source: Own representation based on EY (2017) and Bloomberg (2018)

Since especially direct real estate investments are characterized by no fixed maturity, properties could be a suitable investment strategy for the duration matching within their portfolio.

However, both, short-term and long-term interest rates are currently near their historic lows. Since, on average, more than 80% of the investments of German life insurers are invested in fixed income securities, this continuing long-term period of low interest rates is challenging the whole insurance industry. In order to address the struggling of the bond market because of the ECB monetary policy and the resulting yield compression in the European bond market, an increasing pressure on existing structures arose.

Thus, the real estate asset class experienced a growing significance for financial intermediaries in recent years. These changes were reinforced by a long upturn in the real estate markets. Since asset managers can allocate their available capital into different asset classes with various risk-return profiles. Thus, different asset classes usually results in an optimized risk-return profile. Ross and Zisler (1991) have shown that the risk of unleveraged equity real estate investments lies midway between that of stocks and bonds. Because of the high economic relevance of the insurance sector in their role as financial intermediary, and the overall economic benefits from risk-transfer and indemnification, the security of these investments is one of the highest priority. Furthermore, the expected return for German life insurers was 4.4% (4.7%) for direct (indirect) real estate in 2017, a rising real estate rate could be a possible investment strategy for the institutional investors. Fig. 1 shows that the 10-year yield for German Federal Bonds is actually lower than guaranteed commitments of life insurance companies. Nevertheless, the net interest on capital investment is still high enough to fulfill their obligations, even though the last five years were characterized by increased realizations of valuation reserves. Furthermore, the property ratio of German insurers is constantly rising from 4.9% directly (2.1% indirect) in 2013 to 7.5% (2.2%) in 2017 and thus is facing a historic high. Forecasts for 2018 estimate the overall ratio to be 10.7% on average (see EY, 2013–2017).

The insurance industry has been reacting to these findings for several years by expanding its portfolio ratio, which is still far too low from a portfolio-theoretical point of view. Currently, many insurance companies have a real estate share of

less than 10%. Numerous scientific studies suggest that the optimal property ratio should be closer to 15% (see Heinrich et al. 2015). However, because of the lacking investment possibilities in core-investments, this development was accompanied by the increasing use or introduction of innovative and new real estate products in Germany, such as Real Estate Private Equity, Real Estate Securisation or Real Estate Investment Trusts (see for example Busching 2007).

4 Real estate prices in Germany

In Germany, there were various phases or cycles in recent real estate history. In fact, there had been four cycles which were determined by certain events each of which initially led to a boom followed by a recession. The first and second cycle were caused by real economic issues, such as the economic upturn due to the German reunification in the 1990s or the dot-com bubble, respectively the new economy boom, in the early 2000s. The real economic cycles were initially triggered by the demand side (German reunification respectively boom in the IT industry), but delayed reactions on the supply side initiated or exacerbated the downturn. The two following upswings were caused by financial factors. The real estate boom, which started globally at the beginning of the century and in Germany in 2004, had its peak in 2007/08. After the crash during the global financial crisis, an upswing followed again in 2009, which continues until today. These two cycles are characterized by the fact that real estate prices grew much faster than rents.

Due to World War II, there was a mandatory need for reconstruction work—not only because of the war damages, but also to provide housing space for refugees and displaced persons all over Europe. Moreover, in the following years other migrants (e. g., from the German Democratic Republic (GDR), Eastern Europe and migrant workers especially from Southern European states) established themselves in Germany, also increasing the demand for housing space. In addition, an increased level of income also stimulated the need for real estate. In the period from 1950 until 1985, at least 500,000 apartments were completed each year. As a result, both, rents and prices for condominiums increased significantly from 1975 to the early 1980s. Whereas it was observed an overall stagnation in the housing market in the 1980s.

After the fall of the Berlin Wall until the mid-1990s, the German reunification had a decisive, but time-shifted, effect on the subsequent development in the housing market. Due to the strong internal migration, especially to West German cities, the demand increased disproportionately in such places.

The economic prosperity and income developments because of reunification led to a high demand in terms of both, quantity and quality. For example, the German reunification resulted in a construction boom, although this upswing was initially unable to offset the exploding demand—rents and house prices grew. In the subsequent years, the completion of housing space was doubled and because of the time-lagged effect in the real estate construction sector, high excess capacities were built up. As a consequence, this led to a phase of stagnation in the housing market in the following years, which ended in the middle of the last decade.

Due to overcapacities in the housing market, rents and housing prices stagnated nominally from the mid-1990s to the end of the real estate boom in 2007/08. Thus, the housing completion rates decreased, since there was a lack of new impulses. Furthermore, the abolition of specific government subsidies ("Eigenheimzulage") on German federal level in 2006 changed the regulatory framework and thus lowered the demand. Moreover, the promotion of social housing went into the exclusive legislative competence of the federal states, which de facto resulted in a long-term decrease of state subsidies.

In 2008/09 residential property experienced price dynamics that were similar to those in the beginning of the 1990s, following the first shock caused by the social anxiety as a consequence of inflation and currency fears. According to data from the German Pfandbrief Banks (Verband Deutscher Pfandbriefbanken—vdp), as shown in Fig. 2, prices have risen by over 50% for single-family homes and about 60% for condominiums from 2008 to 2017. The rents for apartments in Germany have not risen as much as real estate prices. The rental price trend is attributed to fundamental causes—such as positive economic development and demographic immigration. However, speculation on housing prices is not—or only to a limited extent—seen as a determining factor on rental price development. Consequently, the factors/multipliers for condominiums have grown significantly since 2010.

The effect of this is that there is a typical pattern of price developments: First, there is an increase of prices in the cities and only then in the peripheral areas. A comparison of regional price developments showed that only a few municipalities were affected by price increases above consumer price inflation in the long-term. As a matter of fact many regions a rather stagnant development of real estate prices was to be observed. The German housing market therefore is fragmented. Because of the migration and the consequential oversupply, which placed additional pressure on prices and rents. The highest demand for housing space is still to be expected in the German metropolises and their surrounding areas. The demand is higher, the more households with strong purchasing power are looking for adequate housing.

On the one hand, the price increase is attributed to nearly 15 years of low new construction activity. Only in recent years was there another observable increase. It is expected that the construction of new houses in 2018 will be almost twice as high with more than 300,000 apartments as the low point in 2008/9. In terms of population, construction completions have risen from a low of approx. 19 to more than 30 completions per 10,000 inhabitants in 2017. The annual demand for living space is currently only partially covered by construction activity. In addition, the need to catch up with the omissions of past years remains.

On the other hand, there is a dynamic in the factors influencing demand. The disproportionate price increases in the metropolitan areas are, firstly, an expression of a demographic increase in demand due to the influx into the metropolitan areas. According to *Federal Statistical Office (2017)* household forecasts, the number of households will even increase by 2030 due to the current trend towards smaller households. Similarly, in the view of a rising life expectancy, the proportion of senior citizens' households is likely to increase. Based on the most recent regionalized population projections, core cities are expected to remain highly dynamic in agglomerations and urbanized areas. Through economically stable structures, employment

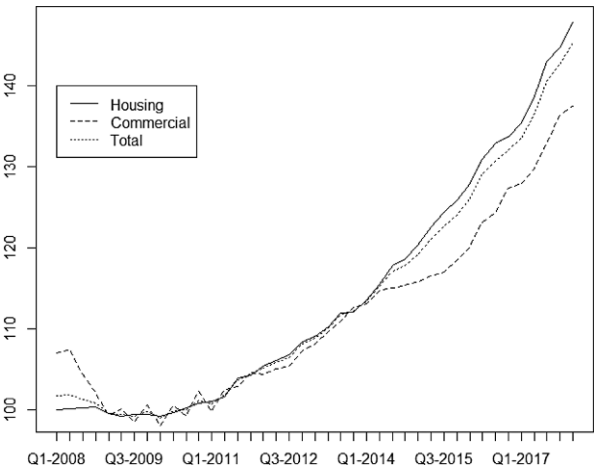


Fig. 2 Price development in the real estate market Source: Own representation based on vdp Research (2018)

opportunities, high urbanity and diverse recreational and cultural opportunities, as well as a well-developed infrastructure, they attract both, national and international residents. The migration to strong economic areas will continue to be the central reason for the dynamism of these regions.

A second factor besides demographic issues is the income development. This was reinforced by a favorable economic environment. In Germany, real household net incomes stagnated for a long time, only since the middle of the last decade there has been an increase as a result of the economic upturn. Since the middle of the last decade, the number of people in employment has risen steadily. At the same time, the unemployment rate has fallen almost continuously in recent years (Fig. 3). A favorable employment situation ceteris paribus leads to higher personal income. Recent labor market data published by the Federal Employment Agency confirming this long-term trend. The positive outlook for employment development points to an increasing willingness to pay and thus to a higher demand for housing—also in the future.

However, the housing prices are not just determined by the same fundamental factors as the rents. In addition to the factors described above, there are fiscal parameters influencing the pricing development. The monetary policy interventions of the European Central Bank, e. g. following a financial and economic crisis, have drastically increased the liquidity of investors and, at the same time, resulted in a long-term period of low interest rates (Fig. 4). These financial factors do not affect the development of rents, but are the value drivers on real estate investment markets. According to *KfW and Empirica Institut (*2017*)*, drastic price exaggerations on the order of 40% to 50% in the big A cities and almost 75% in Munich are possible.

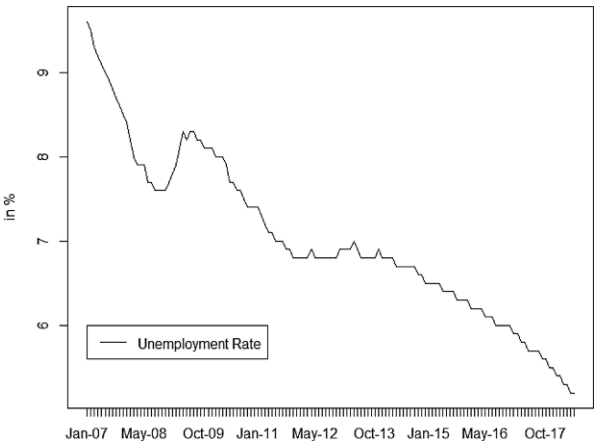


Fig. 3 Unemployment rate in Germany. Source: Own representation based on BA (2018)

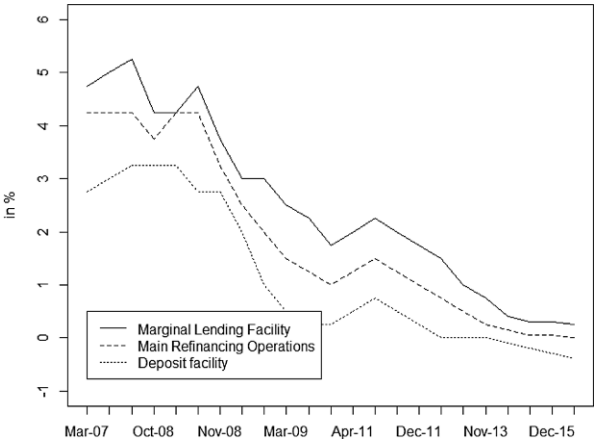


Fig. 4 Monetary policy interventions of the European Central Bank. Source: Own representation based on ECB (2018)

5 Some empirical evidence from the US

An early warning indicator system for real estate investments certainly is in need of relevant information about possible future developments of house prices. Phrased somewhat differently, a useful leading indicator of housing activity should be searched (see Croce and Haurin 2009). As already indicated above, sentiment indicators can be helpful in this context.

Due to the quite limited availability of house price and real estate sentiment data in Germany we focus on empirical evidence from the US. The National Association of Home Builders (NAHB) housing market index is usually considered to be the most popular leading indicator for US real estate prices and other variables that are related to housing activity (see, for example, Goodman 1994 and Marcato and Nanda 2016). This monthly survey among NAHB members asks builders for their attitudes and expectations for the demand for single-family homes and house market conditions in general (see Wilcox 2015). Our measure of house prices in the US is the S&P/

Case-Shiller 20 city home price index. This price index reflects the development of real estate prices in 20 US metropolitan areas. The different S&P/Case-Shiller home price index time series are quite popular among financial economists and are often used as proxy for US real estate prices in empirical studies (see, for example, Beltratti and Morana 2010 and Marcato and Nanda 2016).

The ability of sentiment indicators to serve as leading indicators of housing activity in the US obviously is of some relevance not only for risk or asset managers in the financial services industry. In the literature there is no clear picture at the moment. Most importantly, Marcato and Nanda (2016) recently have reported that the NAHB housing market index can help to predict US real estate prices using Granger causality tests. Croce and Haurin (2009), on the other hand, have been more skeptical with regards to the ability of the NAHB sentiment index to be used as leading indicator of housing activity in the US. While their empirical evidence seems to suggest that the NAHB housing market index can help to predict some important time series measuring real estate activity, there is no Granger causality in other cases. Moreover, when Granger causality is a phenomenon of economic relevance Croce and Haurin (2009) have usually found evidence for the existence of feedback effects (bidirectional Granger causality) in the relationship between the coincident indicators measuring housing activity and the NAHB sentiment index. This fact could also cause some doubts about the potential of the NAHB housing market index as an adequate leading indicator for the US real estate market. In order to improve the understanding of the relationship we use a different empirical approach that is robust to the presence of unit roots in the variables examined and we focus on house prices alone.

In order to test for Granger causality (see Granger 1969) among US house prices and the NAHB sentiment indictor we employ a modified Wald test based on Toda and Yamamoto (1995) examining an augmented vector autoregressive (VAR) model in levels. This approach guarantees the asymptotic χ^2 distribution of the Wald statistics. As is well known this test procedure does not require extensive pre-testing. Most importantly, it is not necessary to search for cointegration among the variables examined using this approach. Cointegration is known to be an important concept in time series econometrics when non-stationary variables are examined. Two time series that are integrated of order 1 are said to be cointegrated when there exists a linear combination of the two time series that is integrated of order 0 (see Engle and Granger 1987). In this case the two time series do follow common stochastic trends. From the viewpoint of economic theory this important empirical finding would imply the existence of an equilibrium relationship among the variables. However, it can be somewhat tricky to test for cointegration (see, for example, Dickey et al. 1991 and Breitung 2005). Moreover, the process of pre-testing might also be somewhat problematic in the context examined here. In fact, Mashi and Mashi (2001) have suggested to use the procedure proposed by Toda and Yamamoto (1995) in applied empirical research to avoid the need of pre-testing.

Given the research question examined here the concept of Granger causality is of central importance. As a matter of fact, one variable is said to Granger-cause another variable when the information about the first variable can help to predict the second variable (see, for example, Biswas and Saunders 1986 and Kunze et al. 2017).

Table 2 Phillips-Perron Unit Root Test Case Shiller 20 Cities (Levels). Source: Own calculations

		Adj. t-Stat	Prob.[a]
Phillips-Perron test statistic		–1.495657	0.5341
Test critical values:	1% level	–3.460313	–
	5% level	–2.874617	–
	10% level	–2.573817	–

Null Hypothesis: Case Shiller 20 has a unit root
Exogenous: Constant
[a] MacKinnon (1996) one-sided *p*-values

Table 3 Phillips-Perron Unit Root Test Case Shiller 20 Cities (1st Differences). Source: Own calculations

		Adj. t-Stat	Prob. [a]
Phillips-Perron test statistic		–3.968862	0.0019
Test critical values:	1% level	–3.460453	–
	5% level	–2.874679	–
	10% level	–2.573850	–

Null Hypothesis: D (Case Shiller 20) has a unit root
Exogenous: Constant
[a] MacKinnon (1996) one-sided *p*-values

Therefore, time series that Granger-cause other variables could be very helpful when trying to construct an early warning indicator system.

In order to test for Granger causality an augmented VAR model in the levels of the data with k + d time lags is estimated where k is the optimal number of time lag for the VAR model (which is determined using the traditional information criteria and also considering the serial correlation of the residuals of the VAR) and d is the highest order of integration of any variable considered in the model. The d additional lags are added to the VAR as exogenous variables. Then tests for Granger causality are performed using pairwise equations and modified Wald tests.

We examine monthly data. Our sample is January 2000 to March 2018. Both time series are taken from Bloomberg. The unit root testing procedure suggested by Phillips and Perron (1988) is employed to determine the order of integration of the two variables examined. In all cases a constant is added. Both the NAHB sentiment index and the Case Shiller house price index seem to be non-stationary time series integrated of order one (see Tables 2, 3, 4 and 5). As a consequence, d in the case examined here is 1.

While all information criteria (not reported to conserve space) suggests to include 3 time lags in the VAR we added a 4 lag to remove serial correlation in the residuals (see Table 6). Therefore, k in the case examined here is 4.

Consequently, the augmented VAR is estimated considering 4 lags and—following the Toda and Yamamoto (1995) approach—a 5th lag of both variables is then added to the model as exogenous variable.

The empirical evidence reported in Table 7 does indicate that there is Granger causality running from the NAHB housing market index to the S&P/Case-Shiller house price index—but not vice versa. Phrased somewhat differently, we have found

Table 4 Phillips-Perron Unit Root Test NAHB Housing Market Index (Levels). Source: Own calculations

		Adj. t-Stat	Prob. [a]
Phillips-Perron test statistic		–1.167399	0.6887
Test critical values:	1% level	–3.460035	–
	5% level	–2.874495	–
	10% level	–2.573751	–

Null Hypothesis: NAHB has a unit root
Exogenous: Constant
[a] MacKinnon (1996) one-sided *p*-values

Table 5 Phillips-Perron Unit Root Test NAHB Housing Market Index (1st Differences). Source: Own calculations

		Adj. t-Stat	Prob. [a]
Phillips-Perron test statistic		–13.73016	0.0000
Test critical values:	1% level	–3.460035	–
	5% level	–2.874495	–
	10% level	–2.573751	–

Null Hypothesis: D (NAHB) has a unit root
Exogenous: Constant
[a] MacKinnon (1996) one-sided *p*-values

Table 6 Serial Correlation of the VAR Residuals. Source: Own calculations

Lags	LM-Stat	Prob
3	4.106560	0.3918
4	0.707298	0.9504

VAR Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation
Included observations: 215

Table 7 Augmented VAR Granger Causality Test. Source: Own calculations

VAR Granger Causality/Wald Tests
Included observations: 214
Dependent variable: Case Shiller 20

Excluded	Chi-sq	df	Prob
NAHB	9.798740	4	0.0440
All	9.798740	4	0.0440
Dependent variable: NAHB			
Excluded	Chi-sq	df	Prob
SPCS20	3.070557	4	0.5461
All	3.070557	4	0.5461

unidirectional Granger causality running from the sentiment index to house prices. Thus, there are no feedback effects. This is also of some importance given the research question examined here (see Croce and Haurin 2009) and speaks for the ability of the NAHB housing market index to act as a leading indicator of US real estate prices.

6 Conclusion

The results of our empirical investigations reported above do show that using the approach suggested by Toda and Yamamoto (1995) are clear signs for unidirectional Granger causality running form the NAHB housing market index to the S&P/Case-Shiller 20 city house price index. Therefore, the NAHB data seems to be quite helpful predicting US house prices. This empirical finding is of high relevance with regards to the construction of early warning indicator systems for real estate investments. Indeed, the US data does suggest that examining the results from sentiment indicators in the real estate sector could really be helpful to financial risk managers that try to get an idea about possible future developments. Given that European insurers usually do not invest strongly in US real estate assets it would certainly be helpful to have data from other countries (e. g., Germany or France). In Germany the Deutsche Hypo Immobilienklima sentiment indicator could be a possible candidate to be used as leading indicator for real estate prices. Additional empirical research focusing on Europe seems to be necessary. In fact, the results from the US which are reported above seem to indicate that housing market sentiment indicators could provide relevant information that should be used constructing an early warning system for real estate prices.

References

Ahrens, R.: Predicting recessions with interest rate spreads: a multicountry regime-switching analysis. J. Int. Money Finance **21**(4), 519–537 (2002)

Aizenman, J., Pinto, B., Sushko, V.: Financial sector ups and downs and the real sector in the open economy: up by the stairs, down by the parachute. Emerg. Mark. Rev. **16**, 1–30 (2013)

Ang, A., Piazzesi, M., Wei, M.: What does the yield curve tell us about GDP growth? J. Econom. **131**(1), 359–403 (2006)

Ba (German Federal Employment Agency): Statistics. https://statistik.arbeitsagentur.de/. (2018)

Bannister, J.E., Bawcutt, P.A.: Practical risk management. Witherby, London (1981)

Barrell, R., Davis, E.P., Karim, D., Liadze, I.: Bank regulation, property prices and early warning systems for banking crises in OECD countries. J. Bank. Finance **34**(9), 2255–2264 (2010)

Basse, T., Friedrich, M., Krampen, B., Krummaker, S.: Strategisches Asset-Liability Management in der Versicherungswirtschaft—Ein Ansatz zur integrierten Bilanzstrukturoptimierung. Z. Ges. Versicherungswiss. **96**, 617–648 (2007)

Basse, T., Friedrich, M.: Solvency II, asset liability management, and the European bond market—theory and empirical evidence. Z. Ges. Versicherungswiss. **97**, 155–171 (2008)

Basse, T., Friedrich, M., Kleffner, A.: Italian government debt and sovereign credit risk: an empirical exploration and some thoughts about consequences for European insurers. Zeitschrift für die gesamte Versicherungswissenschaft **101**(5), 571–579 (2012)

Basse, T., Friedrich, M., Kleffner, A., v. d. Schulenburg, J.M.: Are interest rates too low? Empirical evidence and implications for German life insurers. Z. Ges. Versicherungswiss. **103**, 31–43 (2014)

Beltratti, A., Morana, C.: International house prices and macroeconomic fluctuations. J. Bank. Finance **34**, 533–545 (2010)

Bengtsson, E., Grothe, M., Lepers, E.: Home, safe home: cross-country monitoring framework for vulnerabilities in the residential real estate sector. J. Bank. Finance (2018). https://doi.org/10.1016/j.jbankfin.2017.12.006

Berg, A., Borensztein, E., Pattillo, C.: Assessing early warning systems: how have they worked in practice? IMF Economic Review, **52**(3), 462–502 (2005)

Bernoth, K., Pick, A.: Forecasting the fragility of the banking and insurance sectors. Journal of Banking & Finance, **35**(4), 807–818 (2011)

Betz, F., Oprică, S., Peltonen, T.A., Sarlin, P.: Predicting distress in European banks. J. Bank. Finance **45**, 225–241 (2014)

Biswas, B., Saunders, P.J.: Money-income casuality: further empirical evidence. Atl. Econ. J. **14**, 65–75 (1986)
Black, L., Correa, R., Huang, X., Zhou, H.: The systemic risk of European banks during the financial and sovereign debt crises. J. Bank. Finance **63**, 107–125 (2016)
Bleaney, M., Mizen, P., Veleanu, V.: Bond spreads and economic activity in eight European economies. Econ. J. (London) **126**(598), 2257–2291 (2016)
Bloomberg: Database. Subscription Service (2018)
Breitung, J.: A parametric approach to the estimation of cointegration vectors in panel data. Econom. Rev. **24**, 151–173 (2005)
Bromiley, P., McShane, M., Nair, A., Rustambekov, E.: Enterprise risk management: review, critique, and research directions. Long Range Plann. **48**(4), 265–276 (2015)
Busching, T.: Germany enters the REIT universe with a big bang. J. Retail Leis. Prop. **6**(3), 181–187 (2007)
Carey, A.: Effective risk management in financial institutions: the Turnbull approach. Balance Sheet **9**(3), 24–27 (2001)
Chamon, M., Crowe, C.: Predictive indicators of financial crises. In: The Evidence and Impact of Financial Globalization, pp. 499–505. (2013)
Clayes, G., Efstathiou, K., Schoenmaker, D.: Spotting excessive regional house price growth and what to do about it. Policy Contrib. (26) (2017)
Coudert, V., Gex, M.: Does risk aversion drive financial crises? Testing the predictive power of empirical indicators. J. Empir. Finance **15**(2), 167–184 (2008)
Croce, R.M., Haurin, D.R.: Predicting turning points in the housing market. J. Hous. Econ. **18**, 281–293 (2009)
Cummins, J.D., Weiss, M.A.: Systemic risk and the US insurance sector. J. Risk Insur. **81**(3), 489–528 (2014)
Dawood, M., Horsewood, N., Strobel, F.: Predicting sovereign debt crises: an early warning system approach. J. Financ. Stab. **28**, 16–28 (2017)
Demirguc-Kunt, A., Detragiache, E.: The determinants of banking crises in developing and developed countries. Staff Pap. Int. Monet. Fund **45**(1), 81–109 (1998)
Dickey, D.A., Jansen, D.W., Thornton, D.L.: A primer on cointegration with an application to money and income. Fed. Reserve Bank St. Louis Rev. **73**, 58–78 (1991)
Doff, R.: A critical analysis of the solvency II proposals. Geneva Pap. Risk Insur. Issues Pract. **33**, 193–206 (2008)
ECB (European Central Bank): Statistical Data Warehouse, http://sdw.ecb.europa.eu/. (2018)
Edison, H.J.: Do indicators of financial crises work? An evaluation of an early warning system. Int. J. Finance Econ. **8**(1), 11 (2003)
Eling, M., Schmeiser, H.: Insurance and the credit crisis: impact and ten consequences for risk management and supervision. Geneva Pap. Risk Insur. Issues Pract. **35**, 9–34 (2010)
Eling, M., Schmeiser, H., Schmit, J.T.: The solvency II process: overview and critical analysis. Risk Manag. Insur. Rev. **10**, 69–85 (2007)
Engle, R., Granger, C.: Cointegration and error correction: representation, estimation and testing. Econometrica **55**, 251–276 (1987)
Estrella, A., Mishkin, F.S.: Predicting US recessions: financial variables as leading indicators. Rev. Econ. Stat. **80**(1), 45–61 (1998)
EY (Ernst & Young Real Estate GmbH): Trendbarometer Immobilienanlagen der Assekuranz 2013 (2013)
EY (Ernst & Young Real Estate GmbH): Trendbarometer Immobilienanlagen der Assekuranz 2014 (2014)
EY (Ernst & Young Real Estate GmbH): Trendbarometer Immobilienanlagen der Assekuranz 2015 (2015)
EY (Ernst & Young Real Estate GmbH): Trendbarometer Immobilienanlagen der Assekuranz 2016 (2016)
EY (Ernst & Young Real Estate GmbH): Trendbarometer Immobilienanlagen der Assekuranz 2017 (2017)
Ferrari, S., Pirovano, M., Cornacchia, W.: Identifying early warning indicators for real estate-related banking crises. ESRB occasional paper series, vol. 8. (2015)
Frankel, J., Rose, A.: Currency crashes in emerging markets: an empirical treatment. J. Int. Econ. **41**(3–4), 351–366 (1996)
Frankel, J., Saravelos, G.: Can leading indicators assess country vulnerability? Evidence from the 2008–09 global financial crisis. J. Int. Econ. **87**(2), 216–231 (2012)
Gatzert, N., Martin, M.: Quantifying credit and market risk under solvency II: standard approach versus internal model. Insur. Math. Econ. **51**, 649–666 (2012)
GDV (German Insurance Association): Statistical Yearbook of German Insurance 2017, Karslruhe (2017)
Ghosh, A.R., Ostry, J.D., Tamirisa, N.: Anticipating the next crisis-what can early warning systems be expected to deliver? Finance Dev. **2009**(9), 35–37 (2009)

Goodman, J.: Using attitude data to forecast housing activity. J. Real Estate Res. **9**, 445–453 (1994)
Granger, C.W.: Investigating causal relations by econometric models and cross-spectral methods. Econometrica **37**, 424–438 (1969)
Harrington, S.E.: The financial crisis, systemic risk, and the future of insurance regulation. J. Risk Insur. **76**(4), 785–819 (2009)
Hatzius, J., Hooper, P., Mishkin, F.S., Schoenholtz, K.L., Watson, M.W.: Financial conditions indexes: A fresh look after the financial crisis. NBER working paper no. 16150. National Bureau of Economic Research, Massachusetts (2010)
Heathcotte, B., Apilado, V.P.: The Predictive Content of Some Leading Economic Indicators for Future Stock Prices. Journal of Financial and Quantitative Analysis, 247–258 (1974)
Heinrich, M., Wurstbauer, D.: The impact of risk-based regulation on European insurers' investment strategy. Z. Ges. Versicherungswiss. **107**(3), 239–258 (2018)
Heinrich, M., Just, T., Schreck, T.: Auswirkungen von Solvency II auf die Immobilienanlagen Europäischer Versicherer. International Real Estate Business School Beiträge zur Immobilienwirtschaft, vol. 12. (2015)
Hermansen, M., Röhn, O.: Economic resilience: The usefulness of early warning indicators in OECD countries. OECD Economics Department Working Papers, vol. 1250. OECD Publishing, Paris (2015)
IPD (Investment Property Databank): The IPD Solvency II Review (2011)
Kaminsky, G., Lizondo, S., Reinhart, C.: Leading indicators of currency crises. Staff Pap. Int. Monet. Fund. **45**(1), 1–48 (1998)
KfW, Empirica Institut: Herausforderungen und Perspektiven für den deutschen Wohnungsmarkt (2017)
Kim, D.H., Lee, S.J., Oh, K.J., Kim, T.Y.: An early warning system for financial crisis using a stock market instability index. Expert Syst. **26**(3), 260–273 (2009)
Kliesen, K.L., Owyang, M.T., Vermann, E.K.: Disentangling diverse measures: a survey of financial stress indexes. Fed. Reserve Bank St. Louis Rev. **94**(5), 369–397 (2012)
Koetter, M., Poghosyan, T.: Real estate prices and bank stability. J. Bank. Finance **34**(6), 1129–1138 (2010)
Kunze, F., Wegener, C., Bizer, K., Spiwoks, M.: Forecasting European interest rates in times of financial crisis—What insights do we get from international survey forecasts? J. Int. Financ. Mark. Inst. Money **48**, 192–205 (2017)
Lainà, P., Nyholm, J., Sarlin, P.: Leading indicators of systemic banking crises: Finland in a panel of EU countries. Rev. Financ. Econ. **24**(1), 18–35 (2015)
Lindberg, D.L., Seifert, D.L.: Risk management in the insurance industry: a comparison of solvency II to US insurance regulations. J. Insur. Issues **38**(2), 233–243 (2015)
Linderkamp, T., Pollmer, S., Schmidt, P., Siefert, P., Schwalba, M.: Neue Wege in der Kapitalanlage: Die Symbiose zwischen Banken und Versicherungen im Bereich der 'Alternative Assets'. Z. Ges. Versicherungswiss. **102**, 273–289 (2013)
MacKinnon, J.G.: Numerical distribution functions for unit root and cointegration tests. J. Appl. Econom. **11**, 601–618 (1996)
Manasse, P., Roubini, N., Schimmelpfennig, A.: Predicting Sovereign Debt Crises. IMF working paper, vol. 221. International Monetary Fund, Washington (2003)
Marcato, G., Nanda, A.: Information content and forecasting ability of sentiment indicators: case of real estate market. J. Real Estate Res. **38**, 165–203 (2016)
Masih, R., Masih, A.M.: Long and short term dynamic causal transmission amongst international stock markets. J. Int. Money Finance **20**, 563–587 (2001)
Phillips, P.C., Perron, P.: Testing for a unit root in time series regression. Biometrika **75**, 335–346 (1988)
Rochette, M.: From risk management to ERM. Journal of Risk Management in Financial Institutions, **2**(4), 394–408 (2009)
Romeike, F.: Balanced Scorecard in Versicherungen—Strategien erfolgreich in der Praxis umsetzen (2003)
Ross, S., Ziesler, R.: Risk and return in real estate. The Journal of Real Estate Finance and Economics, **4**(2) (1991)
Toda, H.Y., Yamamoto, T.: Statistical inference in vector autoregressions with possibly integrated processes. J. Econom. **66**, 225–250 (1995)
Tsolacos, S., Brooks, C., Nneji, O.: On the predictive content of leading indicators: the case of US real estate markets. J. Real Estate Res. **36**(4), 541–573 (2014)
vdp (The German Pfandbrief Banks): Time series property price indices QI2003-QIII2018. https://www.vdpresearch.de. (2018)
Wilcox, J.A.: The home purchase sentiment index: a new housing indicator. Bus. Econ. **50**, 178–190 (2015)

Module 5

Forward-Looking Financial Risk Management and the Housing Market in the United Kingdom: Is there a Role for Sentiment Indicators?

Kunze, F. / Basse, T. / Rodriguez Gonzalez, M. / Vornholz, G. (2020)

Published in:
The Journal of Risk Finance, Vol. 21, No. 5, pp. 659–678. DOI:
https://doi.org/10.1108/JRF-10-2019-0191.

The article can be found here:

https://doi.org/10.1108/JRF-10-2019-0191

Module 6

Leading Indicators for US House Prices: New Evidence and Implications for EU Financial Risk Managers

Rodriguez Gonzalez, M. / Basse, T. / Saft, D. / Kunze, F. (2021)

Published in:
European Financial Management. DOI:
https://doi.org/10.1111/eufm.12325.

DOI: 10.1111/eufm.12325

ORIGINAL ARTICLE

EUROPEAN FINANCIAL MANAGEMENT WILEY

Leading indicators for US house prices: New evidence and implications for EU financial risk managers

Miguel Rodriguez Gonzalez[1] | **Tobias Basse**[2,3] | **Danilo Saft**[2,4] | **Frederik Kunze**[2]

[1]Centre for Risk and Insurance, Leibniz University Hannover, Hannover, Germany

[2]Norddeutsche Landesbank Girozentrale, Hannover, Germany

[3]Touro College Berlin, Berlin, Germany

[4]Department of Economic Sciences and Media, Group for Service Information Systems Engineering, Ilmenau Technical University, Ilmenau, Germany

Correspondence
Miguel Rodriguez Gonzalez, Centre for Risk and Insurance, Leibniz University Hannover, Otto-Brenner-Straße 7, 30159 Hannover, Germany.
Email: mr@ivbl.uni-hannover.de

Abstract

This study draws on machine learning as a means to causal inference for econometric investigation. We utilize the concept of transfer entropy to examine the relationship between the US National Association of Home Builders Index and the S&P CoreLogic Case-Shiller 20 City Composite Home Price Index (SPCS20). The empirical evidence implies that the survey data can help to predict US house prices. This finding extends the results of Granger causality tests performed by Rodriguez Gonzalez et al. in 2018 using a new machine learning approach that methodologically differs from traditional methods in empirical financial research.

KEYWORDS

financial risk management, leading indicators, machine learning, transfer entropy, US house prices

We would like to thank the editor John A. Doukas, an anonymous associated editor and an anonymous referee for extremely helpful comments. Their efforts have been essential in significantly improving this paper. We also have benefited greatly from comments made by Tristan Hirsch, Bernd Krampen, J.-Matthias v. d. Schulenburg, Christoph Schwarzbach, Günter Vornholz, and Christoph Wegener.

JEL CLASSIFICATION
C58, G01, G11, R30

1 | INTRODUCTION

Risk management frameworks today are supposed to be forward looking (see e.g., Breden, 2008; Jorion, 2009). More specifically, Rochette (2009) has argued convincingly that all organisations should try to not forgo the advantages and opportunities that an adequate risk management programme can deliver, and that in order to ensure this a strong risk culture has to be implemented, that creates an environment where risk managers are not just waiting for bad things to happen. This could be of special importance for the financial services industry. As a matter of fact, Vazquez and Federico (2015) have noted that the global financial crisis has casted some doubts on the quality of bank risk management practices. These concerns have also been felt by bank regulators (see e.g., Liu et al., 2011; Vazquez & Federico, 2015). Moreover, it has also been questioned how the subprime crisis—a problem in a rather small segment of overall US financial markets—was able to hurt the global economy so badly (see Bullard et al., 2009; Eichengreen et al., 2012). This important question still is not answered in an adequate way yet. In any case, US house prices without a doubt have played a key role in this crisis (see e.g., Bullard et al., 2009; Wegener et al., 2019). As will be discussed in more detail, the European financial services industry also seems to be of some importance in this context (see e.g., Mizen, 2008; Noeth & Sengupta, 2012). Similarily, Rodriguez Gonzalez et al. (2018) have argued convincingly that risk managers should try to develop an early warning indicator system for real estate prices in the United States. Financial market prices that are determined in highly liquid markets should reflect information about the future. Stock prices, for example, ought to be helpful in forecasting the development of corporate earnings at the level of individual firms and the business activity in the economy as a whole (see e.g., Aylward & Glen, 2000; Goddard et al., 2006). Therefore, it could be argued that the stock market should be a leading indicator of corporate profitability and economic growth. Assuming a certain degree of market efficiency other prices that are determined by the activities of rational buyers and sellers in the financial sphere should also provide relevant information about future developments. However, with regard to house prices it has been argued convincingly that the property market could be inefficient due to its heterogeneity (see, most importantly, Clayton et al., 2009; Dietzel et al., 2014). Moreover, Hausler et al. (2018) have noted that real estate investors may be especially sensitive to changes in sentiment due to the specific characteristics of real estate markets such as the relatively low market transparency or long transaction periods. Therefore, sentiment indicators are likely to be perfect candidates on which to base an effective early warning system. Thus, financial time series that belong to the two categories house prices and sentiment indicators seem to be particularly suitable candidates when searching for use cases trying to implement forward looking financial risk management approaches that use the concepts of Granger causality or entropy. In this context, the concept of Granger causality obviously is of special importance. This is more or less true by definition because a certain variable is said to be Granger causing a second variable when it is useful in forecasting future values of the other time series (see, most importantly, Granger, 1969, 1988). One possibility is that a variable Granger causes another variable and that in the same time this second time series also Granger causes the first time series. In this case there are feedback effects among the two variables examined and consequently there is bidirectional Granger causality (see e.g., Hiemstra & Jones,

1994; Xie & Chen, 2014). Unidirectional Granger causality, on the contrary, is said to exist when one variable Granger causes the other variable but not vice versa.

The concept of Granger causality is of some importance in the field of real estate economics. This approach has, for example, been used to analyze the lead–lag relationship between house prices in different neighbouring regions (see e.g., Blake & Gharleghi, 2018; Teye et al., 2017) and between house prices and macroeconomic variables or the stock market (see, amongst others, Green, 2002; Luo et al., 2007). Moreover, this technique is also quite popular in the macroeconomic literature. In fact, Granger causality is an important concept for econometricians searching for leading indicators of economic activity (see e.g., Breitung & Candelon, 2006; Huh, 2002). Rodriguez Gonzalez et al. (2018) have employed this empirical approach to assess whether the National Association of Home Builders (NAHB) Market Index—an important sentiment indicator for economic activity in the US real estate sector—respectively its subcomponents can be a suitable leading indicator for property prices. The empirical evidence reported in this study seems to indicate that the NAHB data indeed can help to forecast house prices in the United States.

The tools developed in the field of machine learning right now are starting to have an impact on the real estate economics literature. Pioneering work in this area was done by Hausler et al. (2018). This very important study uses machine learning techniques to construct sentiment indicators for real estate markets. Our paper however adopts a completely different approach. We employ techniques of machine learning in combination with the concept of transfer entropy to improve early warning systems that are based on sentiment indicators and have been constructed using the tools of traditional time series analysis. Even though econometrics has a long-standing background in the application of Granger causality (e.g., from Cheng, 1979 and Geweke, 1984 to Luu Duc Huynh, 2019 and Osiobe, 2020), we further will consider emerging approaches from the field of machine learning and also will use the technique of transfer entropy (see e.g., Behrendt & Prange, 2021; Dimpfl & Peter, 2014). Here, we wish to highlight machine learning workflows based on transfer entropy parameter studies as promising frameworks for causal inference to aid the development of econometric models. More specifically, we use the concept of transfer entropy in combination with some tools from the field of machine learning to validate the results of the important study by Rodriguez Gonzalez et al. (2018) by employing a completely different methodology. As will be discussed later on in more detail the empirical research strategy used here can be helpful to cope with potential problems due to nonlinearities. Additionally, employing the transfer entropy approach in combination with techniques of machine learning might also be interesting because it will provide additional information about the relationship under investigation (especially with regard to the selection of the number of time lags to be considered in empirical models). At this point it has to be noted that the empirical evidence presented below just shows one possible application of the concept of transfer entropy in the field of financial economics. Obviously, this technique can be employed to analyze numerous other questions that are of relevance in economics and finance. As a matter fact, some ideas for future research will be discussed in the conclusion. However, it also has to be noted that the use case examined here—namely, the search for an appropriate leading indicator for house prices that can be helpful implementing forward-looking risk management approaches—is very important. The results of our empirical study, therefore, are highly relevant by themselves. This fact has clearly been demonstrated by the major economic problems that have been caused by US subprime crisis—a disaster that also had major consequences for financial risk managers in Europe and other parts of the world. In sum, our empirical findings seem to make a valuable contribution to the

literature in the fields of real estate economics, financial risk management and machine learning.

The paper is structured as follows: Section 2 briefly surveys the relevant literature focusing on empirical evidence from the United States and the United Kingdom. Section 3 then examines some general machine learning issues that are of special importance for this study. In Section 4, the concept of transfer entropy is discussed. Section 5 provides some information about the data examined. Moreover, some first empirical evidence with regard to the time series properties of the variables examined are presented here. Section 6 then reports and also discusses the empirical evidence that was obtained using the transfer entropy methodology in some detail. Before concluding in Section 8, Section 7 examines why the results of our empirical investigations are important for risk managers working in the European financial industry.

2 | SOME EMPIRICAL EVIDENCE FROM THE UNITED STATES AND THE UNITED KINGDOM

Meanwhile, numerous empirical studies have searched for a suitable leading indicator of housing activity in a number different countries (see e.g., Croce & Haurin, 2009; Rodriguez Gonzalez et al., 2018). As will be shown, the focus of the literature lies on data from the United States and from the United Kingdom. Without a doubt, sentiment indicators might be helpful in this context. As already noted, there is some empirical evidence suggesting that sentiment indicators can be helpful to predict changes in the market for real estate assets (see e.g., Dietzel et al., 2014; Tsolacos, 2012). In this context Tsolacos (2012) has argued convincingly that sentiment and confidence indicators could be particularly helpful when it comes to the identification of turning points in real estate markets. Given that that such phases are of crucial importance for investors and risk managers, the recent interest in this topic is certainly well understandable. Thus, it should come as no surprise that there is some related literature. As a matter of fact, there meanwhile are a number of relevant studies examining data from the United States. Moreover, some applied econometricians recently also have analyzed time series from the United Kingdom. As already noted, the NAHB housing market index is usually considered to be the most popular leading indicator for US real estate prices and other variables that are related to housing activity (see, amongst others, Goodman, 1994; Marcato & Nanda, 2016). The ability of this sentiment indicator to act as leading indicators of housing activity in the United States is discussed quite controversially in the literature. Marcato and Nanda (2016), for example, have shown that the NAHB housing market index can be helpful predicting house prices in the United States. To do so they have employed Granger causality tests. However, the empirical evidence presented by Croce and Haurin (2009) is less promising. They have examined the ability of the NAHB sentiment indicator to forecast US housing activity by also performing Granger causality tests. Though the results reported in this paper seem to imply that the NAHB data can indeed help to predict some important time series measuring real estate activity in the United States, there are still problems in a number of cases. Moreover, in the cases where Granger causality between the NAHB housing market index and other relevant time series from the US housing market has been detected Croce and Haurin (2009) have usually found evidence for the existence of bidirectional Granger causality. Thus, there seem to be, possibly

nonlinear feedback effects. This would certainly be a problem using the NAHB housing market index as a leading indicator for the US real estate market activity employing the traditional techniques of time series econometrics. Additional research that can define the extent of causality and recognise possibly nonlinear feedback loops would be necessary to improve our understanding about the way the two time series are related to each other and about the predictive power of the sentiment indicator. Ideally, this would be an analysis that is updated and evolves with the time series themselves. This challenge revisits one of the major aspects of machine learning workflows with their ability to update analysis results on the fly and learn even nonlinear relationships from the data. Such relationships, as we will see in this article, can be captured and measured not only in existence, but also extent, by the concept of transfer entropy.

Given the importance of the question whether the NAHB data constitutes a suitable basis for an early warning system for US real estate activity Rodriguez Gonzalez et al. (2018) have tested for Granger causality employing the approach suggested by Toda and Yamamoto (1995). The main advantage of this approach is that it does not require major pretesting efforts that can cause problems (e.g., cointegration tests). Only the order of integration of the time series under investigation has to be determined. There is no need to examine variables in differences. Moreover, the test procedure is also very popular because of a Monte Carlo study by Zapata and Rambaldi (1997) that has shown some very favourable characteristics of this approach. This technique requires the estimation of an augmented vector autoregressive (VAR) model in levels. The empirical evidence reported by Rodriguez Gonzalez et al. (2018) shows that the VAR model should consider three to four time lags. Using this approach there are clear signs for Granger causality running from the NAHB housing market index to the S&P/Case-Shiller 20 city house price index. Consequently, the data compiled by the NAHB indeed seems to be helpful forecasting real estate prices in the United States. Another study of great importance for our empirical work is Hausler et al. (2018) because this paper uses techniques of machine learning to develop a news-based approach for prediction purposes examining data from the US real estate market. More specifically, the authors employ machine learning techniques to construct a text-based sentiment analysis tool that can be used to construct a useful leading indicator. The paper has reported very favourable empirical evidence. It certainly is an important door opener for the use of machine learning techniques in the field of real estate economics.

With regard to international evidence on the relationship between sentiment indicators and house prices there is some highly relevant recent empirical work from the United Kingdom. In fact, Wood (2003) and McLaren and Shanbhogue (2011) have suggested to utilize data from the Housing Market Survey which is compiled by the Royal Institution of Chartered Surveyors (RICS) to forecast house prices in this country. McLaren and Shanbhogue (2011) have shown that the combination of the RICS data with Internet search data (more specifically, people interested in both buying and selling properties) can be helpful to forecast house prices. Moreover, Kunze et al. (2020), meanwhile, have reported quite favourable empirical evidence testing for Granger causality between the RICS survey data and the level of house prices in the United Kingdom. Doing so they also have employed the approach that has been suggested by Toda and Yamamoto (1995). Therefore, Kunze et al. (2020)—which also builds on Rodriguez Gonzalez et al. (2018)—is of some importance for the empirical evidence to be presented later on.

3 | SOME GENERAL THOUGHTS ABOUT MACHINE LEARNING IN THE CONTEXT OF TRANSFER ENTROPY

The history of machine learning is closely linked to the development of computational capabilities and methodologies in computer science (see Athey, 2018). As key properties of data—such as variety, velocity and volume—grew over the past decades, traditional systems for handling and analysing data became infeasible. The exponential growth of what has been dubbed the big data trend was accompanied by an exponential growth of computational power. Computer science and software development—as original fields of growth—continuously created efficient algorithms and workflows to better work with multivariate, possibly incomplete, nonlinear, and unstructured data. Ease of utilization and flexible workflow adjustments have been at the heart of this development since. Machine learning best practices and frameworks emerged largely independent from established methodologies in fields such as econometrics. In this context, Athey (2018) has noted that there has not yet been much diffusion of econometric concepts into machine learning, but there is some overlap in common statistical assets. Above that, we argue that machine learning best practices will diffuse into the field of econometrics as it will become augmented by the tools and data science workflows codeveloped therein.

Machine learning applications and thorough methodologies have existed for a few decades already (see Mjolsness & Decoste, 2001). Nevertheless, especially breakthroughs in analysis of unstructured data (e.g., Hinton et al., 2012) and value creation associated with formerly underutilized data sets have led to accelerated attention, financing and development in all current disciplines of artificial intelligence, including traditional machine learning and data science approaches. As of yet, the focus of these disciplines has been seen in predictive analytics and pattern recognition (the latter centred around unsupervised clustering and dimensionality reduction) in big data sets (e.g., Athey, 2018; López de Prado, 2019). Basuchoudhary et al. (2017) underline the focus of prediction when utilizing machine learning for economic tasks. This seems natural from two perspectives: As it is hard from an epistemological perspective to understand large, frequently updated data sets and find their underlying structure with traditional or manually quickly traceable algorithms, a layer of abstraction for prediction and other tasks was built. Using this machine learning toolbox layer, researchers are able to efficiently and effectively provide higher predictive power at the cost of being able to apply models of complexity. Direct prediction on the contrary, offers many decision makers in the economy higher value-creating power than just deriving complex relationships and models from the data, at a minimal additional effort. However, we do not see the development to stop at prediction and reject efforts to categorise machine learning by the criterion of trying to predict something. As research continues, concepts well established in econometrics such as causal inference gain modern counterparts in machine learning. In fact, López de Prado (2019) argues that for every step in econometrics, machine learning already features a homologous step.

The interfaces of the toolboxes that were built in machine learning are easy to use for such tasks and offer tuning capabilities combined with high performance. This factor of automation of efficient workflows will be the driver of said continuous diffusion process of machine learning frameworks into different fields of science. The swiftness of the development in machine learning is underlined by the fact that the languages R (see R Core Team, 2019) and Python (see van Rossum & Drake, 2009) rank high in the IEEEs spectrum of programming languages (Cass, 2018). Python has been gaining wide popularity for its ease of use and flexibility, whereas Rs continued best practice support of data wrangling and analysis tasks will

keep it relevant. The increasing amount of libraries and packages available to solve specific tasks enable quick and novel solution processes in both of these languages.

The focus on performance and being able to handle even complex data resulted in approaches that 'let the data speak for itself' (see Bzdok et al., 2017). After enabling the utilization of unstructured data in, for example, the medical sciences, we have not arrived at a point where we can demonstrate said homologous concepts in machine learning for original tasks in econometrics. We will demonstrate an efficient causal inference workflow using machine learning toolboxes not relying on Granger causality or the concept of cointegration. Moreover, we offer a methodology utilizing modern machine learning pipelines, modern big data handling technology stacks and tools. Importantly, this approach can be generalised to create machine learning supported causal inference pipelines in economic investigation to many structured and unstructured data set. Hence, though we demonstrate the bivariate, nonlinear numerical case as an introduction above what is possible with Granger causality measurements, this workflow can be extended further to multivariate nonlinear numeric, discrete and even textual data sets.

As a first principle in this workflow, we utilize a different empirical approach—namely transfer entropy—to examine the relationship between the time series analyzed by Rodriguez Gonzalez et al. (2018) with toolboxes and methods available from the machine learning realm. This concept recently has become quite popular in financial economics (see, among others, Behrendt & Prange, 2021; Dimpfl & Peter, 2014).

4 | TRANSFER ENTROPY AND AVAILABLE MACHINE LEARNING LIBRARIES FOR R AND PYTHON

Shannon entropy (see Shannon, 1948) is a measure of uncertainty of description of a random variable X with a distribution $P(x_i)$ by a certain number of base 2 bits, that is, it is possible to measure the quantity of information contained in X in bits by defining the average number of bits needed to encode draws from $P(x_i)$ via

$$H(X) = -\sum_{i=1}^{n} [P(x_i) \log P(x_i)].$$

Other measures of entropy exist that have a more parametrised approach to measuring information content, for example, Rényi entropy (see Rényi, 1970). Shannon entropy is the most widely used criterion to measure information content within a discrete variable.

Transfer entropy was introduced in Schreiber (2000), relying on Shannon entropy and the Kullback-Leibler distance, as a quantitative measure of statistically significant transfer of information in time series that is able to distinguish between driving and responding elements in such systems (see Bossomaier et al., 2016b; Simon et al., 2019). It, therefore, aims at detecting dynamic causation links between a paired time series (see Syczewska & Struzik, 2014). Simon et al. (2019) summarise accordingly, that information flow from a process J to a process I can be measured by quantifying the deviation from the generalised Markov property $p(i_{t+1} \mid i_t^{(k)}) = p(i_{t+1} \mid i_t^{(k)}, j_t^{(l)})$ given that I_{t+1} is conditional on the k previous observations (Markov process of order k) and J_{t+1} is conditional on the l previous observations of J (Markov process of order l) as well as relying on the Kullback–Leibler distance (see Schreiber, 2000). Therefore, transfer entropy based on Shannon entropy determines an information flow $T_{J \to I}$ by calculating

$$T_{J\to I}(k,l) = \sum_{i,j=0}^{n} p(i_{t+1}, i_t^{(k)}, j_t^{(l)}) \times \log\left(\frac{p(i_{t+1}, i_t^{(k)}, j_t^{(l)})}{p(i_{t+1} | i_t^{(k)})}\right).$$

Transfer entropy is a model free measure of information flow from one time series to another (see Bossomaier et al., 2016a; Vicente et al., 2011). This greatly distinguishes it from Granger causality. However, according to Bossomaier et al. (2016b), transfer entropy may be considered to be a generalisation of Granger causality and is in this respect, able to answer the question how much information is transferred at a certain timestep from the past of one time series to the current state of another time series. Bossomaier et al. (2016b) emphasise that transfer entropy is an asynchronous measure of information flow and, therefore, able to quantify differing amounts of information flow from a time series X to a time series Y opposed to the flow from Y to X. Previous entropy based measures (e.g., mutual information) did not expose this directional characteristic.

Syczewska and Struzik (2014) argue that financial time series often show autoregressive conditional heteroscedasticity and show non-Gaussian statistics alongside nonlinear correlations. In this respect, they give an overview of Granger causality tests for nonstationary financial time series and refer to the method published by Toda and Yamamoto (1995) as well as concepts for nonlinear Granger causality that may be applied in financial analysis, yet require more complicated steps to prepare and analyze such data. Dimpfl and Peter (2012) state that Granger causality has been a predominant measure to detect relationships between time series, however, its insights may often only be used to interpret the existence, and possibly compare statistics, rather than measure the exact quantity of information flow in financial time series as several assumptions about the underlying statistics and dynamics must be met for a quantitative interpretation of Granger causality. Transfer entropy on the contrary, according to Dimpfl and Peter (2012), is not limited to the assumptions made by the predominantly applied measures of Granger causality, especially regarding linear dynamics. Other methods, such as the Hasbrouck information share, assume cointegration between time series, whereas transfer entropy does again not have such prerequisites. Therefore, Dimpfl and Peter (2012) state that transfer entropy is applicable even if one cannot be sure about whether the assumptions required by the standard models are met by the data. Considering the abovementioned discussions, transfer entropy is a promising generalized measure for quantifying the extent and direction of information flow between financial time series.

Moreover, a derivative of transfer entropy, called 'effective transfer entropy', has been introduced by Marschinski and Kantz (2002) to account for bias effects from small sample sizes. Towards measuring bivariate transfer entropy and effective transfer entropy, an established library for the programming language R exists (Simon et al., 2019) and similar approaches to counter bias effects exist in the well-established approach developed by Wollstadt et al. (2013) that can quantify bi- and multivariate transfer entropy.

5 | DATA AND INITIAL ANALYSIS

This empirical study tries to validate the results reported by Rodriguez Gonzalez et al. (2018) employing a completely different methodological approach. Therefore, the same data set (variables and sample) is also examined here. As already noted, the NAHB housing market index is a very popular leading indicator for US real estate prices and other variables that are related to

housing activity that is widely observed by investors in different segment of the global financial market. This time series is based on the results of a monthly survey among the members of the National Association of Home Builders asking the participants for their attitudes and expectations with regard to the demand for single-family homes and house market conditions in general (see e.g., Rodriguez Gonzalez et al., 2018; Wilcox, 2015). The measure of US real estate prices analyzed by Rodriguez Gonzalez et al. (2018)—and, therefore, also here—is the S&P/Case-Shiller CoreLogic 20 City Composite Home Price Index which reflects the development of house prices in 20 metropolitan areas of the United States. This real estate price index is quite popular among financial economists and consequently is often used in applied empirical studies (see e.g., the recent studies by Huang, 2019; Ramirez, 2019). The sample examined here is from January 1995 to April 2018. The data that is used for all calculations is taken from Bloomberg.

The time series properties (order of integration) of the variables have been one important reason for Rodriguez Gonzalez et al. (2018) to use the procedure suggested by Toda and Yamamoto (1995). Nonstationarity in single time series replications needs consideration using the transfer entropy approach, too (see e.g., Behrendt & Prange, 2021). Stationarity requirements of transfer entropy measurements are usually considered and evaluated in a strict sense (stationarity in mean, variance, covariance) and, therefore mitigated, for example, by taking differences. This may result in excluding possibly important information. It is, however, still under discussion whether a strict interpretation of stationarity is necessary or whether weaker assumptions may apply for such causal inference, for example, under the presence of a confounding driving factor for the nonstationarity (see Runge, 2018). In any case, the transfer entropy measurement libraries employed here offer ways to deal with nonstationary time series under certain additional assumptions. One way is to provide replications of the nonstationary time series process to infer significance of the measured causal relations. Typically, these ensemble methods allow for taking approximately stationary cyclic repetitions under similar conditions (e.g., for different subjects in neuroscientific experiments under similar experimental setup). Taking approximately stationary subsamples of the nonstationary time series to attain the required number of repetitions, under the assumption of an only slowly changing nonstationary regime, has been mentioned as a viable method outside domains such as neuroscience—where fast changes in time series are more common (see Gómez-Herrero, 2015).

As we deem the number of samples in the considered time series long enough, we wish to include both, the nonstationary original series, as well as the stationary derivative in a hyperparameter study on transfer entropy behaviour. First of all, the results of unit root tests are reported in the Tables 1 and 2. Here, the approach suggested by Elliott et al. (1996) is employed. This testing procedure is known for its improved power compared to more traditional unit root

TABLE 1 Unit root test results for the National Association of Home Builders (NAHB) Housing market index

This table reports the results of Elliott–Rothenberg–Stock unit root test and the appropriate critical values (5% error level) examining the NAHB Housing market index (in levels and first differences). Null hypothesis: Time series has a unit root; Exogenous: Constant.

	Data in levels	Data in first differences
Elliott–Rothenberg–Stock test statistic	21.554	0.225
5% critical value	3.179	3.179

TABLE 2 Unit root test results for the S&P/Case-Shiller CoreLogic 20 City Composite Home Price Index (SPCS20)

This table reports the results of Elliott–Rothenberg–Stock unit root test and the appropriate critical values (5% error level) examining the S&P/Case-Shiller CoreLogic 20 City Composite Home Price Index (in levels and first differences). Null hypothesis: Time series has a unit root; Exogenous: Constant.

	Data in levels	Data in first differences
Elliott–Rothenberg–Stock test statistic	20.751	0.645
5% critical value	3.178	3.178

tests (see, amongst others, Cooray & Wickremasinghe, 2007; Maddala & Wu, 1999). Cooray and Wickremasinghe (2007), for example, have stressed that the approach that has been suggested by Elliott et al. (1996) dominates other commonly used unit root tests when a time series has an unknown mean or a linear trend.

The empirical findings obtained using this approach seem to imply that both time series are nonstationary variables integrated of order one. Consequently, the results reported by Rodriguez Gonzalez et al. (2018) are confirmed using a different unit root testing procedure.

For calculating transfer entropy, different estimators of the mutual information distribution of the processes can be employed (see Lizier, 2014). A Gaussian estimator assumes approximately a pairwise jointly Gaussian distribution of all processes. Figure 1 shows that for diff(NAHB) versus diff(SPCS20), we observe an approximately jointly Gaussian pattern. For NAHB versus SPCS20, strong deviations from a joint Gaussian distribution pattern are exposed. The Gaussian estimator further only exposes linear relations in the data. That being said, this estimator is far less computationally expensive than others and may be a good start for a quick coarse overview when traversing large parameter spaces (as suggest by Lizier, 2014). Because of the limitations of the Gaussian estimator, we will concentrate on the Kraskov–Stögbauer–Grassberger mutual information estimator (KSG) (see Kraskov et al., 2004) for narrow interpretations, but will compare the behaviour to the Gaussian estimator for completeness of the parameter study.

6 | MACHINE LEARNING WORKFLOW AND DERIVED EMPIRICAL EVIDENCE

The machine learning workflow we developed constitutes advances over traditional econometric approaches as we were able to perform a hyperparameter grid search in a parallel manner. Scanning the hyperparameter space and drawing conclusions from the robustness of the observed phenomena is a scheme typical for machine learning pipelines that we deem advantageous for consideration in econometric investigations—especially in a situation such as the one at hand where some empirical studies arrive at slightly differing results depending on the methodology employed. Hence, a hyperparameter grid search traverses the meta-space of results dependent on methodological settings such as the chosen lags for causal inference, strictly stationary versus not strictly stationary processes considered, conditional mutual information estimator used for transfer entropy, and so forth. The parameter space we wish to traverse is indicated by combinations of the following value sets:

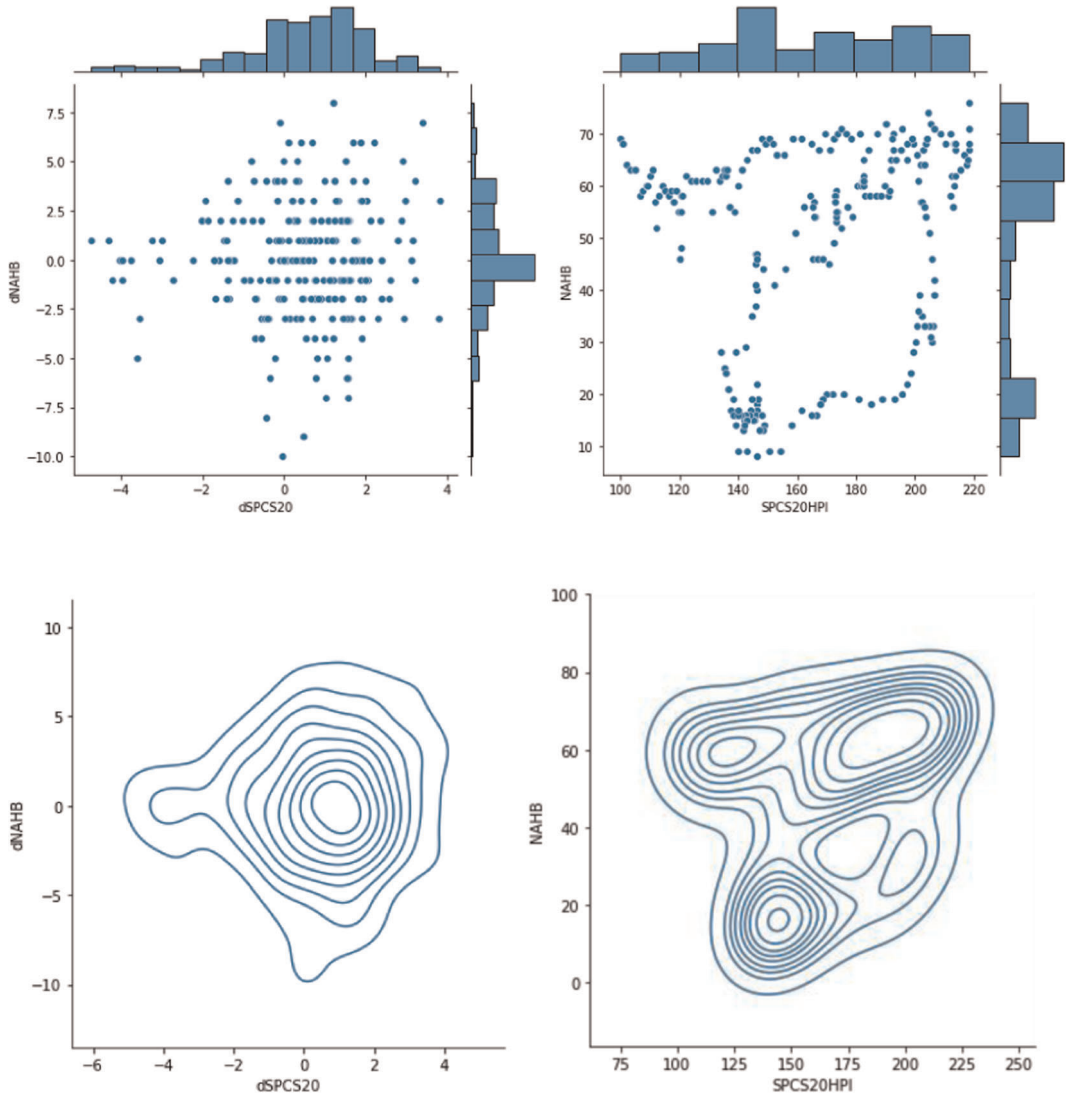


FIGURE 1 Bivariate scatter plot, marginal histograms (top row) and derived contour plots of the joint distributions (bottom row) for the differences processes (left column) and original processes (right column). These figures are plotted to gain insights about the data examined here. Processes that are considered 'jointly Gaussian' will show a circular accumulation and concentration of scatterpoints. Here, the differenced processes show an approximately jointly Gaussian distribution of their values, whereas the original time series deviate largely from this assumption

- Time series analyzed: (original, differenced)
- Subsampling method:
  - o Eighteen chunks (replications) of 13 data points in each subsample of the original full series available (239 observations)
  - o A single long series, with different start and end months to account for possible sample bias. Start and end of sample were varied randomly within a window of 40 months at the start and end of the original series. Thirty runs were completed and included as box plot

representations of the measurements to gain insights on the robustness of the results under varying subsample sets.
- Conditional Mutual Information Estimator: (JidtGaussianCMI, JidtKraskovCMI)
- Minimum Lag considered: 0 (no variation)
- Maximum Lag considered depending on the subsampling method above:
  - o 1, ..., 12
  - o 1, ..., 20

From a technical perspective, as the KSG estimation is computationally very expensive, we set up a multiprocessing pool using the *multiprocessing* library for Python. All pipelines ran on a modern 12 core CPU and a machine with 64 GB of RAM. The pipeline is optimised for using as much CPU power as possible, but adhering to the RAM limits. We observed strong RAM consumption with larger permutation settings as large amounts of surrogate data sets of the smaller original time series data are created and temporary objects for mutual information estimation and transfer entropy measurements required memory space in each parallel run.

All settings can also be run with machine learning scheduling software (see e.g., Apache Airflow, 2020) to reduce downtime and necessity of manual reruns. This can be important when analysing transfer entropy as each analysis run takes several hours or even days depending highly on the permutation settings. If constant monitoring is not possible, resources may go unused for significant amounts of time after completion of a fork if no scheduling tool is utilized. Each run of each fork saved its results using the *pickle* library.

For all experiments, we created a standard *conda* environment (see Anaconda Software Distribution, 2020). This environment was set up using Python 3.7 with its libraries *pandas*, *matplotlib* version 2.2 (for compatibility with *idtxl*), *networkx* version 2.4 (for compatibility with *idtxl*), *statsmodels* and *idtxl*. We ingested the original time series data from an Excel export directly from Bloomberg into a *pandas* data frame. We added the stationary derivatives as new columns to the dataframe for selection based on the desired current hyperparameter for the time series to be used (original or differenced). A *numpy* array of the two time series processes was created for further data processing. This included, for example, reshaping the *numpy* array into different subsets to create the abovementioned replications. Graphical plots confirmed the validity of the data. The reshaped *numpy* array was used to initialise an *IDTxl Data* object to subject it to further transfer entropy analysis in our hyperparameter study.

Using our first approach of taking only small subsamples and subjecting them to analysis, we received the results displayed in Figure 2. Considering target process 1 (i.e., testing for a causal relationship from NAHB to SPCS20) the Gaussian estimator found significant causal relationships with several settings for the maximum number of lags considered. These, may however arise due to a non-Gaussian joint distribution of the subsamples and are reported here for the completeness of investigating the behaviour of the estimators on the time series at hand. Hence, we conclude that the results indicate false positive effects of Gaussian estimators under a not-jointly Gaussian distribution of the two time series, respectively, only considering linear effects between processes.

The KSG reported significant causal relations when considering lags 0 to 6. Looking in the other direction, it is important to note that no linear relations from SPCS20 to NAHB were found, as the Gaussian estimator did not measure any significant information transfers.

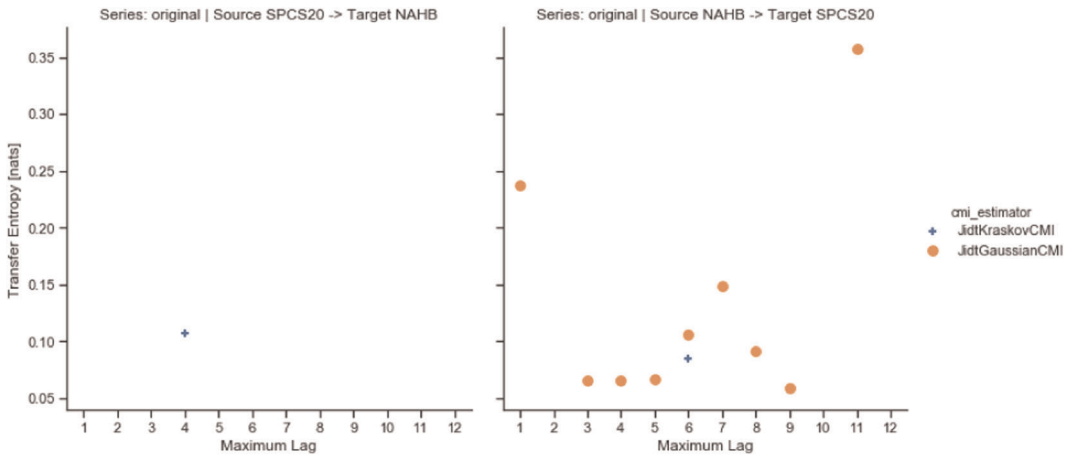


FIGURE 2 Joint transfer entropy results of a subset sampling study with 18 repetitions of 13 months. These figures show the results of the calculations searching for transfer entropy. Markers and colours indicate the CMI (conditional mutual information) estimator used. The *x*-axis shows the maximum lag considered in the measurement. Here, we observe several significant linear causal relations from National Association of Home Builders Index (NAHB) to SPCS20 using the Gaussian estimator. Nonlinear effects from NAHB to SPCS20 are present at lag 6. In the opposite direction, a nonlinear effect is observed at lag 4 only

However, the KSG estimator was able to uncover nonlinear relationships and reported a significant overall information transfer when considering lags 0 to 4. The results here are reported for completeness of methodological opportunities in a machine learning oriented hyperparameter search setting. The shortness of the time series subsamples is probably not suitable to uncover all causal relations, but the results are interesting in terms of comparison opportunities to other hyperparameter settings to gain meta-level knowledge about causal inference behaviour on these processes.

As we wish to include both the nonstationary original series as well as the stationary (i.e., differenced) derivative, we will now continue our hyperparameter study using stationary, that is, diff(NAHB) and diff(SPCS20), time series. We use differenced time series, as we will not need to rely on the presence of several replications of short approximately stationary subsamples to measure valid transfer entropy results. Hence, we will be able to observe transfer entropy for subsamples covering many years of the time series. By repeatedly taking small variations of the start and end points of the subsamples, we can observe the sensitivity of the transfer entropy measurement at each lag by doing several measurements with slight variations. Therefore, we constructed 30 runs with differing start and end points, each of guaranteed length of over 160 months. Figure 3 shows the results of the analysis. The left column of Figure 3 shows the boxplots for the measured information transfers from NAHB to SPCS20 in two subfigures. The right column shows the information transfer that we observed in the opposite direction. Each row indicates the estimator used. Each box plot features all significant transfer entropy measurements that we found amongst the 30 runs for each maximum lag indicated on the *x*-axis. Blue box-plots in the top row show the nonlinear results using the KSG estimator, whereas orange box-plots in the bottom row show the linear results using the Gaussian estimator.

Our empirical findings indicate robust results for information transfer from NAHB to SPCS20, as can be seen in the two subfigures in column 1 of Figure 3. Here, the analysis is very

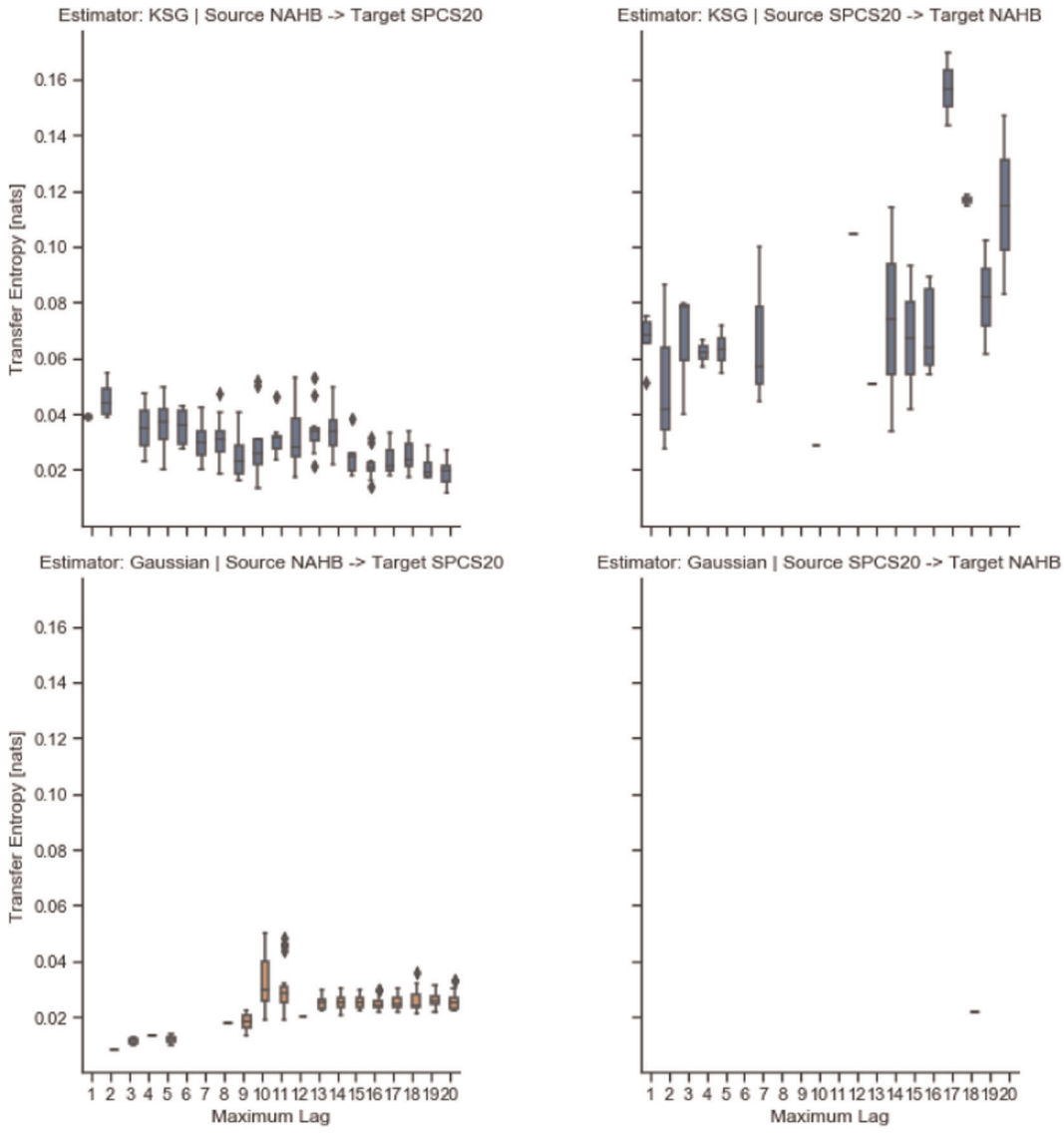


FIGURE 3 Joint transfer entropy results of considering 30 runs of long stationary subsamples of the complete time series. These figures examine the information flow between the variables under investigation here. The top row shows the results using the Kraskov–Stögbauer–Grassberger (KSG) estimator (including nonlinear effects), bottom row shows results using the Gaussian estimator (just including linear effects). Columns indicate the direction of the information flow as stated in the subfigure titles. The *x*-axis shows the maximum lag considered in the measurement. The *y*-axis shows the extent of the measured information transfer over 30 runs

prominent in that both, KSG and Gaussian estimators, converge to similar transfer entropy estimates with higher lags and the box plot bodies are very small in size. This is a plausible outcome for time series with jointly Gaussian distributions. The pattern of this information transfer at different lags for both estimators has also been reproducible with different sets of subsamples repeatedly. Measurements including nonlinear effects seem to differ only slightly

from measures considering only linear effects. One interesting observation is that nonlinear information transfer from NAHB to SPCS20 is higher at lower lags than linear effects.

It is also very interesting to see the results of measuring the opposite directional effect—pictured in the two subfigures in column two of Figure 3. Causal relations from SPCS20 to NAHB are only found with nonlinear estimators and seem to be more dependent on the chosen subsample. We observed moderate variation in the median and interquartile range of these KSG boxplots using different sets of start and end combinations, whereas this was not the case for the transfer from NAHB to SPCS20. Hence, the top right subfigure of Figure 3 features larger boxplots and more erratic measurements. Consequently, there could be a problem with the robustness of these results. It is also important to note that only nonlinear causal relations seem to be observable repeatedly when considering information flow from SPCS20 to NAHB. Hence, the bottom right subfigure of Figure 3 shows no prominent linear information transfer. We conclude that robust information flow at a stable extent can be observed with different estimators when considering causal effects from NAHB to SPCS20, whereas the opposite measures are not robust and only nonlinear, where present at all.

As already discussed, this empirical study uses the transfer entropy approach to confirm or invalidate the results from Granger causality tests reported by Rodriguez Gonzalez et al. (2018). Results of a hyperparameter study indicate that causal information flow from NAHB to SPCS20 seems not to be present in a very robust way when only considering lower lags, however, a joint information transfer is very prominent when considering an increasing number of lags. Further analysis showed that the information transfer from SPCS20 to NAHB seems to be nonlinear and fragile depending on the chosen time series subsample. Our hyperparameter study uncovered interesting behaviours regarding the ability to detect linear and nonlinear relations in different directions depending on the settings. We believe that further insights about the nature of the causal relationship can be derived from studying the results of a deeper hyperparameter analysis. The approach reported here uses machine learning workflows that can easily be extended to incorporate multivariate analysis of time series and further hyperparameter settings. We plan to employ the concept presented here to both, broaden and deepen our study to incorporate further time series to condition on, as well as finer granularities of further parameters. To do this, we can transfer the machine learning pipeline to a data centre cluster as it is able to run in typical big data and machine learning environments.

7 | IMPLICATIONS FOR THE EUROPEAN FINANCIAL SERVICES INDUSTRY

It certainly should not be questioned that European financial service firms with a direct exposure to the US real estate market (e.g., institutions owning commercial or residential real estate assets) ought to closely monitor housing prices in North America. Additionally, credit exposure to US real estate assets has to be kept in focus in this context. In fact, European banks played an important role in the subprime crisis because of their holdings of mortgage backed securities which created direct exposure to the US real estate market (see e.g., Hellwig, 2009; Noeth & Sengupta, 2012). Bullard et al. (2009) have stressed that as long as US house prices were rising most mortgage backed securities performed well (which means before the peak of the subprime crisis was reached) because borrowers were usually able to sell real estate assets without suffering losses when they were unable to make loan payments. But this changed with falling house prices. Consequently, investors that held large portfolios of mortgage backed

securities all of a sudden had to cope with substantial losses. In this context Mizen (2008) has stressed the fact that some international investors had no experience with US real estate practices. In addition to this important problem there may also have been some difficulties with the risk management processes in many financial services firms back then. Lang and Jagtiani (2010), for example, have stressed the role of financial risk managers to improve our understanding of this crisis. As already noted, the crisis also created a challenge for banking regulation. Cherpack and Jones (2013), for instance, have argued convincingly that the subprime crises in the United States has triggered a strong response by regulators forcing the banks to improve their risk management systems. This change in the regulatory environment was not only observable in the United States. In any case, regulators clearly also played a role in the crisis (see e.g., Swan, 2009; Vazquez & Federico, 2015). After some very costly bank bailouts politicians and regulators wanted financial services firms to become more risk averse. There also have been discussions about possible linkages between the US subprime crisis and the European sovereign debt crisis (see e.g., Ureche-Rangau & Burietz, 2013; Wegener et al., 2019). The latter crisis obviously also has brought about major challenges for risk managers in the European financial services industry. More specifically, the events in the US mortgage market may have increased the level of risk aversion among investors in other countries. Therefore, the subprime crisis in the United States might have raised the awareness of asset managers that there could also be neglected risks buying government bonds issued by less fiscally prudent member countries of the European Monetary Union (e.g., Greece or Portugal). Chang and Leblond (2015), for example, have examined the behaviour of fixed income investors before, during and after the sovereign debt crisis in Europe in some detail. In this context, it has to be stressed that the costly bank rescue programmes also worsened the fiscal difficulties in many European countries and increased the premium for sovereign credit risk these issuers of government bonds had to offer to find investors (see e.g., Basse at al., 2012; Ejsing & Lemke, 2011). In any case, European financial services firms with an exposure to North American real estate assets should adopt appropriate measures to monitor the US property market. An early warning system for house prices in North America could definitely be a central component of such a risk management approach.

But there also is a more macroeconomic dimension. Fleming (1997) as well as Fleming and Remolona (1999), for example, have convincingly argued that announcements of surprising data for US key economic indicators can have strong effects on bond prices and interest rates in North America. Given that the real estate market is of high importance for the US economy (see e.g., Bouchouicha & Ftiti, 2012; Dogan & Topuz, 2020) it certainly does also make sense for risk managers working in financial institutions that have no direct or indirect exposure to the real estate market in North America to monitor US housing prices as soon as they hold some fixed income securities denominated in US dollars. In fact, Bouchouicha and Ftiti (2012) have noted real estate prices are considered to be one of the channels through which monetary policy affects the US economy. Therefore, all financial institutions with an exposure to the US bond market should at least in some way also analyze property prices in North America. Additionally, it has to be stressed that the US bond market is of global relevance. Most importantly, there is clear evidence for a rather strong influence of US interest rates on the behaviour of bond yields in Germany and other countries (see e.g., Bremnes et al., 2001; Monadjemi, 1997). Bremnes et al. (2001), for example, have reported convincing empirical evidence that US interest rates have a significant influence on both German and Norwegian interest rates, whereas the reverse effect at best seems to be modest. Moreover, US equity markets also seem to have a special importance for global share prices (see, amongst others,

Gjerde & Sættem, 1995; Syriopoulos, 2007). Syriopoulos (2007), for instance, has noted that there is clear empirical evidence for the very important global role of the US equity market and has also shown that the introduction of the common European currency has not changed this special status. Therefore, even European financial service firms that do not hold US assets could have an incentive to closely monitor the real estate market in North America. Phrased somewhat differently, US house prices seem to matter for the North American bond and equity markets and, therefore, are also potentially relevant for interest rates and stock prices in Europe and other parts of the world. In this context Tiwari et al. (2020) have stressed the need to take into account potential tail events such as the US subprime crisis when analysing spillover-effects between the North American real estate market and financial asset returns. Schwert (2011), for example, has examined the link between financial markets and real economic activity in this crisis in some detail. An extensive literature overview of the causes of the global financial crisis and the European sovereign debt crisis focussing on financial regulation is provided, for example, by Meier et al. (2021). Moreover, Gorton (2009) has analyzed the origins of the crisis. In any case, there are a lot of good reasons for financial services firms (like banks, asset managers or insurance companies) in Europe to closely examine housing prices in the United States — even for those institutions that have no direct exposure to the North American real estate market.

8 | CONCLUSION

The empirical evidence reported above seems to imply that the NAHB housing market index can help to forecast US house prices robustly, even with linear relations. An interesting outcome of our hyperparameter grid search is that only fragile nonlinear relations seem to exist in the opposite direction when considering stationary derivates. The machine learning pipeline presented here offers an easy way to further study these effects in even finer detail on a data centre cluster. Thus, the findings of Rodriguez Gonzalez et al. (2018) are validated and extended using a completely different methodological approach (namely transfer entropy) and were uncovered using a machine learning workflow. Consequently, there is additional empirical evidence for the ability of sentiment indicators to predict real estate prices in the United States. Moreover, the testing procedure used here is not based on the traditional Granger causality approach. This fact renders the results reported above particularly interesting. At this point, it has to be noted that the optimal number of time lags considered in the VAR estimated by Rodriguez Gonzalez et al. (2018) is lower than the optimal number of time lags considered here. In any case, the information provided by the NAHB housing market index certainly can be helpful for financial risk managers building forward-looking early warning system for US house prices. As already noted, this is very important because modern risk management approaches ought to be guided by the idea that the responsible personal in an organisation is not just waiting for bad things to happen. The empirical findings reported above, of course, are of special importance for US financial institutions with a strong exposure to real estate assets in North America. However, the experiences during the recent global financial crisis do show that the results should also matter for banks and other financial services firms that are located in Asia or Europe (see, e.g., Noeth & Sengupta, 2012; Wegener et al., 2019). Moreover, the empirical approach that is used in this paper has also great potential in the field of applied econometrics. In fact, this empirical study shows just one possible application where the concept of entropy can be usefully employed. In particular, this technique can be applied to

check the results of Granger causality tests. With regard to real estate economics the concept of entropy could, for instance, be employed to examine the lead–lag relationship between the returns of real estate investment trusts and changes to house prices. This important research question already has been analyzed using Granger causality tests (see e.g., He, 2000; Myer & Webb, 1993). Of course there are also further potential applications in other fields of economics and finance. Future research in the area of energy economics, for example, could focus on the relationship between energy consumption and economic growth (see, amongst others, Belke et al., 2011; Tsani, 2010). With regard to macroeconomics the concept of entropy might, for instance, be used to search for appropriate leading indicators of economic growth (see e.g., Breitung & Candelon, 2006; Huh, 2002). Beyond that, this approach seems to be suitable to search for ripple effects among regional housing prices (see, amongst others, Lee & Chien, 2011; Shi et al., 2009). Furthermore, the concept of entropy could also be helpful in the corporate finance literature to test for dividend signalling or dividend smoothing examining time series data (see, for instance, Basse & Reddemann, 2011; Goddard et al., 2006).

REFERENCES

Anaconda Software Distribution. (2020). Anaconda documentation. *Anaconda Inc*. https://docs.anaconda.com/

Apache Airflow. (2020). Apache Software Foundation. https://airflow.apache.org/

Athey, S. (2018). The impact of machine learning on economics, *The economics of artificial intelligence: An agenda* (pp. 507–547). University of Chicago Press.

Aylward, A., & Glen, J. (2000). Some international evidence on stock prices as leading indicators of economic activity. *Applied Financial Economics*, *10*, 1–14.

Basse, T., Friedrich, M., & Kleffner, A. (2012). Italian government debt and sovereign credit risk: An empirical exploration and some thoughts about consequences for European insurers. *Zeitschrift für die gesamte Versicherungswissenschaft*, *101*, 571–579.

Basse, T., & Reddemann, S. (2011). Inflation and the dividend policy of US firms. *Managerial Finance*, *37*, 34–46.

Basuchoudhary, A., Bang, J. T., & Sen, T. (2017). *Machine-learning techniques in economics: New tools for predicting economic growth*. Springer.

Behrendt S., Prange P. (2021). What are you searching for? On the equivalence of proxies for online investor attention. *Finance Research Letters*, *38*. http://doi.org/10.1016/j.frl.2019.101401

Belke, A., Dobnik, F., & Dreger, C. (2011). Energy consumption and economic growth: New insights into the cointegration relationship. *Energy Economics*, *33*, 782–789.

Blake, J. P., & Gharleghi, B. (2018). The ripple effect at an inter-suburban level in the Sydney metropolitan area. *International Journal of Housing Markets and Analysis*, *11*, 2–33.

Bossomaier, T., Barnett, L., Harré, M., & Lizier, J. T. (2016a). Information flow in complex systems, *An introduction to transfer entropy* (pp. 1–10). Springer.

Bossomaier, T., Barnett, L., Harré, M., & Lizier, J. T. (2016b). Information flow in complex systems, *An introduction to transfer entropy* (pp. 65–95). Springer.

Bouchouicha, R., & Ftiti, Z. (2012). Real estate markets and the macroeconomy: A dynamic coherence framework. *Economic Modelling*, *29*, 1820–1829.

Breden, D. (2008). Monitoring the operational risk environment effectively. *Journal of Risk Management in Financial Institutions*, *1*, 156–164.

Breitung, J., & Candelon, B. (2006). Testing for short-and long-run causality: A frequency-domain approach. *Journal of Econometrics*, *132*, 363–378.

Bremnes, H., Gjerde, Ø., & Sættem, F. (2001). Linkages among interest rates in the United States, Germany and Norway. *Scandinavian Journal of Economics*, *103*, 127–145.

Bullard, J., Neely, C. J., & Wheelock, D. C. (2009). Systemic risk and the financial crisis: A primer. *Federal Reserve Bank of St. Louis Review*, *91*, 403–418.

Bzdok, D., Krzywinski, M., & Altman, N. (2017). Machine learning: A primer. *Nature Methods*, *14*, 1119–1120. https://doi.org/10.1038/nmeth.4526

Cass, S. (2018). The 2018 top programming languages—Python stays on top and Assembly enters the Top Ten. *IEEE Spectrum*. https://spectrum.ieee.org/at-work/innovation/the-2018-top-programming-languages

Chang, M., & Leblond, P. (2015). All in: Market expectations of eurozone integrity in the sovereign debt crisis. *Review of International Political Economy*, *22*, 626–655.

Cheng, H. (1979). Causality tests in econometrics. *Journal of Economic Dynamics and Control*, *1*, 321–346.

Cherpack, P. L., & Jones, B. W. (2013). Community bank proactive risk management: Concentration management, stress testing and capital planning. *Journal of Risk Management in Financial Institutions*, *6*, 411–432.

Clayton, J., Ling, D. C., & Naranjo, A. (2009). Commercial real estate valuation: Fundamentals versus investor sentiment. *The Journal of Real Estate Finance and Economics*, *38*, 5–37.

Cooray, A., & Wickremasinghe, G. (2007). The efficiency of emerging stock markets: Empirical evidence from the South Asian region. *Journal Of Developing Areas*, *41*, 171–183.

Croce, R. M., & Haurin, D. R. (2009). Predicting turning points in the housing market. *Journal of Housing Economics*, *18*, 281–293.

Dietzel, M. A., Braun, N., & Schäfers, W. (2014). Sentiment-based commercial real estate forecasting with Google search volume data. *Journal of Property Investment and Finance*, *32*, 540–569.

Dimpfl, T., & Peter, F. J. (2013). Using transfer entropy to measure information flows between financial markets. *Studies in Nonlinear Dynamics and Econometrics*, *17*(1). http://doi.org/10.1515/snde-2012-0044

Dimpfl, T., & Peter, F. J. (2014). The impact of the financial crisis on transatlantic information flows: An intraday analysis. *Journal of International Financial Markets, Institutions and Money*, *31*, 1–13.

Dogan, C., & Topuz, J. C. (2020). Real effects of real estate: Evidence from unemployment rates. *Studies in Economics and Finance*, *37*, 605–623.

Eichengreen, B., Mody, A., Nedeljkovic, M., & Sarno, L. (2012). How the subprime crisis went global: Evidence from bank credit default swap spreads. *Journal of International Money and Finance*, *31*, 1299–1318.

Ejsing, J., & Lemke, W. (2011). The Janus-headed salvation: Sovereign and bank credit risk premia during 2008–2009. *Economics Letters*, *110*, 28–31.

Elliott, G., Rothenberg, T. J., & Stock, J. H. (1996). Efficient tests for an autoregressive unit root. *Econometrica*, *64*, 813–836.

Fleming, M. J. (1997). The round-the-clock market for US Treasury securities. *Economic Policy Review*, *3*, 9–32.

Fleming, M. J., & Remolona, E. M. (1999). What moves bond prices? *Journal of Portfolio Management*, *25*, 28–38.

Geweke, J. (1984). Chapter 19. Inference and causality in economic time series models, *Handbook of econometrics* (Vol. 2, pp. 1101–1144). Elsevier.

Gjerde, Ø., & Sættem, F. (1995). Linkages among European and world stock markets. *European Journal of Finance*, *1*, 165–179.

Goddard, J., McMillan, D. G., & Wilson, J. O. (2006). Dividend smoothing vs dividend signalling: evidence from UK firms. *Managerial Finance*, *32*, 493–504.

Goodman, J. (1994). Using attitude data to forecast housing activity. *Journal of Real Estate Research*, *9*, 445–453.

Gorton, G. (2009). The subprime panic. *European Financial Management*, *15*, 10–46.

Granger, C. W. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica*, *37*, 424–438.

Granger, C. W. (1988). Some recent development in a concept of causality. *Journal of Econometrics*, *39*, 199–211.

Green, R. K. (2002). Stock prices and house prices in California: New evidence of a wealth effect? *Regional Science and Urban Economics*, *32*, 775–783.

Gómez-Herrero, G., Wu, W., Rutanen, K., Soriano, M. C., Pipa, G., & Vicente, R. (2015). Assessing coupling dynamics from an ensemble of time series. *Entropy*, *17*, 1958–1970.

Hausler, J., Ruscheinsky, J., & Lang, M. (2018). News-based sentiment analysis in real estate: A machine learning approach. *Journal of Property Research*, *35*, 344–371.

He, L. (2000). Causal relationships between apartment REIT stock returns and unsecuritized residential real estate. *Journal of Real Estate Portfolio Management*, *6*, 365–372.

Hellwig, M. F. (2009). Systemic risk in the financial sector: An analysis of the subprime-mortgage financial crisis. *De Economist*, *157*, 129–207.

Hiemstra, C., & Jones, J. D. (1994). Testing for linear and nonlinear Granger causality in the stock price-volume relation. *Journal of Finance*, *49*, 1639–1664.

Hinton, G. E., Krizhevsky, A., & Sutskever, I. (2012). Imagenet classification with deep convolutional neural networks. *Advances in Neural Information Processing Systems*, *25*, 1106–1114.

Huang, M. (2019). Markov-switching impacts of housing-market expectations on credit markets. *Managerial Finance*, *46*(3), 381–400. http://doi.org/10.1108/mf-08-2019-0391

Huh, H. S. (2002). GDP growth and the composite leading index: A nonlinear causality analysis for eleven countries. *Economics Letters*, *77*, 93–99.

Jorion, P. (2009). Risk management lessons from the credit crisis. *European Financial Management*, *15*, 923–933.

Kraskov, A., Stögbauer, H., & Grassberger, P. (2004). Estimating mutual information. *Physical Review E*, *69*, 066138.

Kunze, F., Basse, T., Rodriguez Gonzalez, R., & Vornholz, G. (2020). Forward-looking financial risk management and the housing market in the United Kingdom: Is there a role for sentiment indicators? *Journal of Risk Finance*, *21*, 659–678.

Lang, W. W., & Jagtiani, J. A. (2010). The mortgage and financial crises: The role of credit risk management and corporate governance. *Atlantic Economic Journal*, *38*, 123–144.

Lee, C. C., & Chien, M. S. (2011). Empirical modelling of regional house prices and the ripple effect. *Urban Studies*, *48*, 2029–2047.

Liu, S., Sathye, M., Chang, C. L., Jiménez-Martín, J. Á., McAleer, M., & Pérez-Amaral, T. (2011). Risk management of risk under the Basel Accord: Forecasting value-at-risk of VIX futures. *Managerial Finance*, *37*, 1088–1106.

Lizier, J. T. (2014). JIDT: An information-theoretic toolkit for studying the dynamics of complex systems. *Frontiers in Robotics and AI*, *1*, 11.

Luo, Z., Liu, C., & Picken, D. (2007). Granger causality among house price and macroeconomic variables in Victoria. *Pacific Rim Property Research Journal*, *13*, 234–256.

Luu Duc Huynh, T. (2019). Spillover risks on cryptocurrency markets: A look from VAR-SVAR Granger causality and Student's t copulas. *Journal of Risk and Financial Management*, *12*, 52.

López de Prado, M. (2019). Beyond econometrics: A roadmap towards financial machine learning. https://ssrn.com/abstract=3365282

Maddala, G. S., & Wu, S. (1999). A comparative study of unit root tests with panel data and a new simple test. *Oxford Bulletin of Economics and Statistics*, *61*, 631–652.

Marcato, G., & Nanda, A. (2016). Information content and forecasting ability of sentiment indicators: Case of real estate market. *Journal of Real Estate Research*, *38*, 165–203.

Marschinski, R., & Kantz, H. (2002). Analysing the information flow between financial time series. *European Physical Journal B*, *30*, 275–281.

McLaren, N., & Shanbhogue, R. (2011). Using Internet search data as economic indicators. *Bank of England Quarterly Bulletin*, *51*, 134–140.

Meier, S., Rodriguez Gonzalez, M., & Kunze, F. (2021). The global financial crisis, the EMU sovereign debt crisis and international financial regulation: Lessons from a systematic literature review. *International Review of Law and Economics*, *65*, 105945. https://doi.org/10.1016/j.irle.2020.105945

Mizen, P. (2008). The credit crunch of 2007-2008: A discussion of the background, market reactions, and policy responses. *Federal Reserve Bank of St. Louis Review*, *90*, 531–567.

Mjolsness, E., & Decoste, D. (2001). Machine learning for science: State of the art and future prospects. *Science (New York, N.Y.)*, *293*, 2051–2055. https://doi.org/10.1126/science.293.5537.2051

Monadjemi, M. S. (1997). International interest rates linkages: evidence from OECD countries. *International Review of Financial Analysis*, *6*, 229–240.

Myer, F. N., & Webb, J. (1993). Return properties of equity REITs, common stocks, and commercial real estate: A comparison. *Journal of Real Estate Research*, *8*, 87–106.

Noeth, B., & Sengupta, R. (2012). Global European banks and the financial crisis. *Federal Reserve Bank of St. Louis Review*, *94*, 457–479.

Osiobe, E. U. (2020). Human capital, capital stock formation, and economic growth: A panel Granger causality analysis. *Journal of Economics and Business*, *3*, 569–582.

R Core Team (2019). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. https://www.R-project.org/

Ramirez, S. R. (2019). An examination of firm licensing behaviour after a payday-loan ban. *Applied Economics*, *51*, 5090–5103.

Rochette, M. (2009). From risk management to ERM. *Journal of Risk Management in Financial Institutions*, *2*, 394–408.

Rodriguez Gonzalez, M., Basse, T., Kunze, F., & Vornholz, G. (2018). Early warning indicator systems for real estate investments: Empirical evidence and some thoughts from the perspective of financial risk management. *Zeitschrift für die gesamte Versicherungswissenschaft*, *107*, 387–403.

van Rossum, G., & Drake, F. L. (2009). *Python 3 reference manual*. CreateSpace.

Runge, J. (2018). Causal network reconstruction from time series: From theoretical assumptions to practical estimation. *Chaos: An Interdisciplinary Journal of Nonlinear Science*, *28*, 075310.

Rényi, A. (1970). *Probability theory*. North-Holland.

Schreiber, T. (2000). Measuring information transfer. *Physical Review Letters*, *85*, 461–464.

Schwert, G. W. (2011). Stock volatility during the recent financial crisis. *European Financial Management*, *17*, 789–805.

Shannon, C. E. (1948). A mathematical theory of communication. *Bell System Technical Journal*, *27*, 379–423.

Shi, S., Young, M., & Hargreaves, B. (2009). The ripple effect of local house price movements in New Zealand. *Journal of Property Research*, *26*, 1–24.

Simon, B., Thomas, D., Franziska, J. P., & David, J. Z. (2019). RTransferEntropy—Quantifying information flow between different time series using effective transfer entropy. *SoftwareX*, *10*(100265), 1–9.

Swan, P. L. (2009). The political economy of the subprime crisis: Why subprime was so attractive to its creators. *European Journal of Political Economy*, *25*, 124–132.

Syczewska, E. M., & Struzik, Z. R. (2014). Granger causality and transfer entropy for financial returns. *Acta Physica Polonica A*, *127*(3–A), 129–135.

Syriopoulos, T. (2007). Dynamic linkages between emerging European and developed stock markets: Has the EMU any impact? *International Review of Financial Analysis*, *16*, 41–60.

Teye, A. L., Knoppel, M., de Haan, J., & Elsinga, M. G. (2017). Amsterdam house price ripple effects in The Netherlands. *Journal of European Real Estate Research*, *10*, 331–345.

Tiwari, A. K., André, C., & Gupta, R. (2020). Spillovers between US real estate and financial assets in time and frequency domains. *Journal of Property Investment and Finance*, *38*, 525–537.

Toda, H. Y., & Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. *Journal of Econometrics*, *66*, 225–250.

Tsani, S. Z. (2010). Energy consumption and economic growth: A causality analysis for Greece. *Energy Economics*, *32*, 582–590.

Tsolacos, S. (2012). The role of sentiment indicators for real estate market forecasting. *Journal of European Real Estate Research*, *5*, 109–120.

Ureche-Rangau, L., & Burietz, A. (2013). One crisis, two crises... the subprime crisis and the European sovereign debt problems. *Economic Modelling*, *35*, 35–44.

Vazquez, F., & Federico, P. (2015). Bank funding structures and risk: Evidence from the global financial crisis. *Journal of Banking and Finance*, *61*, 1–14.

Vicente, R., Wibral, M., & Lindner, M. (2011). Transfer entropy—A model-free measure of effective connectivity for the neurosciences. *Journal of Computational Neuroscience*, *30*, 45–67.

Wegener, C., Kruse, R., & Basse, T. (2019). The walking debt crisis. *Journal of Economic Behavior and Organization*, *157*, 382–402.

Wilcox, J. A. (2015). The home purchase sentiment index: A new housing indicator. *Business Economics*, *50*, 178–190.

Wollstadt, P., Lizier, J., Vicente, R., Finn, C., Martinez-Zarzuela, M., Mediano, P., Novelli, L., & Wibral, M. (2019). IDTxl: The Information Dynamics Toolkit xl: a Python package for the efficient analysis of multivariate information dynamics in networks. *Journal of Open Source Software*, *4*(34) http://doi.org/10.21105/joss.01081

Wood, R. (2003). The information content of regional house prices: can they be used to improve national house price forecasts? *Bank of England Quarterly Bulletin*, *43*, 304–314.

Xie, Z., & Chen, S. W. (2014). Untangling the causal relationship between government budget and current account deficits in OECD countries: Evidence from bootstrap panel Granger causality. *International Review of Economics and Finance*, *31*, 95–104.

Zapata, H. O., & Rambaldi, A. N. (1997). Monte Carlo evidence on cointegration and causation. *Oxford Bulletin of Economics and Statistics*, *59*, 285–298.

How to cite this article: Rodriguez Gonzalez, M., Basse, T., Saft, D., & Kunze, F. (2021). Leading indicators for US house prices: New evidence and implications for EU financial risk managers. *European Financial Management*, 1–22.
https://doi.org/10.1111/eufm.12325

Module 7

Asset Liability Management and the Euro Crisis — Sovereign Credit Risk as a Challenge for the German Life Insurance Industry

Rodriguez Gonzalez, M. / Kunze, F. / Schwarzbach, C. / Dieng, C. (2017)

Published in:
The Journal of Risk Finance, Vol. 18, No. 4, pp. 466–483. DOI:
https://doi.org/10.1108/JRF-01-2017-0016.

The article can be found here:

https://doi.org/10.1108/JRF-01-2017-0016

Module 8

Risk Premia and the European Government Bond Market: New Empirical Evidence and some Thoughts from the Perspective of the Life Insurance Industry

Tholl, J. / Basse, T. / Meier, S. / Rodriguez Gonzalez, M. (2021)

published in:
Zeitschrift für die gesamte Versicherungswissenschaft. DOI:
https://doi.org/10.1007/s12297-021-00503-2.

ZVersWiss
https://doi.org/10.1007/s12297-021-00503-2

ABHANDLUNG

Risk premia and the European government bond market: new empirical evidence and some thoughts from the perspective of the life insurance industry

Johannes Tholl · Tobias Basse · Samira Meier · Miguel Rodriguez Gonzalez

Accepted: 6 August 2021

Abstract We study yield spreads between government bonds in the European Monetary Union. This segment of the global fixed income market is of particular importance for insurance companies in Europe. Our empirical research strategy is inspired by Gunay (2020) who has analyzed the relationship between credit and liquidity risk in the United States using Granger causality tests. More specifically, we employ the procedure developed by Toda and Yamamoto (1995) to test for Granger causality among yield spreads in five different member countries of the European Monetary Union (namely Austria, Belgium, France, Italy and Ireland) relative to Germany. We examine interest rate data from bonds with three different maturities (5, 10 and 30 years). Given the importance of long-term bonds as asset class for European life insurers and pension funds, the empirical results from the often ignored market for government bonds with a maturity of 30 years should be of interest. With regard to long-term sovereign debt, there is no evidence for Granger causality among the time series examined here. Consequently, the risk premia required by investors to hold government bonds of one specific member country of the EMU do not help to forecast the risk premia that have to be paid by other countries. Given the structure of their liabilities, this empirical finding should be of high relevance for portfolio and

Johannes Tholl
Universität Bayreuth, Universitätsstraße 30, 95447 Bayreuth, Germany

Tobias Basse
Norddeutsche Landesbank Girozentrale, Friedrichswall 10, 30159 Hannover, Germany

Touro College Berlin, Am Rupenhorn 5, 14055 Berlin, Germany

Samira Meier
Mendel University Brno, Zemědělská 1665, 61300 Brno-sever-Černá Pole, Czech Republic

Miguel Rodriguez Gonzalez (✉)
Leibniz University Hannover, Otto-Brenner-Straße 7, 30159 Hannover, Germany
E-Mail: mr@ivbl.uni-hannover.de

risk managers in the European life insurance industry and in pension funds. With regard to the yield spreads to be observed in the market for 10-year government bonds, there seems to be no clear picture. Focusing on fixed income securities with a maturity of 5 years, there is one very interesting empirical finding. The test results reported here seem to imply that there is unidirectional Granger causality running from the yield spreads in all other four countries to Austria. Given that Austria is a comparably small country which is assumed to be in a fiscally stable position, this result could be interpreted as evidence for credit risk premia as being helpful to forecast liquidity risk premia in the market for medium-term government bonds issued by member states of the European Monetary Union.

JEL-Codes G12, G18, G22, G28, G52.

Risikoprämien am europäischen Staatsanleihenmarkt: Neue empirische Erkenntnisse und Überlegungen aus der Sicht der Lebensversicherungsbranche

Zusammenfassung Diese Studie untersucht Zinsdifferenzen am Markt von Staatsanleihen der Mitgliedsländer der Europäischen Währungsunion. Dieses Segment des globalen Rentenmarktes hat eine besondere Bedeutung für europäische Versicherungsunternehmen. Unsere empirische Studie ist von Gunay (2000) inspiriert, der den Zusammenhang zwischen Kredit- und Liquiditätsrisiko in den Vereinigten Staaten mittels Grangerkausalitätstests untersucht. Genauer gesagt findet hier der Ansatz von Toda und Yamamoto (1995) Anwendung. Untersucht werden die Zinsdifferenzen von fünf Ländern (Österreich, Belgien, Frankreich, Italien und Irland) zu Deutschland. Dabei wird auf drei Laufzeiten (5, 10 und 30 Jahre) geblickt. Der häufig in empirischen Studien ignorierte Markt für Staatsanleihen mit einer Restlaufzeit von 30 Jahren dürfte aufgrund der Struktur der Verbindlichkeiten von besonderem Interesse für Lebensversicherer und Pensionsfonds sein. In diesem Segment des europäischen Staatsanleihemarktes konnten wir keine Hinweise auf Grangerkausalität zwischen den Zinsdifferenzen finden. Die von den hier betrachteten Ländern für ihre Schulden zu zahlenden Risikoprämien helfen somit nicht, die Risikoprämien in den jeweils anderen untersuchten Nationen vorherzusagen. Dieses Ergebnis sollte von hoher Bedeutung für Kapitalanleger und Risikomanager bei europäischen Lebensversicherungen und Pensionsfonds sein. Im Laufzeitsegment 10 Jahre ergibt sich kein klares Bild. Bei den Zinsdifferenzen der Papiere mit einer Laufzeit von 5 Jahren zeigt sich dagegen klar, dass die Risikoprämien in allen anderen Ländern helfen, die Zinsdifferenz von Österreich zu Deutschland vorherzusagen. Da Österreich eher ein kleines Land mit relativ soliden Staatsfinanzen ist, mag dieses Ergebnis ein Hinweis darauf sein, dass das Kreditrisiko in diesem Segment des europäischen Rentenmarktes zur Prognose des Liquiditätsrisikos verwendet werden kann.

1 Introduction

Low interest rates are currently a major problem for the European life insurance industry (see, for example, Basse et al. 2014 and Berdin and Gründl 2015). As a matter of fact, Berdin and Gründl (2015) have argued convincingly that prolonged periods with low long-term interest rates can be regarded as a possibly very dangerous threat to the solvency of those life insurers in Europe that, in the past, have extensively sold policies with expensive guarantees to their customers. This problem is particularly acute in the case of those life insurers that have invested in fixed income securities with durations shorter than those of their liabilities. In any case, the current interest rate environment has caused a hunt for yield among investors that traditionally prefer to buy high quality fixed income securities (see, for example, Conner 2016 and Boubaker et al. 2017). Generally speaking, the low level of interest rates observed today regarding low-risk bonds denominated in Euro is, of course, a direct consequence of the European Central Bank's (ECB) monetary policy. This policy has applied conventional and unconventional tools to provide stimuli to the crisis-shaken economies in the currency union (see, for example, Burriel and Galesi 2018 and Rodriguez Gonzalez et al. 2019). As will be discussed subsequently in more detail, the severe fiscal problems faced by some countries that belong to the European Monetary Union (EMU) have also caused fears about sovereign credit risk and redenomination risk among investors. As a consequence, risk premia have increased resulting in higher yield spreads of bonds issued by countries that suffer from fiscal challenges. In fact, given the regulatory environment (Solvency II) implemented in the European Union (EU) it could be an interesting option for life insurers to buy government bonds issued by member states of the EMU that have to cope with budgetary difficulties (see, most importantly, Basse et al. 2012 and Ludwig 2014).

The rather high risk premia, that the EMU member countries with fiscal imbalances have to pay in order to issue bonds at the moment, certainly could help life insurers to cope with the problems originating from the guarantees embedded in the old policies they have sold to their customers. However, as Lempérière et al. (2017) have persuasively outlined, there are still major problems when trying to explain how risk premia are determined. Additional empirical evidence with regard to interest rate differentials between government bond yields issued by EMU member countries, with and without budgetary problems, certainly is of importance. Currently, the literature examining sovereign yield spreads in the Eurozone seems to follow a macroeconomic approach by, for instance, analyzing the role of the volume of government debt relative to the respective real gross domestic product or the terms of trade as explanatory variables for interest rate differentials (see, amongst others, Maltritz 2012 and Oliveira et al. 2012). This paper takes a different approach by focusing on the information flow between the sovereign yield spreads, examining data from selected member countries of the EMU. To be more precise, lead-lag relationships between interest rate differentials in a number of member countries of the common currency area are examined in detail. Consequently, the question of predictability is another issue. In other words, it is analyzed whether specific interest rate differentials can help to predict other yield spreads. In order to do so, the

concept of Granger causality is employed (see, most importantly, Granger 1969). More specifically, the procedure suggested by Toda and Yamamoto (1995) is used to test for Granger causality (respectively Granger non-causality). Gunay (2020) has already applied this technique to analyze the relationship between liquidity risk and credit risk in the United States. Our study tries to further explore this issue. As already noted we focus on data from the European government bond market. Moreover, the results of our empirical investigations are then primarily assessed from the perspective of the European life insurance industry. However, these findings obviously should also be of interest for the financial economics community in general.

The paper is structured as follows: Section 2 considers the role of government bonds as asset class for European life insurers. In the 3rd section, regulatory issues are examined focusing on Solvency II. Section 4 then briefly addresses the relevant types of risk. The 5th section discusses the tendencies towards interest rate convergence in the currency union after the introduction of the Euro, and then considers the role of the European sovereign debt crisis as well as other related problems. In this context, the ECB's monetary policy response to the economic crisis caused by the on-going Covid-19 pandemic in Europe and other parts of the world is considered in the 6th section. After discussing some relevant methodological issues, the data is presented in the 7th section. The results of our empirical investigations are discussed and evaluated in section 8. The last section then concludes.

2 Government bonds as asset class for European life insurers

Since long-maturity sovereign bonds are an asset class of particular importance for long-term investors like life insurance companies, this chapter sheds some light on the manifold reasons for the relevance of this asset class for European life insurers. In general, life insurers' business models are broadly clustered into two product categories: life risk products covering the risk of mortality, and life savings products covering the risk of longevity. Especially the old-age provision business of life insurance is particularly susceptible to interest rate changes. Because of these liabilities with a high duration, the investment horizon of life insurers is rather long-term oriented. This fact may even help to stabilize financial markets by anti-cyclical investment behavior, respectively stimulating economic growth (see, for example, Della Croce et al. 2011 and Focarelli 2017). This highlights the macroeconomic relevance of this financial sector, even though, in the case of sovereign bonds, there are indications of a pro-cyclical investment behavior in economic crises—like the European sovereign debt crisis (see, for instance, Bijlsma and Vermeulen 2016 and Fache Rousová and Giuzio 2019). Moreover, Düll et al. (2017), find evidence for a transmission of sovereign risk to the default risk of insurance companies in the wake of the European sovereign debt crisis, which further illustrates the usefulness of empirical evidence on the lead-lag relationships of EMU sovereign yield spreads. Obviously, the ability to predict future developments of government bond spreads is not only of interest to risk and asset managers in the life insurance industry, as

well as policymakers and regulators, but also to pension funds and other long-term investors with high exposure to sovereign bonds in their portfolios.

As already stated above, investors worldwide faced aggravating developments in capital markets in the follow-up of the Global Financial Crisis. Indeed, Domanski et al. (2017) argue that in case of the EMU, the relevance of long-term government bonds has increased during the European low interest rate environment (see, for instance, ECB 2015 for a detailed discussion of the difficulties faced by the European insurance sector in a prolonged period of low interest rates). Overall, yields on European government bonds have fallen sharply, not only due to the aforementioned hunt for yield among European investors, but also because of a self-reinforcing herding effect and a hunt for duration in the insurance sector, which is to some extent explained by an increasing negative duration gap (see Domanski et al. 2017). Likewise, Gründl et al. (2017) argue, that in the context of sovereign bonds, life insurers are especially interested in long-maturity bonds to match the duration of their assets to their mostly long-term liabilities. According to the 2018 EIOPA insurance stress test report, the average duration of sovereign bond assets is 7.4 years in the insurance industry, in contrast, the average duration of technical provisions (weighted Macaulay) amounts to 12.5 years for life insurers, and thus, indicating an asset liability mismatch (Battiston et al. 2019). Especially large providers of savings products have to deal with a long-term debt structure.

To demonstrate the negative effects in the insurance sector, Fig. 1 shows the guarantee rate contained in classic German life insurance products and the average current interest rate (the sum of the operating profit participation and the guaranteed interest for the life insurance industry weighted by market share) for new business with classic annuity policies. Since the calculation of the maximum technical interest

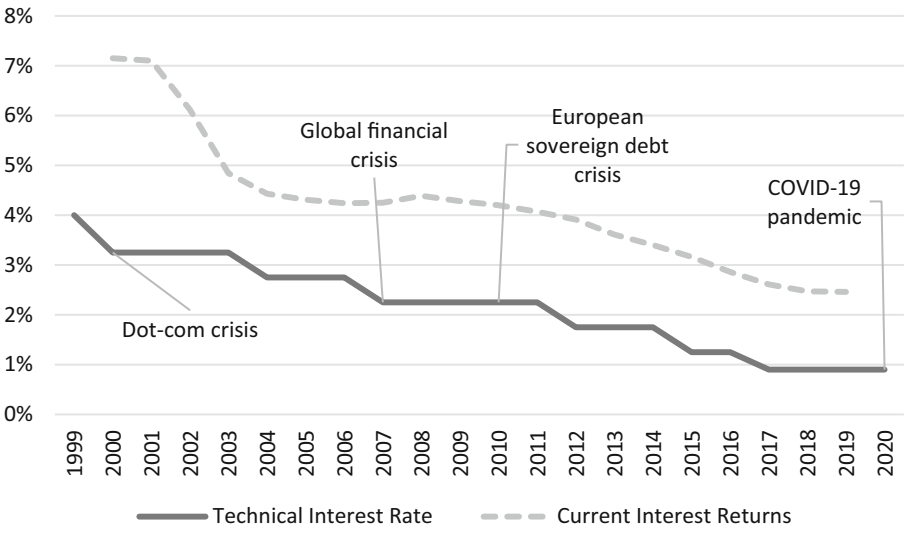


Fig. 1 The current interest rate and the technical interest rate of German life insurance companies. (Source: Own representation based on Statista Research Department (2020) and German Association of Actuaries (2020).)

rate is based on average historical government bond yields (see Eling and Holder 2013), the figure shows that both values are continuously decreasing over time, undoubtedly, because of past financial and economic crises and the current low interest rate environment. Since many insurance contracts have a maturity of several decades and some older policies carry interest rates of up to 4%, many life insurers in Germany still have guarantee obligations of around 2–3% in their portfolios. Accordingly, there is a combination of existing high yield liabilities and continuously decreasing average yields in the traditional life insurance business.

In fact, the ECB's expansive monetary policy reduced interest rates in Europe, which further challenged the EMU insurance market's returns due to a high sensitivity to interest rate changes in this sector (see, for instance, Van Riet 2017 and Jareño et al. 2020). Berdin and Gründl (2015) state that the impact of the ongoing low interest rate environment will be particularly strong for small and medium-sized life insurance companies that are invested strongly in sovereign bonds. According to the authors, two major features of the life insurance industry trigger these effects: firstly, the high share of fixed income securities in insurers' portfolios, and secondly, the high sensitivity of interest rate effects on discount rates of insurance liabilities. Besides the current interest rate landscape that puts further pressure on government bond yields, due to low interest rates combined with high financial obligations (see Niedrig 2015), the impact of the Covid-19 pandemic could affect the insurers' investment behavior, for example because of a lack (and possible worsening) of investment opportunities. However, as described in more detail below, there are many indications that investments in sovereign bonds will prevail, as this is still a preferred investment strategy for the European life insurance industry.

In general, according to Fache Rousová and Giuzio (2019), there are at least five aspects that may influence the insurers' investment behavior: Namely "[...] the type of firm and its business model, the structure of the balance sheet, the investment preferences of its management and stakeholders, market developments and the regulatory framework under which an insurance firm operates." (see Fache Rousová and Giuzio 2019, p. 8). Furthermore, when compared to property-liability insurance, life insurers are interested in generating stable cash flows to generate a more predictable calculation of payouts in life insurance products. Moreover, in the life insurance business, the policy provider and the policyholder usually have a business relationship lasting many decades. For this reason, customers' trust in the long-term solvency of the insurance company is of central importance. Therefore, life insurers are known as conservative investors in the institutional environment, as they are primarily interested in secure investments with low volatility (see Focarelli 2017). As a result, the relationship in European (long-term) government bond yield spreads is of special importance for asset managers in the insurance industry.

In the case of the EMU, also tighter regulatory and solvency requirements, put pressure on investment strategies of pension funds and insurance companies (Gründl et al. 2017). Due to the issuing country's membership in the currency union, EMU government bonds in particular were seen as safe investments—at least until the default of Greece in 2012. In addition, government bonds are particularly important to life insurers because of their regulatory treatment under the Solvency II Directive in EMU countries (see Ludwig 2014 and Braun et al. 2017). In fact,

Table 1 Investment behavior of European insurance companies (in %). (Source: Own representation based on EIOPA (2020a).)

Investments (other than assets held for index-linked and)	2018 Q2	2018 Q3	2018 Q4	2019 Q1	2019 Q2	2019 Q3	2019 Q4	2020 Q1
Propeirntkye (do tchoenrt trhaacnts for own use)	3.19	3.27	3.42	3.27	3.22	3.04	3.11	3.31
Holdings in related undertakings, including participations	6.35	6.25	6.37	6.55	6.13	5.04	6.45	6.08
Equities	5.04	5.05	4.08	4.29	4.23	3.85	3.76	3.72
Equities—listed	4.15	4.12	3.14	3.37	3.33	2.89	2.90	2.69
Equities—unlisted	0.89	0.93	0.95	0.92	0.90	0.96	0.86	1.03
Bonds	69.65	69.59	67.32	66.46	66.34	66.37	64.82	65.66
Government Bonds	34.95	34.78	33.85	33.29	33.37	34.26	32.51	33.63
Corporate Bonds	32.48	32.63	31.42	31.09	30.95	30.18	30.46	30.02
Structured notes	1.39	1.36	1.27	1.23	1.21	1.17	1.31	1.18
Collateralised securities	0.84	0.82	0.77	0.85	0.81	0.77	0.54	0.84
Collective Investments Undertakings	13.40	13.57	16.40	16.56	17.04	17.90	18.45	16.95
Derivatives	1.21	1.14	1.30	1.64	1.88	2.67	2.27	3.09
Deposits other than cash equivalents	0.83	0.82	0.78	0.90	0.82	0.77	0.77	0.86
Other investments	0.32	0.31	0.34	0.32	0.33	0.34	0.36	0.34

Table 2 Insurance companies' asset exposure of CIC 1 government bond assets in selected European countries in Q2 2020. (Source: Own representation based on EIOPA (2020b).)

Country	Exposure	Austria	Belgium	France	Germany	Ireland	Italy	Total
Austria	in %	23.85	9.19	9.92	7.13	3.44	2.95	100
	in EURm	5759	2219	2395	1721	830	711	24,148
Belgium	in %	4.09	52.69	13.16	5.05	1.91	4.57	100
	in EURm	5821	75,056	18,745	7190	2714	6511	142,440
France	in %	2.60	5.42	65.08	2.92	1.08	5.52	100
	in EURm	19,638	40,880	490,854	22,053	8142	41,670	754,270
Germany	in %	4.67	7.78	9.48	41.21	1.77	0.94	100
	in EURm	18,015	30,027	36,589	159,096	6816	3639	386,101
Ireland	in %	4.01	3.67	19.31	13.89	6.43	9.49	100
	in EURm	1732	1586	8345	6002	2778	4102	43,224
ITALY	in %	23.85	9.19	9.92	7.13	3.44	2.95	100
	in EURm	2060	6127	13,742	5719	3780	330,822	415,895

the regulatory minimum capital requirements under the Solvency II regime enable the regulator to provide incentives for supposedly safe asset classes—for example, EMU government bonds. This will be discussed in more detail later on in chapter 3. However, Düll et al. (2017) find empirical evidence for regulatory flaws in the Solvency II Directive related to risks in insurers' government bond portfolios being crucial drivers of insurers' default risk in Europe. To clarify, the equal regulatory treatment of government bonds issued by EMU countries in the internal risk model motivates insurers to invest in European sovereign bonds with the same capital backing requirements, but higher risk premia at the same time. Therefore, in our study, compared to "safe haven assets" like German government bonds, we will analyze both, European government bonds with higher risk premia (like Italy) and lower risk premia (like Austria). Other classification categories are core member states (Austria, Belgium, France) and peripheral member states (Ireland) of the EMU.

The importance of sovereign bonds as asset class is also illustrated by current investment data on the asset structure in the European insurance industry. In Europe, the life insurance sector accounts for 53.62% of all insurers' assets in the second quarter of 2020 and is consequently the largest investor in this industry.[1] In the first quarter of 2020, these companies invested primarily in fixed income products like bonds (65.66%). Table 1 shows that the largest share of capital is invested in government bonds (33.63%) and corporate bonds (30.02%) followed by investment funds (16.95%). These collective investment undertakings represent additional important channels for investing in fixed income securities (see Fache Rousová and Giuzio 2019). Additionally, Table 2 shows the relative and absolute exposures to government bonds in the portfolios of European insurers for the countries analyzed in this paper. The data shows that a high proportion of exposure arises in the domestic market (except in the case of Ireland), but also a large proportion of the total exposure to government bonds in other EMU countries. In brief, Table 1 shows the importance of EMU government bonds as asset class for European insurers, whereby Table 2 stresses the particular importance of being able to identify cross-country lead-lag movements in EMU government bond yield spreads because of the high exposure of bonds of other EMU member countries. As already discussed, insurance market data confirm the relevance of information on this asset class. The EIOPA data shows that Europe's insurance industry is mostly invested in government bonds. However, long-term government bonds are of particular importance for European life insurers, as the average duration of assets is highest for them.

To conclude, life insurance companies and pension funds are long-term investors and, therefore, of particular importance for the financial and economic development. Besides, negative impacts on capital investments of institutional investors are likely to endure, for example, due to the economic impact of the Covid-19 pandemic. Moreover, new risks in insurers' sovereign bond portfolios could emerge—like, for example, climate risks (see, for example, Battiston et al. 2019). However, it can be expected that insurers will continue to be increasingly invested in government bonds in the future. If the exposure is even increased, for example to lower the negative duration gap, a higher share of long-term fixed income securities would also imply

[1] Authors' own calculations based on EIOPA (2020c).

higher risks of interest rate changes in the insurers' portfolios. Such developments could further aggravate the already precarious situation to a so-called "double blow", as for example happened in Japan in the 1990s. Because of various risk scenarios, like a long-lasting low interest rate environment, as well as the danger of a "double blow", or the danger of rising interest rates, our empirical investigation is of specific interest for the insurance industry. Therefore, empirical evidence on the information flow among sovereign yield spreads could be helpful for improving financial risk measures in insurers' asset liability management approaches.

3 Some regulatory issues

Aiming to harmonize the EU's regulatory landscape, a reform process targeting the European insurance industry was introduced resulting in a renewed and modernized regulatory framework—the Solvency II Directive (2009/138/EC) (see, for example, Doff 2008 and Ashby 2011). The establishment of a universal industry standard and the underlying political process are widely regarded as ambitious (see, for instance, Smith 2010 and Basse 2020). Amongst others, Quaglia (2011) and Van Hulle (2011), provide an overview of this political reform process and the underlying drivers. Despite its approval in 2009, the Solvency II Directive only entered into force in 2016. Delays and amendments (for example, the Omnibus II Directive approved by the EU Parliament in 2014), which may at least be partly attributed to the emergence of the sovereign debt crisis, prolonged the process (see, most importantly, Doff 2016). In addition to harmonizing the EU insurance market and improving EU insurers' competitiveness, Solvency II mainly aims at promoting a more resilient regulation, effective risk management and transparency (see, for instance, Rae et al. 2018 and Hopt 2013).

To achieve the latter, a so-called three-pillar structure had been designed: the first of the three pillars established quantitative regulation of insurance companies' capital requirements, e.g. the market-consistent valuation of assets and liabilities as well as the determination of the minimum capital requirements (see, for example, Liebwein 2006 and Braun et al. 2018). Hereby, capital requirements for insurance companies in the European Union are harmonized and quantitative reporting is imposed. The second pillar contains qualitative elements of supervision, such as principles for internal risk management and control as well as the supervision of such (see, most importantly, Elderfield 2009). The third pillar predominantly concerns transparency and disclosure requirements, for example, provision of data and information to the supervisor with the overarching aim to promote market discipline (see, for example, Eling et al. 2007 and Liebwein 2006). The three-pillar structure follows a twofold objective: on the one hand, policy holders shall be protected as insurers are required to hold sufficient economic capital, and on the other hand, financial stability is increased (see, amongst others, Boonen 2017 and Gatzert and Wesker 2012). Besides its complexity (see, for instance, Monkiewicz 2013 and Meier, Rodriguez Gonzalez and Kunze, 2020), the Solvency II Directive and its risk-based approach is regarded as highly sophisticated and viewed as a significant improvement to previous regula-

tory frameworks governing the EU's insurance industry (see, for example, Rae et al. 2018 and Doff 2016).

However, Solvency II does not come without criticism. For example, Eling et al. (2007) review the cost appropriateness of Solvency II, whereas Monkiewicz (2013) criticizes comprehensiveness and complexity which could be viewed as indicators of compliance costs insurers face. Moreover, another crucial area with room for improvement is addressed in this paper, namely sovereign credit risk under Solvency II.

Vis-a-vis, it is investigated how sovereign credit risk is treated under the three pillars of Solvency II. This evaluation shall help determine whether the current regulatory framework adequately reflects this specific type of risk. With respect to Pillar I, the solvency capital requirements (SCR) specify the amount of funds insurers shall constantly hold in order to withstand an extreme crisis with significant losses. This is a formula-based figure which is newly determined every 12 months quantifying various risks and intending to ensure that insurance companies may avoid default with a 99.5% probability (see, most importantly, European Parliament 2009). In essence, there are two possible approaches to calculate the SCR: (1) applying an internal, bespoke model which requires approval by the supervisor or (2) using the so-called European standard formula (see European Parliament 2009). When applying the standard formula, however, sovereign bonds issued by member states of the European Economic Area (EEA) are classified as risk free with zero risk weight (this has already been discussed briefly in section 2—moreover see, for instance, Basse et al. 2012 and Ludwig 2014). In other words, when an insurance company's regulatory capital requirements are calculated with the standard formula, sovereign credit and default risks are neglected. As a result, these risks are not accounted for under Pillar I of the Solvency II Directive when quantitative risk-based calculations of capital are conducted from a regulatory point of view.

Simultaneously, it should be noted, that Pillar II of the governance system requires insurers to thoroughly examine their sovereign risk exposure. To be precise, under Pillar II insurers are supposed to undertake the so-called own risk and solvency assessment (ORSA), a strategic analysis of an individual company's risk profile and risk management practice to be published as a qualitative report (see, amongst others, Düll et al. 2017; European Parliament 2009). The ORSA aims to ensure that solvency needs related to an individual insurer's risk profile are met, particularly those that are not included or only partly included in the risk assessment based on the standard formula. Consequently, as European government bonds have a zero-risk weight under the standard formula, sovereign risk is supposed to be one of the relevant factors to be determined in the ORSA. In theory, insurers exposed to significant sovereign risk shall reflect scenarios like default of one or more states in their stress tests (Von Saldern 2016). However, ORSA remains ill-defined, especially with respect to the interplay with the calculation of the aforementioned capital requirements (see, most importantly, Gründl and Gal 2013). Ergo, in practice, the results and analysis presented in ORSA reports are not always reliable; this has, for example been stressed by Grima (2017).

Additionally, Pillar II is based on the so-called prudent person principle which states that insurers are only allowed to invest in those kinds of assets of which they are able to properly assess, measure, monitor and manage risks (see, most

importantly, European Parliament 2009). Naturally, this also applies to sovereign bonds (Von Saldern 2016). Moreover, as outlined in Art. 5 (1) of the amendment to the Credit Rating Regulation of 2013, insurers are required to undertake their individual credit risk assessments, including risk assessment of government bonds or any other financial instrument contained in their portfolios (see, for example, European Parliament 2013 Von Saldern 2016). For example, indicators like political stability, quality of governance (see, most importantly, Boysen-Hogrefe 2017) as well as a comparison of national economic indicators, such as budget deficits or debt-to-GDP, are useful to properly assess a sovereign bond's default risk (see, most importantly, Maltritz and Molchanov 2014).

Considering the aforementioned challenges and the long-term low interest rate environment in particular, it has become crucial to review the sovereign credit risk treatment under Solvency II, specifically under the standard formula. Due to the zero-risk weight under the standard formula, any government bond that is issued by any EEA member state in its domestic currency is exempt from solvency capital requirements (see, for instance, Basse et al. 2012 and Ludwig 2014). In consequence, Solvency II does not account for sovereign default risk and ignores sovereign credit risk differentials of member states. Thus, from a regulatory point of view, government bonds issued by countries with comparably larger fiscal imbalances, like e.g. Italy or Spain, are viewed as equally risky and equally unlikely to default as those sovereign bonds issued by fiscally stronger member states, such as Germany, Austria or Finland (see, for example, Basse et al. 2012 and Basse 2020). However, this approach is problematic as government bonds are exposed to individual credit and default risks (see, most importantly, Chaumont 2020). In fact, this has been particularly demonstrated during the Sovereign Debt Crisis in the European Monetary Union (see, most importantly, Meier, Rodriguez Gonzalez and Kunze, 2020). Still, due to the classification as risk-free under SCR, these specific risks are neglected (see, for instance, Basse et al. 2012 and Ludwig 2014). Yet, empirical evidence further proves that sovereign credit risk is priced in by market participants in government bond markets (see, amongst others, Bernoth et al. 2012 and Gruppe and Lange 2014). As pointed out by Basse et al. (2012), it is important to note that regulatory arbitrage may arise when sovereign credit risk is disregarded under Solvency II as this specific risk is generally feared by at least some financial market participants (see, for example, Gruppe and Lange 2014 and Ludwig 2014).

4 Risk premia and different types of risk

Risk premia in the segments of the fixed income market that are examined in this paper mainly seem to be driven by three different types of risk—namely liquidity risk, sovereign credit risk and redenomination risk. While liquidity certainly is a key concept in financial economics, there seems to be no well-accepted definition for this important type of risk. Most observers would probably accept the idea that liquidity risk is the risk that a specific asset cannot always be sold without causing a price drop due to a lack of demand for this particular asset. Boudoukh and Whitelaw (1993) have stressed the fact that the value of liquidity seems to be the result

of uncertainty concerning future trading needs of current investors. Investors, for example, might be hit by liquidity shocks that would force them to sell assets at specific points in time when prices may be low (see, for instance, Goldreich et al. 2005 and Officer 2007). In these situations, prices of illiquid assets tend to decline more strongly than prices of more liquid assets. As a consequence, investors should be compensated for the existence of liquidity risk. Phrased somewhat differently, a liquidity risk premium ought to exist. However, buy-and-hold investors normally do not plan to sell assets. Therefore, it might be attractive for these investors to prefer holding illiquid assets ("liquidity premium harvesting"). It could be argued that, due to their business model, life insurance companies—which are characterized by a long-term perspective—might not have problems buying assets that cannot be sold instantly without losses due to their illiquidity (see, for example, Möhlmann 2021 and Chodorow-Reich et al. 2021). Liquidity risk obviously does matter for European government bond prices and is directly related to market size (see, for example, Jankowitsch et al. 2006 and Gómez-Puig 2006). Generally speaking, while other factors are also of relevance (for instance active trading in futures), a larger volume of outstanding government debt ought to increase liquidity. Therefore, the smaller member countries of the EMU (e.g., Finland, Ireland or Portugal) should in principle have to pay higher risk premia than the bigger ones (Germany, France and Italy). In fact, empirically evidence seems to clearly point in this direction (see for example, Jankowitsch et al. 2006 and Gómez-Puig 2006).

As discussed below in more detail, sovereign credit risk and redenomination risk did not seem to matter that much for the pricing of government bonds issued by member states of the currency union in the early days of the Euro (see, for example, Gibson et al. 2014 and Basse, Wegener and Kunze, 2018). This has definitely changed since severe fiscal problems have emerged in some member countries of the EMU in the aftermath of the house price collapse in the United States. In any case, the term sovereign credit risk describes the risk that, because of different possible reasons, governments are unable (for example, due to fiscal problems) or unwilling (for instance, because of certain political pressures) to repay their debt (see, for example, Dincecco 2009 and Rodriguez Gonzalez et al. 2019). Should markets anticipate sovereign defaults, investors certainly will demand a compensation for this risk. Countries that are considered to be vulnerable in this context are therefore likely to have to pay higher interest rates to their investors in order to compensate investors for this risk.

Redenomination risk is a very special type of currency risk (see, for example, Grund 2017 and Rodriguez-Gonzalez et al. 2017). A member state that is leaving a currency union because of, for example, fiscal problems or a very strong currency that is hurting the international competitiveness of the respective state's domestic economy, could decide to introduce a new currency and to redenominate its outstanding government bonds that are not governed by foreign law (see, for example, Grund 2017 and Lapavitsas 2018). This measure of economic policy would most certainly affect investors that hold these fixed income securities in a negative way because the new currency of the country leaving the monetary union would likely devalue against the currency that is still used by the states that remain in the currency union. Consequently, investors should demand a compensation for holding bonds

that could be redenominated in a weaker new currency. As a result, countries would have to offer higher interest rates in order to sell such fixed income securities.

The different types of risk discussed here seem to be interconnected. As a matter of fact, Paltalidis et al. (2015) have argued convincingly that macroeconomic shocks can have effects on the level of liquidity in financial markets. Negative news flow or losses at certain banks may, for example, lead to contagious fire sales of banks. This could have an impact on liquidity in financial markets. In this context, Paltalidis et al. (2015) have highlighted the importance of sovereign credit risk. From this perspective, our empirical research approach to search for lead-lag-relationships among risk premia certainly makes a lot of sense. As already noted, this approach has already been used by Gunay (2020) to examine the relationship between credit and liquidity risk in the United States.

5 Interest rate convergence in the European Monetary Union

In January 1999, the Euro became the new currency in initially 11 European countries (see, for example, Pollard 2003 and Gruppe et al. 2017). From this point on, these states have started to form the EMU. The creation of the common currency in Europe resulted in the founding of the ECB, a new supranational institution assuming responsibility for monetary policy in the common currency area (see, for example, Kool 2000 and Pollard 2003). There is only one so-called Main Refinancing Operations Announcement Rate determined by the ECB. This key interest rate is identical in all member states of the monetary union. Consequently, the introduction of the Euro should—more or less by definition—have resulted in a convergence of money market interest rates in the member states of the EMU (see, for example, Holder 1999 and Gruppe et al. 2017). Obviously, the introduction of the Euro not only had substantial impact on money markets, but also on bond markets. In fact, Kim et al. (2006) have argued convincingly that the adoption of the new common currency caused structural change in the European bond market. First of all, short and long-term interest rates are closely connected to each other. Moreover, the Euro has eliminated the influencing factor exchange rate risk for investors situated in one member state buying bonds issued in other countries also belonging to the currency union (see, amongst others, Gómez-Puig 2006 and Gruppe et al. 2017). As a matter of fact, Lund (1999) has argued that even before 1999, there already was interest rate convergence between the bond yields in at least some states that later on introduced the Euro because of the pre-agreed binding timetable and the rules for the adoption of the common currency. In any case, the introduction of the Euro and the founding of the ECB caused strong convergence tendencies among nominal short-, medium- and long-term interest rates in the member states of the EMU.

About one decade later, the European Sovereign Debt Crisis changed the way financial markets priced government debt issued by member countries of the monetary union (see, for example, Gruppe and Lange 2014 and Ludwig 2014). Basse (2014) and Sensoy et al. (2019) have stressed, that during the crisis, there have been two groups of countries—namely those with and those without noteworthy fiscal problems. In the context of this crisis, fixed income investors holding bonds

issued by certain member countries of the EMU started to fear sovereign credit and redenomination risk (see, among others, Basse 2014 and Sibbertsen et al. 2014). In this difficult environment, there was no broad convergence of interest rates in the currency union anymore. In fact, even flight-to-quality-effects could be observed back then. The strong demand for German sovereign bonds and those of some other fiscally more stable member states of the currency union pushed down the level of interest rates in these countries (see, for example, Sibbertsen et al. 2014 and Phillips and Shi 2019). Investors indeed seemed to fear a collapse of the financial system in the EMU. As a consequence, the responsible economic policy makers saw an urgent need for action. Afonso et al. (2018), for example, have stressed that the ECB's monetary policy measures taken in August 2012 with the aim to improve the liquidity situation in financial markets seem to have contributed greatly to the reduction of tensions in the market for European government bonds. In fact, meanwhile many observers believe that Mario Draghis's now famous speech ("whatever it takes") has helped to more or less completely eliminate the fears prevalent among investors that the EMU could break up (see, for example, Klose and Weigert 2014 and De Vries and De Haan 2016). Phrased somewhat differently, Draghi's words most probably have dramatically reduced the risk premia compensating buyers of sovereign bonds issued by fiscally weaker member states (like, for example, Italy or Spain) for redenomination risk. Additionally, not only the speech (which certainly had an impact on market expectations) but also the unusual monetary policy measures taken by ECB after Draghi's words (quantitative easing) seem to further have lowered risk premia (see, amongst others, Krampf 2016 and Krishnamurthy et al. 2018).

As a result, the European government bond market seems to be characterized by at least three different pricing regimes for fixed income securities issued by sovereign states (namely before the crisis, after the crisis and after Draghi). Yet the matter is perhaps even more complicated. Arghyrou and Kontonikas (2012), for instance, have suggested that the sovereign debt crisis in Europe should be divided into an early and a later phase and that the mounting fiscal problems in Greece could be of some importance in this context. The meltdown of the housing market in the United States and its effect on the global financial system may also be of relevance (see, most importantly, Wegener, Kruse and Basse 2019). Accompanied by a higher level of risk aversion among investors due to the collapsing mortgage market in North America, the fears of costly bank bail-out programs in Europe (see Basse et al. 2012 and Wegener, Kruse and Basse, 2017) could, in fact, help to explain, why "all of sudden" a sovereign debt crisis has disrupted the government bond market in the EMU. Therefore, it seems reasonable to distinguish between an early phase of the crisis that probably was caused by problems in the banking industry and a more fundamental macroeconomic crisis in specific member countries. The empirical evidence that has been presented by Ejsing and Lemke (2011) seems to point in this direction. Accepting this perspective, there could be at least four different relevant pricing regimes for government bonds issued by member states of the monetary union after the introduction of the Euro in 1999 (before the crisis, early crisis, late crisis and after Draghi). Moreover, the political turmoil in Italy after the election in 2018 and the monetary policy response to the economic crisis caused by the Covid-19 virus might also have affected sovereign bond markets in Europe.

In any case, meanwhile many observers seem to believe that there certainly was an underpricing of sovereign credit risk in the EMU before 2008 (see, for example, Gibson et al. 2014 and Basse, Wegener and Kunze, 2018) and possibly also an overpricing of redenomination risk and sovereign credit risk after the debt crisis in Greece (see, on the one hand, Gibson et al. 2014 and, on the other hand, the more cautionary comments by Afonso et al. 2020).

Italy represents a suitable example where the two aforementioned crises culminated. The country that is home to the oldest bank in the world was hit not only by a sovereign debt crisis, but also by a financial sector crisis that inflicted harm to each other. Domestic banks suffered from Italy's sovereign rating downgrades that had a negative impact on default rates which adversely affected banks' balance sheets as these were exposed to large volumes of Italian sovereign assets. The same mechanism applies to receivables against the sovereign. Simultaneously, Italy's national budget suffered due to the fact that domestic banks fell into financial distress and required financial support from the government (see Tholl et al. 2020).

6 How monetary policy aims at combatting Covid-19

As a lesson learned from the Global Financial Crisis, many governments introduced fiscal measures to tackle a symmetric decline in aggregated demand immediately after the Covid-19 virus began to spread around the world. The fiscal impulse was accompanied by monetary stimuli from central banks following the intention to provide crisis relief more swiftly compared to the 2008 Global Financial Crisis (see Haas and Neely 2020). As this kind of economic shock has been unprecedented in its scale and speed of impact, extensive fiscal and monetary responses have been regarded as proportional to the purpose (see Altig et al. 2020). The monetary authorities repeatedly adjusted their key interest rates due to the pandemic induced supply-and-demand shock (see Botta et al. 2020). As a consequence of the interest rate cuts, the gaps between the key interest rates of major central banks narrowed (see Haas and Neely 2020). In order to understand why the ECB adopted the Pandemic Emergency Purchase Program (PEPP) shortly after Covid-19 began to spread in Europe, the learnings from the sovereign debt crisis in 2011/2012 should be taken into account. Valiante (2011) identified two main drivers of the debt crisis: macroeconomic imbalances and flaws in the institutional organization. In fact, some observers seem to belive that the ECB did not adopt the role as lender of last resort and thereby did not manage to prevent yield spreads of sovereign issuers from the periphery of the EMU to rise. This only changed with the introduction of the Outright Monetary Transactions (OMT) which helped to calm the financial markets (see Filoso et al. 2021).

Prior to the outbreak of Covid-19, the United States experienced interest rate levels that had returned towards some kind of normalization, while the ECB maintained its deposit facility rate (DFR) at record low levels. In September 2019, the DFR was reduced even further to –0.50% (see Aguilar et al. 2020). The ECB also continued with its Asset Purchase Programme (APP) comprising of a volume of €20 billion and claimed to do so until inflation rates would rise (see Boeckx et al. 2020). The

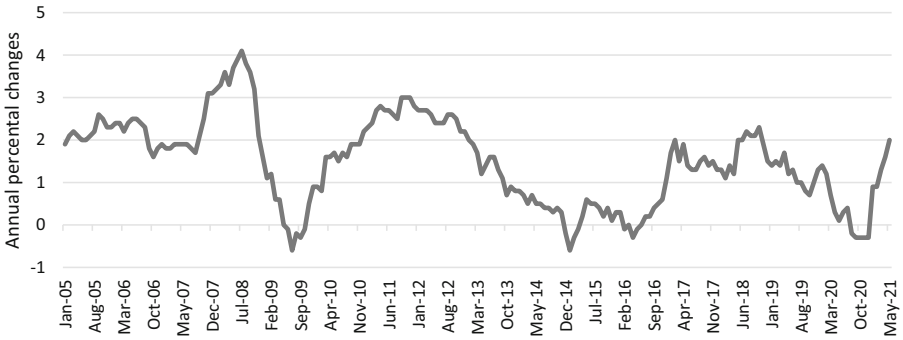


Fig. 2 Inflation rate Euro Area (consumer prices). (Source: Own representation based on ECB (2021a).)

ECB aimed at achieving its inflation rate target of close to 2% by keeping this course of expansive monetary policy (see Asshoff et al. 2020). Since July 2019 and April 2021, the ECB has failed to meet its inflation target. The latter has been defined by its Governing Council in 2003, proclaiming its pursuit of price stability that is given when inflation rates remain "below, but close to, 2% over the medium term (see ECB 2021c)." The clarification "but close to" compared to the definition of 1998 can be interpreted as ECB's intention to eliminate potential deflationary fears (see Paloviita et al. 2021). In times of very low inflation rates, monetary policymakers have to deal with the challenge of navigating between Scylla and Charybdis by either falling into the deflation trap or the inflation trap (see Brunnermeier 2021). This implies the increased risk in case of an external shock, that expansive monetary policy measures conducted to prevent a deflation trap may provoke an over-shooting, and thus, could cause an inflationary spiral. As a result of its current monetary policy review, the ECB adopted a new inflation target of 2% and is willing to tolerate short periods of inflation rates "moderately above target" (see ECB 2021d). This change in the ECB's monetary policy strategy may be interpreted as an effort to widen the corridor between the deflation and the inflation trap.

With interest rates lowered to levels below zero, traditional monetary tools have limited effect to stimulate economic activity and the ECB continued to adopt unconventional monetary policy instruments as crisis response (see Benmelech and Tzur-Ilan 2020). As a result, the ECB not only expanded but also accelerated its unconventional monetary policy. In consequence, the year 2020 recorded the highest asset purchases per month since the APP was launched (see Fig. 2). The growing ECB balance sheet reflects this process (see Haas and Neely 2020). Thanks to these immediate actions, the central banks' purchase programmes helped to control the yield curve which is especially beneficial for high-debt countries and corporations that issue investment grade bonds (see Zabala and Prats 2020). Due to the monetizing mechanism, governments suffering from fiscal imbalances are somewhat protected from running into a debt crisis as the central banks' behavior implicitly guarantees that there is a stable demand for sovereign bonds issued by these countries. This, in turn, keeps interest rates close to those of low-debt countries. Thereby, the ECB aimed at preventing this economic crisis from mutating into yet another sovereign

Table 3 Bimonthly breakdown of public sector securities under PEPP. (Source: Own representation based on ECB (2020a).)

Book value as at end-July 2020 (EUR millions)	Net purchases June-July 2020	Cumulative net purchases as at end-July 2020[b]	Current WAM[a] of public sector securities holdings under the PEPP[c]	WAM of eligible universe of public sector securities under the PEPP as at end-July 2020[c]
Austria	5,142	10,056	10.01	7.33
Belgium	6,392	12,853	5.83	9.27
Cyprus	455	936	11.79	8.31
Germany	46,266	93,016	3.97	6.60
Estonia	163	163	9.30	7.29
Spain	23,719	46,111	8.18	7.40
Finland	3,225	6,456	7.56	7.07
France	35,845	59,420	9.05	7.07
Greece	5,256	9,946	8.62	9.07
Ireland	2,972	5,972	8.31	9.29
Italy	*36,067*	*73,432*	*7.00*	*6.72*
Lithuania	543	1,593	9.21	10.92
Luxembourg	348	807	6.56	5.74
Latvia	391	787	9.88	9.08
Malta	0	123	6.33	8.02
Netherlands	10,285	20,674	3.60	7.36
Portugal	4,655	8,805	7.14	6.81
Slovenia	958	1,896	6.84	8.71
Slovakia	1,487	3,790	7.17	8.13
Supranationals	14,045	27,980	8.23	7.23
Total	198,214	384,817	6.71	7.12

[a]WAM stands for weighted average maturity
[b]Cumulative net purchase figures represent the difference between the acquisition cost of all purchase operations and the redeemed nominal amounts
[c]Remaining WAM in years

debt crisis (see Blanchard and Pisani-Ferry, 2020). Further support for this argument can be found when considering the announcement of the PEPP program in March 2020, which intended to raise the share of bonds held by ECB by about 30% and helped to narrow yield spreads against German bunds (see Haas and Neely 2020). Particularly Italian sovereign bonds benefitted from the ECB's extensive monetary stimulus to address the Covid-19 induced economic impact (see Bernoth et al. 2020). This is underlined by Table 3, showing the purchases per country under the PEPP regime. It becomes apparent that the Italian share is significantly disproportionate to its economic importance due to the fact that the country was not only severely hit by Covid-19 but it already suffered from a high debt burden even before the pandemic sparked-off.

Given that the EMU has been shaped by two crucial events—the Global Financial Crisis and the sovereign debt crisis, it may be subject to future discussions, whether ECB's reaction to the impact of Covid-19 has been a new landmark in the history of the EMU. Since its creation, the EMU faces criticism referring to the theory of

optimum-currency area (OCA) which proclaims conditions that should be fulfilled by a common currency area, like providing integrated financial markets, in order to cope with the disadvantages of monetary integration. According to these sceptic views, it is a matter of time that the EMU will collapse in the aftermath of an economic crisis, as the Euro Area does not fully meet the conditions of an OCA. Therefore, the EMU is supposed to lack capacity to cope with severe economic shocks (see Eichengreen 1992). In this regard, the Euro Area proved its resilience during and after the Global Financial Crisis and the following sovereign debt crisis as these events sparked financial fragmentation and put the EMU at risk to break up. The ECB was forced to create instruments to tackle the lack of liquidity in financial markets and later the widening of sovereign bond spreads. Hartmann et al. (2021) have provided evidence that the first weeks of the Covid-19 spreading in Europe also show sharp tendencies of financial disintegration. This was driven by a strong demand for money-market instruments and a widening of sovereign spreads among EMU member states which indicates that the economic impact of the COVID-19 crisis could challenge the stability of the Euro Area like the Financial Crisis and the sovereign debt crisis.

In mid-March 2020, the ECB announced the launch of the aforementioned PEPP, including a package of asset purchases and a bank relief program with a volume of originally €120 billion that was later extended to an amount of €750 billion, and even further increased to €1,350 billion in June 2020 (see Fig. 3; Jinjarak et al. 2020), being topped up by further €500 billion in December 2020 totaling €1,850 billion (ECB 2021b). Referring to Mario Draghi's famous "whatever it takes"-quote that helped to calm down market fears (see Claeys 2020), on March 18, 2020 the ECB proclaimed that the PEPP design can be adapted "as much as necessary and for as long as needed" (see Bénassy-Quéré et al. 2020). This program comprises various instruments to not only prevent a credit crunch as consequence of the economic downturn, but also to stabilize markets, so that the monetary policy mechanism is preserved. When investors grasped the economic impact of Covid-19, there was a high risk of liquidity shortfall, and flight to safe-haven assets with

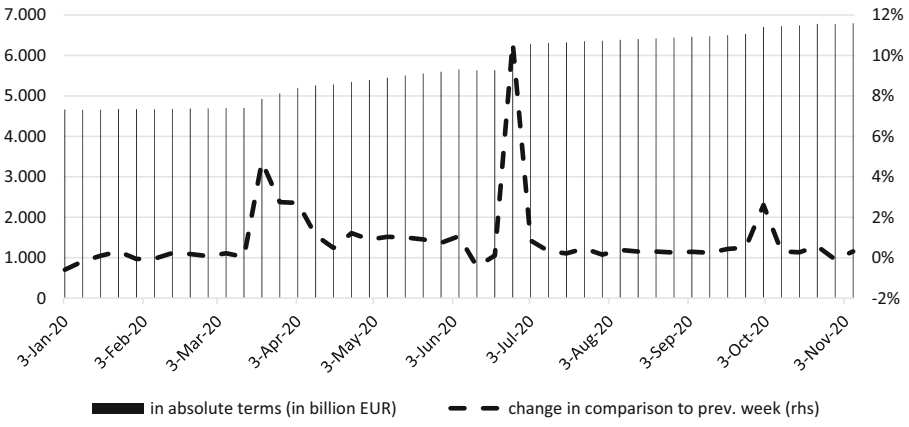


Fig. 3 ECB balance sheet. (Source: ECB (2020b).)

potentially severe consequences, especially for highly indebted member states of a monetary union (see Hutchinson and Mee, 2020). Between the beginning of January 2020 and mid of March of the same year, the yield spreads between German government bonds and, for example, Italian sovereign bonds had widened sharply. After the ECB announced its PEPP-program to cushion the economic effects of Covid-19, Italian and Spanish sovereign bond spreads, interrupted by a widening in April, have narrowed (see Boeckx et al. 2020).

Further crisis response by the ECB includes the Governing Council's decision to extend the additional credit claim (ACC) framework by accepting credit claims as collateral which did not meet the predefined eligibility criteria, inter alia loans with lower credit quality standards (see ECB, 2020c). Furthermore, the threshold for using credit claims as collateral for banks to obtain new liquidity was lowered from formerly €25,000 to 0. This measure was intended to incentivize an additional credit supply to small and medium enterprises. Another ECB instrument to mitigate the economic impact of the Covid-19 pandemic included an increase in tolerating collateral devaluations by 20% (see ECB 2020d). In order to prevent a liquidity shortfall for the real economy, the ECB aimed at establishing improved refinancing conditions for banks as these play an even more important role as financial intermediary in Europe than in the United States. Hence, the ECB continued to provide targeted (TLTROs) and non-targeted liquidity programmes that intend to ease banks' borrowing from ECB, a program launched in September 2019 already. Based on the longer-term refinancing operations (LTROs) that have expired in March 2020, the ECB opted for a continuation named pandemic emergency longer-term refinancing operations or short: PELTROs (see ECB 2020e). On the flip side, lending rates for banks turned negative (see Haas and Neely 2020). Another important change includes the ECB's decision to revise its rules with respect to public bond purchases so that the commitment to hold no more than one third of a country's outstanding government bond was abolished (see Bernoth et al. 2020).

7 Data and methodological issues

This empirical study examines interest rate differentials between 5, 10 and 30 year bond yields in five different member countries of the EMU relative to German sovereign bond yields. Fixed income securities issued by the Federal Republic of Germany are usually considered to be more or less free of default risk. Moreover, there is a very high level of liquidity in the market for German government bonds. Therefore, sovereign bond yields from Germany are frequently used as the benchmark interest rate for the EMU (see, for example, Basse 2014 and Rodriguez Gonzalez et al., 2019). Given the research question under examination here, it is certainly necessary to also consider 30-year interest rate differentials (which is often not done in empirical studies). In fact, Rodriguez Gonzalez et al. (2019) and Basse (2020) have argued convincingly that this segment of the sovereign bond market in the EMU is of special importance for the life insurance industry because of their long-term liabilities. Besides Germany (as benchmark), we examine interest rate data from five other member states of the EMU (namely, Austria, Belgium,

France, Italy and Ireland). Austria is a smaller country that in general is assumed to belong to the fiscally more prudent ones. Therefore, liquidity risk should play a special role for bond prices issued by Austria. France and Italy are large member countries of the EMU with highly liquid government bond markets. Consequently, government bond yields in these two countries should not be driven by liquidity risk. Given the aforementioned recent political turmoil in Rome, sovereign credit risk and redenomination risk should indeed be of some importance for Italian government bond prices. Belgium and Ireland are medium-sized respectively smaller member countries of the EMU. In both cases, liquidity risk, sovereign credit risk and redenomination risk could impact government bond prices and interest rates. Moreover, Ireland was among the countries that suffered most during the European sovereign debt crisis (see, for example, Gómez-Puig and Sosvilla-Rivero 2014 and Wegener, Kruse and Basse, 2017).

The yield spread SP of sovereign debt (see, for example, Gómez-Puig 2006 and Rodriguez Gonzalez et al. 2019) issued by country W (Austria, Belgium, France, Italy and Ireland) relative to German bonds with the maturity Z (5, 10 or 30 years) is calculated form generic government bond yields using Eq. 1:

$$SP_{W,Z} = i_{W,Z} - i_{Germany,Z} \tag{1}$$

All interest rate data is taken from Bloomberg. Given that identical maturities are examined and that investors consider German government bonds to be somewhat special—as already discussed, these fixed income securities characterized by high liquidity, and there no fears of a sovereign default—the interest rate differentials computed according to Eq. 1 can be interpreted as risk premia compensating investors for the higher default and liquidity risk of country W relative to Germany (and, of course, also for the possibly existing redenomination risk). We examine weekly data. In order to avoid problems with structural change, the data sample analyzed is 3/29/2019 to 7/03/2020. Focusing on this period of time does make sense because the 10-year German government bond yield was negative for the whole sample. This is a very important fact with regard to the existence of structural breaks in the bond yield spread time series. The procedure suggested by Phillips and Perron (1988) is employed to test for unit roots in the time series calculated with Eq. 1. According to the results of these tests, all yield spreads seem to be non-stationary variables integrated of order 1. Given the empirical findings that have been reported by Rodriguez Gonzalez et al. (2019), this result is not surprising. Therefore, no test data is reported in order to conserve space.

The concept of Granger causality is of high relevance in the field of time series econometrics. One-time series X is Granger causing another time series Y when past values of X can predict the variable Y (see, most importantly, Granger 1969). Expressed somewhat more formally, the variable X_t is said to not be Granger causing the time series Y_t if for all $n > 0$

$$F(Y_{t+n} \mid \Omega_t) = F(Y_{t+n} \mid \Omega_t - X_t) \tag{2}$$

In Eq. 2, F denotes the conditional distribution, and $\Omega_t - X_t$ is all potentially relevant information except of X_t. Feedback effects may exist between the two variables X_t and Y_t. Then there is bidirectional Granger causality (see, for example, Thornton 1996 and Amiri and Ventelou 2012). On the other hand, there is unidirectional Granger causality in situations where one variable Granger causes the other variable but not vice versa (see, for example, Oxley 1993 and Thornton 1996).

The Granger causality tests are performed using the approach developed by Toda and Yamamoto (1995). This procedure has become very popular among applied econometricians in recent times. As a matter of fact, Bauer and Maynard (2012) have highlighted how useful this approach to test for Granger causality can be. Due to the large number of relevant studies, we can only give two examples here. Amiri and Ventelou (2012), for instance, have used the technique that has been suggested by Toda and Yamamoto (1995) to examine the relationship between healthcare expenditures and economic activity. Moreover, Kunze et al. (2020) have employed this approach to search for a useful leading indicator of house prices in the United Kingdom. This popularity most probably is a result of the favorable Monte Carlo evidence that has been presented by Zapata and Rambaldi (1997). The technique that has been developed by Toda and Yamamoto (1995) is based on the concept of vector autoregressive models. More specifically, vector autoregressions are very useful tools to describe the dynamic interrelationships between two or more-time series (see, most importantly Sims, 1980). The n endogenous variables in a vector autoregressive models are explained by past values of itself and of the remaining other variables examined. In Eq. 3 Y_t is a vector of $(n \times 1)$ endogenous variables, A_i are $(n \times n)$ coefficient matrices, C is a $(n \times 1)$ vector of constants and ε_t is an $(n \times 1)$ vector of random disturbances:

$$Y_t = C + A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_p Y_{t-p} + \varepsilon_t \tag{3}$$

This technique can account for possibly existing feedback effects among the variables that are included in the model. Toda and Yamamoto (1995) have suggested to estimate a vector autoregression in levels considering p time lags and to extend this model by m time lags to then perform modified Wald tests to search for Granger causality, where m is the highest order of integration of any exogenous variable examined and p is the optimal number of time lags for the vector autoregressive model:

$$Y_t = C + A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_p Y_{t-p} + \cdots + A_{p+m} Y_{t-(p+m)} + \varepsilon_t \tag{4}$$

This procedure using a modified Wald test ensures that the test statistic is asymptotically chi-square distributed. The additional m lags in Eq. 4 are added to the augmented model as exogenous variables and p is the optimal number of time lags for the vector autoregression that can, for example, be selected by using the traditional information criteria (in or case AIC). Phrased somewhat differently, the null hypothesis of Granger non-causality is tested by only examining the coefficient matrices A_1 to A_p. The procedure suggested by Toda and Yamamoto (1995) can be problematic when there is structural change (see, most importantly, Gormus et al.

2018; and Nazlioglu et al. 2019); employing the so-called Fourier Toda Yamamoto test should be helpful in these cases. However, working with small sample sizes (as done here) using the traditional test procedure could have advantages. In fact, Monte Carlo evidence presented by Nazlioglu et al. (2019) does suggest that the test procedure developed by Toda and Yamamoto (1995) seems to be less distorted than the Fourier Toda Yamamoto test examining small samples. Moreover, given that we already have selected the data sample examined here in a way that should help to minimize possible problems with structural change (as discussed above), we prefer to employ the traditional version of the test.

8 Empirical analysis

The results of the Granger causality tests (*p*-values) employing the technique suggested by Toda and Yamamoto (1995) are presented in the Table 4 and 5 and 6 and 7 and 8 and 9 and 10 and 11 and 12 and 13. The reported probabilities are calculated using the asymptotic Chi-square distribution. In the tables, X → Y denotes Granger causality running from the variable X to the variable Y, and Y → X denotes Granger

Table 4 Granger causality test Austria and Belgium. (Source: Own calculations.)

Maturity	Austria → Belgium	Belgium → Austria
5 Years	0.2973	0.0000
10 Years	0.0199	0.0225
30 Years	0.5081	0.5016

Table 5 Granger causality test Austria and France. (Source: Own calculations.)

Maturity	Austria → France	France → Austria
5 Years	0.4560	0.0004
10 Years	0.1272	0.2755
30 Years	0.6941	0.4054

Table 6 Granger causality test Austria and Ireland. (Source: Own calculations.)

Maturity	Austria → Ireland	Ireland → Austria
5 Years	0.2130	0.0047
10 Years	0.1151	0.1152
30 Years	0.5237	0.9869

Table 7 Granger causality test Austria and Italy. (Source: Own calculations.)

Maturity	Austria → Italy	Italy → Austria
5 Years	0.1522	0.0197
10 Years	0.0741	0.1704
30 Years	0.1343	0.2800

Table 8 Granger causality test Belgium and France. (Source: Own calculations.)

Maturity	Belgium → France	France → Belgium
5 Years	0.1223	0.0553
10 Years	0.0066	0.0056
30 Years	0.6603	0.9254

Table 9 Granger causality test Belgium and Italy. (Source: Own calculations.)

Maturity	Belgium → Italy	Italy → Belgium
5 Years	0.4027	0.1626
10 Years	0.2156	0.8855
30 Years	0.3214	0.1023

Table 10 Granger causality test Belgium and Ireland. (Source: Own calculations.)

Maturity	Belgium → Ireland	Ireland → Belgium
5 Years	0.0686	0.2799
10 Years	0.5297	0.3274
30 Years	0.2591	0.8005

Table 11 Granger causality test France and Italy. (Source: Own calculations.)

Maturity	Italy → France	France → Italy
5 Years	0.6450	0.0748
10 Years	0.5462	0.0237
30 Years	0.0905	0.3881

Table 12 Granger causality test France and Ireland. (Source: Own calculations.)

Maturity	Ireland → France	France → Ireland
5 Years	0.5007	0.5761
10 Years	0.9434	0.2460
30 Years	0.8838	0.1708

Table 13 Granger causality test Italy and Ireland. (Source: Own calculations.)

Maturity	Ireland → Italy	Italy → Ireland
5 Years	0.0455	0.4472
10 Years	0.1477	0.8209
30 Years	0.6689	0.7892

causality running from the variable Y to the variable X. Examining the empirical findings that are presented in the tables, there are some very interesting results.

From the perspective of asset managers in life insurance companies, it is of predominant importance to note that with regard to interest rate differentials of bonds with a maturity of 30 years, there is no empirical evidence for Granger causality among the time series examined here. As a matter of fact, in no case the null

hypothesis of no causality can be rejected. Consequently, focusing on bonds with high durations yield spreads relative to Germany in one of the member countries of the EMU do not help to forecast yield spreads in the other countries. This is somewhat different in the other segments of the European government bond market. When examining fixed income securities with a maturity of 10 years, there is no clear picture at all. In some cases, there is no Granger causality, in others there is uni- or bidirectional causality. Focusing on medium-term bonds (which here means a maturity of 5 years), there is one very interesting empirical finding. All models do suggest that there exists unidirectional Granger causality running from the yield spreads in all other countries to Austrian interest rate differentials relative to German 5-year bonds. This result is remarkable. As already noted, Austria is a smaller European country which is considered by most investors to be fiscally very sound. Therefore, yield spreads to Germany mainly are compensating holders of Austrian government bonds for liquidity risk and not for sovereign credit risk. Consequently, the data set examined here seems to suggest that sovereign credit risk, which is reflected by the prices of medium-term European government bonds issued by, for example, Italy or Ireland, can help to forecast liquidity risk premia in this segment of the global fixed income market. One explanation for this empirical finding could be that additional fears about sovereign credit risk can lead to liquidity shocks which then tend to increase liquidity premia. This interpretation of the empirical evidence reported here is, of course, based on the point of view that fixed income investors do not seem to believe that sovereign credit risk per se can become a major problem in Austria.

9 Conclusion

Lempérière et al. (2017) have argued convincingly that there still are surprisingly large obstacles when trying to explain how risk premia are determined in financial markets. With this study, we try to close some of the existing knowledge gaps. Doing so, we focus on the government bond market in the EMU. This segment of the global fixed income market is of particular importance for insurance companies in Europe. More specifically, we employ the procedure developed by Toda and Yamamoto (1995) to test for Granger causality among yield spreads in five different member countries of the EMU relative to Germany. The member states included in the analysis are Austria, Belgium, France, Italy and Ireland. We examine interest rate data from bonds with three different maturities (5, 10 and 30 years). Our empirical research approach is inspired by Gunay (2020) who has analyzed the relationship between credit and liquidity risk in the United States using Granger causality tests. With regard to long-term sovereign debt, there is no evidence for Granger causality among the time series examined here. Consequently, the risk premia required by investors to hold government bonds of one specific member country of the monetary union do not help to forecast the risk premia that have to be paid by other countries. Given the structure of their liabilities, this empirical finding should be of relevance for the European life insurance industry. With regard to the yield spreads to be observed in the market for 10-year government bonds, there seems to be no clear

picture. Focusing on fixed income securities with a maturity of 5 years, there is one very interesting empirical finding. The test results reported above seem to imply that there is unidirectional Granger causality running from the yield spreads in all other four countries to Austria. Given that Austria is a smaller country which is viewed to be in a fiscally stable position, this result could be interpreted as evidence for credit risk premia being helpful to forecast liquidity risk premia in the market for medium-term government bonds issued by member states of the EMU. Future empirical research that focuses on the European government bond market should examine the relationship between sovereign credit risk and liquidity risk in more detail. Moreover, the empirical research strategy employed here can also be used to improve our understanding of how risk premia are determined in financial markets in general by analyzing lead-lag-relationships between the historical risk premia offered by different types of investment opportunities (e.g., small cap stocks versus growth stocks).

Funding Open Access funding enabled and organized by Projekt DEAL.

References

Afonso, A., Arghyrou, M.G., Gadea, M.D., Kontonikas, A.: "whatever it takes" to resolve the European sovereign debt crisis? Bond pricing regime switches and monetary policy effects. J. Int. Money Finance **86**, 1–30 (2018)

Afonso, A., Jalles, J.T., Kazemi, M.: The effects of macroeconomic, fiscal and monetary policy announcements on sovereign bond spreads. Int. Rev. Law Econ. **63**, 105924 (2020)

Aguilar, P., Arce, Ó., Hurtado, S., Martínez-Martín, J., Nuño, G., Thomas, C.: The ECB monetary policy response to the Covid-19 crisis. Banco España Documentos Ocasionales **2026** (2020)

Altig, D., Baker, S., Barrero, J.M., Bloom, N., Bunn, P., Chen, S., Davis, S.J., Leather, J., Meyer, B., Mihaylov, E., Mizen, P., Parker, N., Renault, T., Smietanka, P., Thwaites, G.: Economic uncertainty before and during the COVID-19 pandemic. J. Public Econ. **191**, 104274 (2020)

Amiri, A., Ventelou, B.: Granger causality between total expenditure on health and GDP in OECD: evidence from the toda-yamamoto approach. Econ. Lett. **116**(3), 541–544 (2012)

Arghyrou, M.G., Kontonikas, A.: The EMU sovereign-debt crisis: fundamentals, expectations and contagion. J. Int. Financial Mark. Inst. Money **22**(4), 658–677 (2012)

Ashby, S.: Risk management and the global banking crisis: lessons for insurance solvency regulation. Geneva Pap. Risk Insur. Issues Pract. **36**(3), 330–347 (2011)

Asshoff, S., Belke, A., Osowski, T.: Unconventional monetary policy and inflation expectations in the Euro area. Econ. Model. **102**, 105564 (2020)

Basse, T.: Searching for the EMU core member countries. Eur. J. Polit. Econ. **34**, 32–39 (2014)

Basse, T.: Solvency II and sovereign credit risk: additional empirical evidence and some thoughts about implications for regulators and lawmakers. Int. Rev. Law Econ. **64**, 105933 (2020)

Basse, T., Friedrich, M., Kleffner, A.: Italian government debt and sovereign credit risk: an empirical exploration and some thoughts about consequences for European insurers. Z. Gesamt. Versicherungswiss. **101**(5), 571–579 (2012)

Basse, T., Wegener, C., Kunze, F.: Government bond yields in Germany and Spain — empirical evidence from better days. Quantitative Finance **18**(5), 827–835 (2018)
Basse, T., Friedrich, M., Kleffner, A., Graf von der Schulenburg, J.-M.: Are interest rates too low? Empirical evidence and implications for German life insurers. Z. Gesamt. Versicherungswiss. **103**(1), 31–43 (2014)
Battiston, S., Jakubik, P., Monasterolo, I., Riahi, K., van Ruijven, B.: Climate risk assessment of the sovereign bond portfolio of European insurers. EIOPA financial stability report, December 2019. 69–89 (2019). https://www.eiopa.europa.eu/sites/default/files/publications/reports/eiopa_dec2019_financial-stability-report-thematic_review_climate_risk.pdf, Accessed 28 Nov 2020
Bauer, D., Maynard, A.: Persistence-robust surplus-lag Granger causality testing. J. Econom. **169**(2), 293–300 (2012)
Bénassy-Quéré, A., Boot, A., Fatás, A., Fratzscher, M., Fuest, C., Giavazzi, F., Marimon, R., Martin, P., Pisani-Ferry, J., Reichlin, L., Schoenmaker, D., Teles, P., Weder die Mauro, B.: A proposal for a Covid credit line (2020). https://voxeu.org/article/proposal-covid-credit-line, Accessed 14 Dec 2020
Benmelech, E., Tzur-Ilan, N.: The determinants of fiscal and monetary policies during the COVID-19 crisis. NBER Working Paper No. 27461. (2020)
Berdin, E., Gründl, H.: The effects of a low interest rate environment on life insurers. Geneva Pap. Risk Insur. **40**(3), 385–415 (2015)
Bernoth, K., Dany-Knedlik, G., Gibert, A.: ECB and fed monetary policy measures against the economic effects of the Coronavirus pandemic have little effect. DIW focus No. 3. (2020)
Bernoth, K., von Hagen, J., Schuhknecht, L.: Sovereign risk premiums in the European government bond market. J. Int. Money Finance **31**(5), 975–995 (2012)
Bijlsma, M., Vermeulen, R.: Insurance companies' trading behaviour during the European sovereign debt crisis: flight home or flight to quality? J. Financial Stab. **27**, 137–154 (2016)
Blanchard, O., Pisani-Ferry, J.: Monetisation: Do not panic. Vox CEPR Policy Portal. https://voxeu.org/article/monetisation-do-not-panic (2020). Accessed 15 July 2020
Boeckx, J., Deroose, M., Vincent, E.: The ECB's monetary policy response to COVID-19. NBB Econ. Rev. (2), 37–52 (2020)
Boonen, T.J.: Solvency II solvency capital requirement for life insurance companies based on expected shortfall. Eur. Actuar. J. **7**(2), 405–434 (2017)
Botta, A., Caverzasi, E., Russo, A.: Fighting the COVID-19 emergency and re-launching the European economy: debt monetization and recovery bonds. GPERC Policy Briefs No. PB26. (2020)
Boubaker, S., Gounopoulos, D., Nguyen, D.K., Paltalidis, N.: Assessing the effects of unconventional monetary policy and low interest rates on pension fund risk incentives. J. Bank. Finance **77**, 35–52 (2017)
Boudoukh, J., Whitelaw, R.F.: Liquidity as a choice variable: a lesson from the Japanese government bond market. Rev. Financ. Stud. **6**(2), 265–292 (1993)
Boysen-Hogrefe, J.: Risk assessment on Euro area government bond markets—the role of governance. J. Int. Money Finance **73**, 104–117 (2017)
Braun, A., Schmeiser, H., Schreiber, F.: Portfolio optimization under solvency II: implicit constraints imposed by the market risk standard formula. J. Risk Insur. **84**(1), 177–207 (2017)
Braun, A., Schmeiser, H., Schreiber, F.: Return on risk-adjusted capital under solvency II: implications for the asset management of insurance. Geneva Pap. Risk Insur. Pract. **43**(3), 456–472 (2018)
Brunnermeier, M.K.: De-and inflationary traps: strengthening ECB's second pillar to avoid fiscal and financial dominance. ECB Forum on Central Banking. Conference Proceedings., pp 275–283 (2021)
Burriel, P., Galesi, A.: Uncovering the heterogeneous effects of ECB unconventional monetary policies across Euro area countries. Eur. Econ. Rev. **101**, 210–229 (2018)
Chaumont, G.: Sovereign debt, default risk and the liquidity of government bonds. University of Rochester (2020). https://doi.org/10.2139/ssrn.3714870
Chodorow-Reich, G., Ghent, A., Haddad, V.: Asset insulators. Rev Financ Stud **34**(3), 1509–1539 (2021)
Claeys, G.: The European Central Bank in the COVID-19 crisis: whatever it takes, within its mandate. European Parliament Monetary Dialogue Papers (2020)
Conner, R.: Bubble or overblown: ambiguous signals in the subprime auto lending market. J. Struct. Finance **22**(3), 32–44 (2016)
Croce, D.R., Stewart, F., Yermo, J.: Promoting longer-term investment by institutional investors: selected issues and policies. OECD J. Financial Mark. Trends (2011). https://doi.org/10.1787/fmt-2011-5kg55b0z1ktb
Dincecco, M.: Political regimes and sovereign credit risk in Europe, 1750–1913. Eur. Rev. Econ. Hist. **13**(1), 31–63 (2009)

Doff, R.: A critical analysis of the solvency II proposals. Geneva Pap. Risk Insur. Pract. **33**(2), 193–206 (2008)
Doff, R.: The final solvency II framework: will it be effective? Geneva Pap. Risk Insur. **41**(4), 587–607 (2016)
Domanski, D., Shin, H.S., Sushko, V.: The hunt for duration: not waving but drowning? IMF Econ. Rev. **65**(1), 113–153 (2017)
Düll, R., König, F., Ohls, J.: On the exposure of insurance companies to sovereign risk—portfolio investments and market forces. J. Financial Stab. **31**, 93–106 (2017)
ECB: Decisions taken by the Governing Council of the ECB (in addition to decisions setting interest rates) (2020c). https://www.ecb.europa.eu/press/govcdec/otherdec/2020/html/ecb.gc200731, Accessed 14 Dec 2020
ECB: Euro area insurers and the low interest rate environment. Financial stability review, november 2015 (2015). https://www.ecb.europa.eu/pub/pdf/fsr/financialstabilityreview201511.en.pdf, Accessed 14 July 2020
ECB: Inflation rate (HICP) (2021a). https://sdw.ecb.europa.eu, Accessed 18 June 2021
ECB: Monetary policy accounts: meeting of 29–30 April 2020 (2020e). https://www.ecb.europa.eu/press/accounts/2020/html/ecb.mg200522, Accessed 14 Dec 2020
ECB: Pandemic emergency purchase programme (PEPP) (2020a). https://www.ecb.europa.eu/mopo/implement/pepp/html/index.en.html, Accessed 14 Dec 2020
ECB: Pandemic emergency purchase programme (PEPP) (2021b). https://www.ecb.europa.eu/mopo/implement/pepp/html/index.en.html, Accessed 7 Oct 2021
ECB: Press release: ECB announces package of temporary collateral easing measures (2020b). https://www.ecb.europa.eu/press/pr/wfs/html/index.en.html, Accessed 14 Dec 2020
ECB: The definition of price stability (2021c). https://www.ecb.europa.eu/mopo/strategy/pricestab/html/index.en.html, Accessed 7 Oct 2021
ECB: The ECB's monetary policy strategy statement (2021d). https://www.ecb.europa.eu/home/search/review/html/ecb.strategyreview_monpol_strategy_statement.en.html, Accessed 7 Oct 2021
ECB: The impact of the ECB's monetary policy measures taken in response to the COVID-19 crisis. Economic Bulletin Boxes. 5, 37–43 (2020d). https://www.ecb.europa.eu/pub/economic-bulletin/focus/2020/html/ecb.ebbox202005_03, Accessed 14 Dec 2020
Eichengreen, B.: Is Europe an optimum currency area? In: Borner, S., Grubel, H. (eds.) The European Community after 1992, pp. 138–161. Palgrave Macmillan, London (1992)
EIOPA: EEA Group quarterly balance sheet statistics (2020a). https://www.eiopa.europa.eu/tools-and-data/insurance-statistics_en, Accessed 28 Nov 2020
EIOPA: Solo quarterly asset exposure statistics (2020b). https://www.eiopa.europa.eu/tools-and-data/insurance-statistics_en, Accessed 28 Nov 2020
EIOPA: Solo quarterly balance sheet data (2020c). https://www.eiopa.europa.eu/tools-and-data/insurance-statistics_en, Accessed 28 Nov 2020
Ejsing, J., Lemke, W.: The Janus-headed salvation: sovereign and bank credit risk premia during 2008–2009. Econ. Lett. **110**(1), 28–31 (2011)
Elderfield, M.: Solvency II: setting the pace for regulatory change. Geneva Pap. Risk Insur. Pract. **34**(1), 35–41 (2009)
Eling, M., Holder, S.: Maximum Technical Interest Rates in Life Insurance in Europe and the United States: An Overview and Comparison. The Geneva Papers on Risk and Insurance — Issues and Practice **38**, 354–375 (2013)
Eling, M., Schmeiser, H., Schmit, J.T.: The solvency II process: overview and critical analysis. Risk. Manag. Insur. Rev. **10**(1), 69–85 (2007)
European Parliament: Directive 2009/138/EC of the European parliament and of the council of 25 november 2009 on the taking-up and pursuit of the business of insurance and Reinsurance (solvency II) (recast). Official journal of the European Union (2009on). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX, Accessed 18 Oct 2020
European Parliament: Regulation (EU) no 462/2013 of the European parliament and of the council of 21 May 2013 amending regulation (EC) no 1060/2009 on credit rating agencies (2013). https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32013R0462&from=de, Accessed 18 Oct 2020
Fache Rousová, L., Giuzio, M.: Insurers' investment strategies: pro- or countercyclical?. European central bank working paper series no. 2299 (2019). https://www.ecb.europa.eu/pub/research/working-papers/html/index.en.html, Accessed 13 Dec 2020

Filoso, V., Panico, C., Papagni, E., Purificato, F., Suárez, V.M.: Timing does matter: institutional flaws and the European debt crisis. Rev. Polit. Econ. (2021). https://doi.org/10.1080/09538259.2020.1859717
Focarelli, D.: Why insurance regulation is crucial for long-term investment and economic growth. Insurance regulation in the European Union. In: Marano, P., Siri, M. (eds.) Insurance regulation in the European Union, pp. 339–359. Palgrave Macmillan, Cham (2017)
Gatzert, N., Wesker, H.: A comparative assessment of Basel II/III and solvency II. Geneva Pap. Risk Insur. Pract. **37**(3), 539–570 (2012)
German Association of Actuaries: Hoechstrechnungszins in der Lebensversicherung (2020). https://aktuar.de/unsere-themen/lebensversicherung/hoechstrechnungszins/Seiten/default.aspx, Accessed 14 Dec 2020
Gibson, H.D., Hall, S.G., Tavlas, G.S.: Fundamentally wrong: market pricing of sovereigns and the Greek financial crisis. J. Macroecon. **39**, 405–419 (2014)
Goldreich, D., Hanke, B., Nath, P.: The price of future liquidity: time-varying liquidity in the US treasury market. Rev. Financ. **9**(1), 1–32 (2005)
Gormus, A., Nazlioglu, S., Soytas, U.: High-yield bond and energy markets. Energy Econ. **69**, 101–110 (2018)
Granger, C.W.: Investigating causal relations by econometric models and cross-spectral methods. Econometrica **37**(3), 424–438 (1969)
Grima, S.: The ORSA requirement: insurance practitioners' concerns. 18th Annual Conference Proportionality and Legal Certainty in Insurance Law, Palic., pp 269–278 (2017)
Grund, S.: Restructuring government debt under local law: the Greek case and implications for investor protection in Europe. Cap. Mark. Law J. **12**(2), 253–273 (2017)
Gründl, H., Gal, J.: Own risk and solvency assessment within the solvency II framework and its interplay with the quantitative solvency capital requirements. SAFE Policy Letters. 11. (2013)
Gründl, H., Dong, M.I., Gal, J.: The Evolution of Insurer Portfolio Investment Strategies for Long-term Investing. OECD J. Financial Mark. Trends. **2016**(2), 1–55 (2017)
Gruppe, M., Lange, C.: Spain and the European sovereign debt crisis. Eur J Polit Econ **34**, 3–8 (2014)
Gruppe, M., Basse, T., Friedrich, M., Lange, C.: Interest rate convergence, sovereign credit risk and the European debt crisis: a survey. J. Risk Finance **18**(4), 432–442 (2017)
Gunay, S.: Seeking causality between liquidity risk and credit risk: TED-OIS spreads and CDS indexes. Res. Int. Bus. Finance **52**, 101189 (2020)
Gómez-Puig, M.: Size matters for liquidity: evidence from EMU sovereign yield spreads. Econ Lett **90**(2), 156–162 (2006)
Gómez-Puig, M., Sosvilla-Rivero, S.: Causality and contagion in EMU sovereign debt markets. Int. Rev. Econ. Finance **33**, 12–27 (2014)
Haas, J., Neely, C.J.: Central bank responses to COVID-19. Econ. Synopses (2020). https://doi.org/10.20955/es.2020.23
Hartmann, P., Borgioli, S., Kempf, A., Molitor, P., Mongelli, F.P.: Financial integration and structure in EMU during the corona crisis (2021). https://voxeu.org/article/financial-integration-and-structure-emu-during-corona-crisis, Accessed 19 June 2021
Holder, M.: The Euro impact on European financial markets. Manag. Finance **25**(11), 27–34 (1999)
Hopt, K.J.: Corporate governance of banks and other financial institutions after the financial crisis. J. Corp. Law Stud. **13**(2), 219–253 (2013)
Hutchinson, J., Mee, S.: The impact of the ECB's monetary policy measures taken in response to the COVID-19 crisis. ECB Economic Bulletin Boxes **5**. https://www.ecb.europa.eu//pub/economic-bulletin/focus/2020/html/ecb.ebbox202005_03~12b5ff68bf.en.html (2020). Accessed 14 July 2020
Van Hulle, K.: Solvency II: state of play and perspectives. Z Gesamt. Versicherungswiss. **100**(2), 177–192 (2011)
Jankowitsch, R., Mösenbacher, H., Pichler, S.: Measuring the liquidity impact on EMU government bond prices. Eur. J. Finance **12**(2), 153–169 (2006)
Jareño, F., Tolentino, M., González, M.D.L.O., Medina, M.Á.: Interest rate exposure of European insurers. Int. J. Econ. Bus. **27**(2), 255–268 (2020)
Jinjarak, Y., Ahmed, R., Nair-Desai, S., Xin, W., Aizenman, J.: Pandemic shocks and fiscal-monetary policies in the Eurozone: COVID-19 dominance during January-June 2020. NBER Working Paper No. 27451. (2020)
Kim, S. J., Moshirian, F., Wu, E.: Evolution of international stock and bond market integration: Influence of the European Monetary Union. Journal of Banking and Finance **30**(5), 1507–1534 (2006)
Klose, J., Weigert, B.: Sovereign yield spreads during the Euro crisis: fundamental factors versus redenomination risk. Int. Finance **17**(1), 25–50 (2014)

Kool, C.J.: International bond markets and the introduction of the Euro. Fed. Reserve Bank St. Louis Rev. **82**(5), 41–56 (2000)
Krampf, A.: From transparency to ambiguity: the impact of the ECB's unconventional policies on the EMU. J. Eur. Integr. **38**(4), 455–471 (2016)
Krishnamurthy, A., Nagel, S., Vissing-Jorgensen, A.: ECB policies involving government bond purchases: impact and channels. Rev. Financ. **22**(1), 1–44 (2018)
Kunze, F., Basse, T., Gonzalez, M.R., Vornholz, G.: Forward-looking financial risk management and the housing market in the United Kingdom: is there a role for sentiment indicators? J. Risk Finance **21**(5), 659–678 (2020)
Lapavitsas, C.: The Redenomination risk of exiting the Eurozone: an estimation based on the Greek case. Eur. Law J. **24**(2–3), 226–243 (2018)
Lempérière, Y., Deremble, C., Nguyen, T.T., Seager, P., Potters, M., Bouchaud, J.P.: Risk premia: asymmetric tail risks and excess returns. Quant. Finance. **17**(1), 1–14 (2017)
Liebwein, P.: Risk models for capital adequacy: applications in the context of solvency II and beyond. Geneva Pap. Risk Insur. Pract. **31**(3), 528–550 (2006)
Ludwig, A.: Credit risk-free sovereign bonds under solvency II: a cointegration analysis with consistently estimated structural breaks. Appl. Financial Econ. **24**(12), 811–823 (2014)
Lund, J.: A model for studying the effect of EMU on European yield curves. Eur. Finance Rev. **2**(3), 321–363 (1999)
Maltritz, D.: Determinants of sovereign yield spreads in the Eurozone: a Bayesian approach. J Int Money Finance **31**(3), 657–672 (2012)
Maltritz, D., Molchanov, A.: Country credit risk determinants with model uncertainty. Int. Rev. Econ. Finance **29**, 224–234 (2014)
Meier, S., Rodriguez Gonzalez, M., Kunze, F.: The global financial crisis, the EMU sovereign debt crisis and international financial regulation: lessons from a systematic literature review. International Review of Law and Economics **65**, 105945 (2020)
Möhlmann, A.: Interest rate risk of life insurers: evidence from accounting data. Financ Manage **50**(2), 587–612 (2021)
Monkiewicz, J.: Dialectics of the current regulatory and supervisory developments in insurance. Geneva Pap. Risk Insur. Pract. **38**, 183–188 (2013)
Nazlioglu, S., Gormus, A., Soytas, U.: Oil prices and monetary policy in emerging markets: structural shifts in causal linkages. Emerg. Mark. Finance Trade **55**(1), 105–117 (2019)
Niedrig, T.: Optimal asset allocation for interconnected life insurers in the low interest rate environment under solvency regulation. J. Insur. Issues **38**(1), 31–71 (2015)
Officer, M.S.: The price of corporate liquidity: acquisition discounts for unlisted targets. J financ econ **83**(3), 571–598 (2007)
Oliveira, L., Curto, J.D., Nunes, J.P.: The determinants of sovereign credit spread changes in the Eurozone. J. Int. Financial Mark. Institutions Money **22**(2), 278–304 (2012)
Oxley, L.: Cointegration, causality and export-led growth in Portugal, 1865–1985. Econ. Lett. **43**(2), 163–166 (1993)
Paloviita, M., Haavio, M., Jalasjoki, P., Kilponen, J.: What does "below, but close to, 2 percent" mean? Assessing the ECB's reaction function with real-time data. Int. J. Cent. Bank. **17**(2), 125–169 (2021)
Paltalidis, N., Gounopoulos, D., Kizys, R., Koutelidakis, Y.: Transmission channels of systemic risk and contagion in the European financial network. J. Bank. Finance **61**, 36–52 (2015)
Phillips, P.C., Perron, P.: Testing for a unit root in time series regression. Biometrika **75**(2), 335–346 (1988)
Phillips, P.C., Shi, S.: Detecting financial collapse and ballooning sovereign risk. Oxf. Bull. Econ. Stat. **81**(6), 1336–1361 (2019)
Pollard, P.: A look inside two central banks: the European central bank and the federal reserve. Fed. Reserve Bank St. Louis Rev. **85**, 11–30 (2003)
Quaglia, L.: The Politics of Insurance Regulation and Supervision Reform in the European Union. Comp. Eur. Polit. **9**(1), 100–122 (2011)
Rae, R.A., Barrett, A., Brooks, D., Chotai, M.A., Pelkiewicz, A.J., Wang, C.: A review of solvency II: has it met its objectives? Br. Actuar. J. **23**, 1–72 (2018)
Rodriguez Gonzalez, M., Basse, T., Tholl, J.: Interest rate differentials and monetary policy in the European monetary union: the case of 10 and 30 year bonds. ZVersWiss **108**(1), 19–42 (2019)
Rodriguez-Gonzalez, M., Kunze, F., Schwarzbach, C., Dieng, C.: Asset liability management and the Euro crisis: sovereign credit risk as a challenge for the German life insurance industry. J. Risk Finance **18**(4), 466–483 (2017)

Sensoy, A., Nguyen, D.K., Rostom, A., Hacihasanoglu, E.: Dynamic integration and network structure of the EMU sovereign bond markets. Ann. Oper. Res. **281**(1), 297–314 (2019)
Sibbertsen, P., Wegener, C., Basse, T.: Testing for a break in the persistence in yield spreads of EMU government bonds. J. Bank. Finance **41**, 109–118 (2014)
Sims, C.A.: Macroeconomics and reality. Econometrica **48**(1), 1–48 (1980)
Smith, M.J.-H.: Solvency II: the ambitious modernization of the prudential regulation of insurers and reinsurers across the European Union (EU). Connect. Insur. Law Journal. **16**(2), 357–398 (2010)
Statista Research Department: Laufende Verzinsung der Lebensversicherer in Deutschland von 2000 bis 2019 (2020). https://de.statista.com/statistik/daten/studie/168461/umfrage/ueberschussbeteiligung-der-lebensversicherer-seit-1995/, Accessed 15 Dec 2020
Tholl, J., Schwarzbach, C., Pittalis, S., von Mettenheim, H.J.: Bank funding and the recent political development in Italy: what about redenomination risk? Int Rev Law Econ **64**, 105932 (2020)
Thornton, J.: Cointegration, causality and export-led growth in Mexico, 1895–1992. Econ Lett **50**(3), 413–416 (1996)
Toda, H.Y., Yamamoto, T.: Statistical inference in vector autoregressions with possibly integrated processes. J Econom **66**(1-2), 225–250 (1995)
Valiante, D.: The Eurozone debt crisis: from its origins to a way forward. Center for European Policy Studies Policy Briefs No. 251. (2011)
Van Riet, A.: The ECB's Fight against Low Inflation: On the Effects of Ultra-Low Interest Rates. International Journal of Financial Studies **5**(2):12 (2017). https://doi.org/10.3390/ijfs5020012
Von Saldern, N.: Government bonds: treatment of risk under solvency II. BaFin (2016). https://www.bafin.de/SharedDocs/Veroeffentlichungen/EN/Fachartikel/2016/fa_bj_1607_staatsanleihen_en.html, Accessed 7 Jan 2021
De Vries, T., De Haan, J.: Credit ratings and bond spreads of the GIIPS. Appl. Econ. Lett. **23**(2), 107–111 (2016)
Wegener, C., Kruse, R., Basse, T.: The walking debt crisis. Journal of Economic Behavior and Organization **157**, 382–402 (2019)
Zabala, J.A., Prats, M.A.: The unconventional monetary policy of the European central bank: effectiveness and transmission analysis. World Econ. **43**(3), 794–809 (2020)
Zapata, H.O., Rambaldi, A.N.: Monte Carlo evidence on cointegration and causation. Oxf. Bull. Econ. Stat. **59**(2), 285–298 (1997)

Module 9

Interest Rate Differentials and Monetary Policy in the European Monetary Union: The Case of 10 and 30 Year Bonds

Rodriguez Gonzalez, M. / Basse, T. / Tholl, J. (2019)

Published in:
Zeitschrift für die gesamte Versicherungswissenschaft, Vol. 108, No. 1, pp. 19–42. DOI: https://doi.org/10.1007/s12297-019-00434-z.

ZVersWiss (2019) 108:19–42
https://doi.org/10.1007/s12297-019-00434-z

ABHANDLUNG

Interest Rate Differentials and Monetary Policy in the European Monetary Union: The Case of 10 and 30 Year Bonds

Miguel Rodriguez Gonzalez · Tobias Basse · Johannes Tholl

Published online: 15 March 2019

Abstract This empirical study uses techniques of time series analysis to examine how government bond yield spreads in France, Italy and Spain (relative to Germany) react to central bank actions in the European Monetary Union. More specifically, fixed income securities with maturities of 10 and 30 years are considered. These long term bonds should be of special importance for the European life insurance industry because of the liability structure of these financial services firms. Other central banks already have hiked interest rates and financial markets, as a consequence, now financial markets seem to be waiting for an increase to the Main Refinancing Operations Announcement Rate. Six bivariate VAR models are estimated. Our results imply that in general there is no strong positive reaction of the bond yield spreads to a contractionary monetary policy shock. Furthermore, there seems to be a negative reaction of the monetary policy rate to a positive shock to the government bond yield spread in the first months. In some cases (10 year bonds of France and Italy) this empirical finding is statistically significant. Therefore, the empirical evidence reported here is not only interesting from the viewpoint of economic theory but also has practical implications for asset managers in the European insurance industry.

Zusammenfassung Diese empirische Studie nutzt Techniken der Zeitreihenanalyse um zu untersuchen, wie die Renditedifferenzen von französischen, italienischen und spanischen Anleihen relativ zu deutschen Papieren auf eine Leitzinsanhebung der Europäischen Zentralbank reagieren. Betrachtet werden die Laufzeitsegmente 10

M. Rodriguez Gonzalez (✉)
Gottfried Wilhelm Leibniz Universität, Hannover, Germany
E-Mail: mr@ivbl.uni-hannover.de

T. Basse · J. Tholl
Norddeutsche Landesbank (NORD/LB), Hannover, Germany

T. Basse
Touro College, Berlin, Germany

und 30 Jahre. Papiere mit entsprechend langen Laufzeiten haben, bedingt durch die Struktur der Passiva dieser institutionellen Investoren, eine besondere Relevanz für europäische Lebensversicherungsunternehmen. Da in einigen anderen Währungsräumen bereits Anpassungen des Leitzinsniveaus stattgefunden haben, warten die Finanzmärkte momentan regelrecht auf das Handeln der Europäischen Zentralbank. Sechs bivariate VAR-Modelle werden geschätzt. Unsere Ergebnisse deuten darauf hin, dass es generell keine starke positive Reaktion der Rentenrenditespreads auf eine kontraktive Geldpolitik der EZB zu geben scheint. Weiterhin zeigen sich Hinweise, dass es in den ersten Monaten eine negative Reaktion des Leitzinses auf einen positiven Schock der Rentenrenditespreads zu geben scheint. In manchen Fällen (10-jährige Staatsanleihen von Frankreich und Italien) sind diese empirischen Ergebnisse statistisch signifikant. Die hier dokumentierten empirischen Ergebnisse haben somit nicht nur eine Bedeutung für die ökonomische Theorie, sondern können auch Impulse für die praktische Arbeit in der Kapitalanlage der europäischen Versicherungswirtschaft liefern.

1 Introduction

Central banks all around the world were forced to react to the global financial crisis by lowering short term interest rates (see, for example, Fawley and Neely 2013; Ricci 2015). Additionally, measures of unconventional monetary policy were used to support global economic growth—which essentially means that government bonds and other fixed income securities have been bought by central banks (see, for example, Curida and Woodford 2011; Fawley and Neely 2013). Both types of monetary policy measures have affected bond yields. As a matter of fact, medium and long term bond yields have fallen in many countries. Especially "secure" fixed income securities (for example sovereign bonds issued by some member states of the European Monetary Union) also profited from "flight-to-quality" effects that pushed down interest rates even further (see, among others, Basse 2014; Gürtler and Neelmeier 2018). In Germany, for example, 10 year government bond yields even fell below zero for a while. Low long-term interest rates have caused major problems for the European life insurance industry (see, for example, Basse et al. 2014; Berdin and Gründl 2015). In fact, Berdin and Gründel (2015) have argued convincingly that especially German life insurers have had to face significant challenges due to the situation in the bond market, because these financial services firms were used to sell products with relatively high guaranteed returns to their customers in the past. Financing these guarantees certainly has become a problem for asset managers in the insurance industry (see, for example, Linderkamp et al. 2013;Niedrig 2015). Meanwhile some central banks have started a gradual process of normalization to their monetary policy stance; most notably, of course, the Federal Reserve in the United States began to increase the Fed Funds Target Rate in December 2015 (see, for example, Feroli et al. 2017;Basse et al. 2017). Market participants now seem to wait for the European Central Bank to also increase short term interest rates. Rate hikes in the European Monetary Union most probably should also affect medium and long term interest rates in Germany and the other member states of the

currency union. Major changes to the interest rate environment, of course, would have consequence for life insurers (see, for example, Basse et al. 2014; Berdin and Gründl 2015).

However, not all European sovereign states were confronted with falling medium and long term interest rates during the crisis. As a matter of fact, fears about sovereign credit risk pushed up government bond yields in a number of European countries that were believed to be fiscally less solvent than Austria, Germany or the Netherlands (see, among others Ludwig 2014 and Gruppe et al. 2017). In any case, investors back then demanded significantly higher interest rates as a compensation to fund the budget deficits of some member states of the European Monetary Union (e. g., Portugal, Italy or Spain). Especially the insurers in these countries should also be interested in how government bond yield spreads relative to "secure" German sovereign debt will react to the anticipated rate hikes by the European Central Bank. In fact, these insurance companies often tend to have some kind of home bias concentrating their holdings of sovereign paper on bonds issued by their home countries. Moreover, because of the implementation of one very special rule in Solvency II, this question is also of more general relevance for the European life insurance industry. As a matter of fact, from a regulatory perspective Solvency II treats the debt of all European Union member states as free of default risk. This principle of the new regulatory framework of European insurance industry has been criticized (see, for example, Basse et al. 2012; Ludwig 2014). Indeed, given that market prices of sovereign debt reflect at least some default risk of countries like Italy or Spain there is some room for regulatory arbitrage (see Basse et al. 2012). Therefore, not only insurers in the European Union member states with fiscal problems could be interested in the behavior of government bond yield spreads to rate hikes by the European Central Bank.

This study presents and evaluates new empirical evidence about the linkages between the monetary policy of the European Central Bank and the yield spreads of French, Italian and Spanish government bonds relative to German ones employing techniques of time series analysis. The paper is structured as follows: The 2nd paragraph provides some relevant background information with regard to the behavior of interest rates in the European Monetary Union. The 3rd section introduces the data examined, provides the results of the necessary pre-testing efforts and then discusses a number of important methodological issues. Some data problems are also addressed here. The empirical evidence is presented and evaluated in the 4th paragraph. The 5th section then concludes.

2 Interest Rates and the Euro

Long before the outbreak of the European sovereign debt crisis, there were controversial discussions about the decision which countries should belong to the European Monetary Union (see, for example, Altmann 1994; Calomiris 1999). In fact, even shortly before the start of the new monetary regime there was no clear picture which countries should join the currency union. Although the founders of the European Monetary Union defined some convergence criteria (see, for example, Pollard 1995,

2003) that needed (and still need) to be fulfilled in order to become a member of the euro zone, the "admission tickets" to the prestigious club of member countries of the new currency union most probably were distributed on political thoughts rather than on economic facts. Moreover, it has also been argued that the convergence criteria codified in the Maastricht treaty cannot ensure the needed real convergence among the member states (see, for example, Bayoumi and Eichengreen 1997; Boreiko 2003). Holtemöller (2005) and De Grauwe and Schnabl (2005), for example, have discussed different convergence issues from the perspective of potential accession countries. The theory of optimum currency areas could provide a scientific background when trying to determine which countries (or even regions) should use the same currency. Mundell (1961), McKinnon (1963) and Kenen (1969) have suggested different criteria that an optimum currency area should comply with, helping to minimize the costs of the introduction of a common currency. Among the most important costs of abolishing a country's own currency is that the member states surrender their monetary independence (see, for example, Graboyes 1990; Beetsma and Giuliodori 2010). In fact, a currency union necessarily results in a situation in which the member countries have to give up the ability to autonomously decide about the course of future monetary policy. However, Beine et al. (2003) have questioned the usefulness of the optimum currency area approach to determine which countries should join the European Monetary Union because the potential members of the currency union already were part of an exchange rate system that limited the exchange rate volatility of the currencies participating in this framework. A number of additional studies could be of some relevance at this point. Most importantly, Goodhart (1998) also has challenged the point of view that the theory of optimum currency areas can act as a good starting point trying to analyze how the new monetary union should be designed. This was the so-called European Monetary System. Thus, accepting the German Dominance Hypothesis, the monetary policy decisions taken in Germany also affected the interest rates in the other member states of the European Monetary System (see, for example, Hagen and Fratianni 1990; Herz and Röger 1992). Phrased somewhat differently, even before the introduction of the Euro there was a controversial discussion which countries should be defined as core Eurozone member states, and which countries ought to belong to the periphery. In fact, there even was no agreement with regard to the criteria how to determine which countries should join the currency union and which countries should stay out (at least for the moment). While there was almost no doubt that Germany and France as biggest European economies should belong to the group of core members (this clearly changed with the European sovereign debt crisis—see Basse 2014), no clear picture with regard to the peripheral did exist back then. Thinking about the now well-known acronym "PIIGS" (refering to the Southern European States Portugal, Italy, Greece and Spain, as well as Ireland), it cannot be surprising that Portugal and Spain were classified as peripheral by Beine and Hecq (1997), while Kouparitsas (1999) identified Ireland and Finland. In retrospect, this seems to be counterintuitive as the only Scandinavian country in the currency union clearly has become one of the more "hawkish" members of the Eurozone in terms of financial soundness.

Without any doubt, the birth of the new common currency in Europe was of major importance for international financial markets (see, for example, Holder 1999

and Hardouvelis et al. 2006). Most importantly, the introduction of the Euro led to strong convergence tendencies among nominal short-, medium- and long-term interest rates in the participating countries. This was a direct consequence of the absence of exchange rate risk after the common currency was created (see, for example, Sibbertsen et al. 2014; Basse et al. 2018). Assuming the absence of differences in liquidity or credit risk, the uncovered interest rate parity indeed does predict that the creation of the currency union should have led to convergence among government bond yields (see, for example, Sibbertsen et al. 2014; Basse 2014). As a matter of fact, the European Monetary System, which also reduced exchange rate risk should already have affected bond yields in the member countries of this exchange rate system (see Basse et al. 2012; Basse 2014). However, Graboyes (1990) has stressed that the European Monetary System was no monetary union. There still were exchange rate movements back then. Thus, the introduction of the Euro should still have affected the price of exchange rate risk in the European bond markets. Additionally, there was just one policy rate in all the countries entering the European Monetary Union from the year 1999 onwards (see, for example, Gaspar et al. 2001; Gruppe et al. 2017). This significantly changed monetary policy environment had some consequence for short-term interest rates in the currency union. Clearly, both facts discussed above were important causes for nominal interest rate convergence in the European Monetary Union. However, fiscal solidity still did seem to matter somewhat for fixed income markets back then (see, most importantly, Codogno et al. 2003). v. Hagen et al. (2011), for example, have examined sovereign credit risk premia in the European government bond market in the period between 1991 and 2005 and have shown that yield spreads depended on the difference in the debt-to-GDP-ratios between the respective other member states and Germany, being the reference country. These results have later on been confirmed by Bernoth et al. (2012). Laopidis (2008) also has focused on the development of interest rates in the countries participating in the currency union and was able to split the member countries into two groups using techniques of cointegration analysis—the core countries, like Germany and France, and the peripheral member states like Italy or Ireland.

As already noted, the turmoil that was caused by the financial crisis brought the "PIIGS" into big trouble which was reflected in a significant increase in the interest rate differential between government bonds issued by these countries and German sovereign debt (see, for example, Gruppe and Lange 2014; Ludwig, 2014). Analyzing the interest rate environment in the European Monetary Union at least three different regimes can be identified (see, most importantly, Afonso et al. 2018). More specifically, shortly after (or most probably even before) the Euro had been introduced in 1999, there were clear tendencies for nominal interest rate convergence in the countries that joined the new currency union. The financial crisis then caused increasing risk premia compensating investors for sovereign credit risk (see, most importantly, Sibbertsen et al. 2014). This important development (at least for a while) seems to have ended the tendencies of interest rate convergence in the European Monetary Union. The reaction of the European Central Bank—which (as already discussed above) decided to loosen its monetary policy drastically as a response to the crisis—then was a kind of "game changer" again. Afonso et al. (2018), for example, have argued convincingly that the quantitative easing measures that have

been implemented in 2012 seem to have helped to ease the tensions in the market for European government bonds. As a matter of fact, the unusual monetary policy measures taken by European Central Bank seem to have lowered risk premia again (see, for example, Krempf 2016; Krishnamurthy et al. 2018).

Gruppe et al. (2017) have noted that the timing of structural change detected in the relationship between government bond yields of peripheral member countries of the European Monetary Union and German interest rates is very interesting. In fact, they have argued that the breakpoint dates reported in a number of empirical studies are quite early. This could be a consequence of the subprime mortgage crisis in the United States. The near collapse of the financial system in North America could indeed have increased the risk aversion among European investors in general. Moreover, concerns about costly rescue programmes for European banks that had invested in mortgage backed securities and collateralized debt obligations issued in the United States might also have had negative effects on the solidity of public finances in some member countries of the European Monetary Union. As a matter of fact, Ejsing and Lemke (2011) have detected structural change in the relationship between bank and sovereign credit default swap premia after the bailouts of European banks. Moreover, Quaglia and Royo (2015) have stressed the need to divide the European sovereign debt crisis into a banking crisis and balance of payments crisis. At this point it is important to note that European insurers did not have a very significant exposure to mortgage backed securities and collateralized debt obligations issued in the United States (see Eling and Schmeiser 2010; Reddemann et al. 2010). Therefore, the direct consequences of the subprime debacle seem to have been rather limited. However, Eling and Schmeiser (2010) have stressed the importance of indirect negative effects. Given that numerous central banks were forced to reduce short term interest rates and to supply ample liquidity to financial markets long-term bond yields in many countries (and, of course, also in the European Monetary Union) came under considerable pressure. As already noted, a "flight-to-quality" effect then seems to have increased the demand for low-risk assets pushing down interest rates of German government bonds and similar securities even further (see, for example, Basse 2014 and Gürtler and Neelmeier 2018). Additionally, Niedrig (2015) has noted that life insurers based in the monetary union are important holders of fixed income securities issued by European banks. Therefore, there is a direct financial connection between the two types of financial services firms. Consequently, problems in the European banking industry certainly do matter for the insurance industry in the currency union.

3 Data and methodological issues

Given that European life insurers have to manage the interest rate risk that is a result from their liabilities (guarantees given to their customers), they have to buy debt obligations with high maturities. Therefore, this study examines sovereign bond yield time series calculated from fixed income securities with maturities of 10 and 30 years. German government bond yields are commonly used as the benchmark interest rate for the European Monetary Union (see, for example, Paniagua et al.

2017 and Rodriguez Gonzalez et al. 2017). This can be explained by the fact that financial markets usually do not see any real risk for a sovereign default in the biggest European economy (see, for example, Ang and Longstaff 2013 and van de Ven et al. 2018). Additionally, the market for government debt issued by Germany is characterized by a very high level of liquidity. Therefore, it is very common to examine interest rate differentials to German government bond yields in the literature. Given that German government bonds are highly liquid and that fixed income investors see no real risk of a debt default of this country, it certainly does make sense to use sovereign debt issued by Germany as benchmark for bonds denominated in the currency Euro. More formally, based on the different interest rates *i* that are examined here, yield spreads *SP* of sovereign debt issued by country *X* (France, Italy or Spain) relative to German bonds with the maturity *Z* (10 or 30 years) are calculated using the simple formula:

$$\mathrm{SP}_{\mathrm{X,Z}} = \mathrm{i}_{\mathrm{x,z}} - \mathrm{i}_{\mathrm{Germany,Z}} \tag{1}$$

Equation 1 defines an interest rate differential that can be interpreted as risk premium compensating investors for the higher default and liquidity risk of country *X* relative to Germany. The data is taken from Bloomberg. The 10 year and 30 year interest rate time series all are generic government bond yields calculated from the bid side of market quotes. The monetary policy variable examined is the so-called Main Refinancing Operations Announcement Rate, which is directly controlled by the European Central Bank. The study examines monthly data (end of period) from January 1999 to August 2018. The starting point of the sample is determined by limitations to the availability of data. As already noted, there was no single monetary policy instrument for the whole European Monetary Union before the introduction of the Euro.

Examining data from 1999 to 2018 clearly results in some problems with structural change. As already discussed in some detail, the fears about the stability of the fiscal policies in some member states of the European Monetary Union caused structural change in the relationship between the level of interest rates in these countries and government bond yields in Germany (see, for example, Gruppe and Lange 2014; Ludwig 2014). Moreover, Afonso et al. (2018) have argued convincingly that the quantitative easing measures taken by the European Central Bank in August 2012 have helped to ease the tensions in the European government bond market. Phrased somewhat differently, this policy intervention seems to have affected the pricing of sovereign credit risk in the market (see, among others, Krempf 2016; Krishnamurthy et al. 2018). In sum, government bond yield spreads against Germany are now higher than before the crisis and lower than during the crisis. Therefore, Afonso et al. (2018) have argued that three regimes seem to exist. Arghyrou and Kontonikas (2012) have even gone one step further suggesting that the European government debt crisis should be divided into an early and a later phase. They have argued that the events in Greece played a major role in the first part of the crisis. Moreover, Basse, Wegener and Kunze (2018) have noted that financial markets did not care much about sovereign credit risk before the crisis. Thus, interest rate differentials relative to Germany back then probably were too low from the perspective of finan-

cial risk managers and, as a consequence, might not be a good reference point for making predictions with regard to the behavior of government bond yield spreads today. This problem could simply be handled by reducing the size of the sample in the process of the estimation of an empirical model. Walsh and Wilcox (1995), for example, have suggested to use this empirical modelling strategy. However, given that this study plans to examine how government bond yield spreads in the European Monetary Union will likely react to the first rate hike by the European Central Bank, this approach would be somewhat problematic because there have been no increases to the monetary policy rate since the year 2008. Moreover, Sims (1998) has argued that omitting clearly unusual periods from econometric models examining central bank actions is not necessarily a good idea because these data points should provide important evidence with regard to the effects of monetary policy. Therefore, he has suggested to estimate models using the full sample. This position seems to be based on the general idea that the existence of certain mechanisms should lead to some robust linkages among specific economic and financial time series. Obviously, there are no universal laws in the field of economics that lead to absolutely constant interrelationships. However, certain more or less robust relationships still seem to exist. Well-functioning markets, for example, should lead to a situation where the prices of goods and services react to changes to the demand for or to the supply of these goods and services. From a certain perspective this relationship that determines market prices comes quite close to some kind of universal law. Focusing on the research question examined here it seems to be obvious that monetary policy makers in the European currency union will only hike interest rates when there is clear evidence that the financial crisis is over. But clarity seems to end here. In fact, the crisis period that seems to be ending right know probably is not a good reference point to judge how interest rate increases by the European Central Bank are going to affect sovereign bond yields in the currency union. However, while more convergence among interest rates in the member countries of the European Monetary Union is likely to be seen again after the end of the financial turmoil, it is also improbable that the spread between government bond yields in Germany and in fiscally less stable countries will behave in the future as if there was no crisis in the past (see Sibbertsen et al. 2014). Moreover, given the research question under investigation here, the forecasting financial market literature might also be of some relevance. Dimson et al. (2003), for example, have stressed the need for a long-run perspective projecting the future risk-return trade-off of stock market investments and have argued convincingly that long periods of capital market history should be examined in order to predict the equity risk premium. This approach can help to avoid an overly strong focus on recent historic data that would lead to highly volatile forecasts. In any case, reducing the sample size of regression models as an empirical research strategy to cope with possibly relevant structural change, most probably is not always a good idea.

The unit root test suggested by Phillips and Perron (1988) is performed to determine the order of integration of all variables that are considered in this study. The critical values tabulated by MacKinnon (1996) are used. The results of the unit root tests are reported in Table 1 to 14. All time series seem to be integrated of order 1. Therefore, cointegration between the government bond yield spreads and the mon-

Table 1 Unit Root Test Interest Rate Differential (Level) France and Germany (10 Year Bonds)

Null Hypothesis: time series has a unit root Exogenous: Constant Bandwidth: 4			
		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		–2.086954	0.2502
Test critical values:	1% level	–3.458104	–
	5% level	–2.873648	–
	10% level	–2.573298	–

Table 2 Unit Root Test Interest Rate Differential (First Difference) France and Germany (10 Year Bonds)

Null Hypothesis: time series has a unit root Exogenous: Constant Bandwidth: 4			
		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		–16.76509	0.0000
Test critical values:	1% level	–3.458225	–
	5% level	–2.873701	–
	10% level	–2.573327	–

Table 3 Unit Root Test Interest Rate Differential (Level) France and Germany (30 Year Bonds)

Null Hypothesis: time series has a unit root Exogenous: Constant Bandwidth: 4			
		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		–1.612440	0.4746
Test critical values:	1% level	–3.458104	–
	5% level	–2.873648	–
	10% level	–2.573298	–

Table 4 Unit Root Test Interest Rate Differential (First Difference) France and Germany (30 Year Bonds)

Null Hypothesis: time series has a unit root Exogenous: Constant Bandwidth: 3			
		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		–14.46513	0.0000
Test critical values:	1% level	–3.458225	–
	5% level	–2.873701	–
	10% level	–2.573327	–

etary policy rate could be a phenomenon of economic relevance. This would have implications for the empirical modelling strategy to be used. However, employing the cointegration test procedures developed by Johansen (1988) no signs for cointegration can be found (see Table 15 to 20). This important empirical finding is robust to different deterministic trend assumptions.

Table 5 Unit Root Test Interest Rate Differential (Level) Italy and Germany (10 Year Bonds)

Null Hypothesis: time series has a unit root			
Exogenous: Constant			
Bandwidth: 5			
		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		–1.428626	0.5679
Test critical values:	1% level	–3.458104	–
	5% level	–2.873648	–
	10% level	–2.573298	–

Table 6 Unit Root Test Interest Rate Differential (First Difference) Italy and Germany (10 Year Bonds)

Null Hypothesis: time series has a unit root			
Exogenous: Constant			
Bandwidth: 6			
		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		–15.40881	0.0000
Test critical values:	1% level	–3.458225	–
	5% level	–2.873701	–
	10% level	–2.573327	–

Table 7 Unit Root Test Interest Rate Differential (Level) Italy and Germany (30 Year Bonds)

Null Hypothesis: time series has a unit root			
Exogenous: Constant			
Bandwidth: 2			
		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		–1.175161	0.6855
Test critical values:	1% level	–3.458104	–
	5% level	–2.873648	–
	10% level	–2.573298	–

Table 8 Unit Root Test Interest Rate Differential (First Difference) Italy and Germany (30 Year Bonds)

Null Hypothesis: time series has a unit root			
Exogenous: Constant			
Bandwidth: 1			
		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		–15.39120	0.0000
Test critical values:	1% level	–3.458225	–
	5% level	–2.873701	–
	10% level	–2.573327	–

Table 9 Unit Root Test Interest Rate Differential (Level) Spain and Germany (10 Year Bonds)

Null Hypothesis: time series has a unit root			
Exogenous: Constant			
Bandwidth: 2			
		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		–1.459215	0.5527
Test critical values:	1% level	–3.458104	–
	5% level	–2.873648	–
	10% level	–2.573298	–

Table 10 Unit Root Test Interest Rate Differential (First Difference) Spain and Germany (10 Year Bonds)

Null Hypothesis: time series has a unit root			
Exogenous: Constant			
Bandwidth: 2			
		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		–17.28893	0.0000
Test critical values:	1% level	–3.458225	–
	5% level	–2.873701	–
	10% level	–2.573327	–

Table 11 Unit Root Test Interest Rate Differential (Level) Spain and Germany (30 Year Bonds)

Null Hypothesis: time series has a unit root			
Exogenous: Constant			
Bandwidth: 1			
		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		–1.278942	0.6397
Test critical values:	1% level	–3.458104	–
	5% level	–2.873648	–
	10% level	–2.573298	–

Table 12 Unit Root Test Interest Rate Differential (First Difference) Spain and Germany (30 Year Bonds)

Null Hypothesis: time series has a unit root			
Exogenous: Constant			
Bandwidth: 2			
		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		–17.17415	0.0000
Test critical values:	1% level	–3.458225	–
	5% level	–2.873701	–
	10% level	–2.573327	–

Table 13 Unit Root Test Main Refinancing Operations Announcement Rate (Level)

Null Hypothesis: time series has a unit root			
Exogenous: Constant			
Bandwidth: 9			
		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		–1.149388	0.6963
Test critical values:	1% level	–3.458104	–
	5% level	–2.873648	–
	10% level	–2.573298	–

Table 14 Unit Root Test Main Refinancing Operations Announcement Rate (First Difference)

Null Hypothesis: time series has a unit root			
Exogenous: Constant			
Bandwidth: 9			
		Adj. t-Stat	Prob.*
Phillips-Perron test statistic		–12.62504	0.0000
Test critical values:	1% level	–3.458225	–
	5% level	–2.873701	–
	10% level	–2.573327	–

Table 15 Johansen Cointegration Tests Spread 10 Year France

Sample: 1999M01 2018M12				
Included observations: 231				
Lags interval: 1 to 4				
Selected (0.05 level*) Number of Cointegrating Relations by Model				
Data Trend:	None	None	Linear	Linear
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend
Trace	0	0	0	0
Max-Eig	0	0	0	0

Table 16 Johansen Cointegration Tests Spread 30 Year France

Sample: 1999M01 2018M12				
Included observations: 231				
Lags interval: 1 to 4				
Selected (0.05 level*) Number of Cointegrating Relations by Model				
Data Trend:	None	None	Linear	Linear
Test Type	No Intercept No Trend	Intercept No Trend	Intercept No Trend	Intercept Trend
Trace	0	0	0	0
Max-Eig	0	0	0	0

Table 17 Johansen Cointegration Tests Spread 10 Year Italy

Sample: 1999M01 2018M12				
Included observations: 231				
Lags interval: 1 to 4				
Selected (0.05 level*) Number of Cointegrating Relations by Model				
Data Trend:	None	None	Linear	Linear
Test Type	No Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend
Trace	0	0	0	0
Max-Eig	0	0	0	0

Table 18 Johansen Cointegration Tests Spread 30 Year Italy

Sample: 1999M01 2018M12				
Included observations: 231				
Lags interval: 1 to 4				
Selected (0.05 level*) Number of Cointegrating Relations by Model				
Data Trend:	None	None	Linear	Linear
Test Type	No Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend
Trace	0	0	0	0
Max-Eig	0	0	0	0

Table 19 Johansen Cointegration Tests Spread 10 Year Spain

Sample: 1999M01 2018M12				
Included observations: 231				
Lags interval: 1 to 4				
Selected (0.05 level*) Number of Cointegrating Relations by Model				
Data Trend:	None	None	Linear	Linear
Test Type	No Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend
Trace	0	0	0	0
Max-Eig	0	0	0	0

The empirical findings discussed above do have implications for the modelling strategy to be used in this study. As a matter of fact, vector autoregressions (VAR) can be employed to examine the relationship between the interest rate differentials calculated with Eq. 1 and the monetary policy instrument used by the European Central Bank. Meanwhile, this technique is considered to be an important analytic tool in the field of applied time series econometrics. This approach has been suggested by Sims (1980) and is able to adequately model the feedback relationships among a set of relevant endogenous variables. Therefore, it is certainly no surprise that VAR models have often been used to analyze the effects of central bank actions (see, for

Table 20 Johansen Cointegration Tests Spread 30 Year Spain

Sample: 1999M01 2018M12				
Included observations: 231				
Lags interval: 1 to 4				
Selected (0.05 level*) Number of Cointegrating Relations by Model				
Data Trend:	None	None	Linear	Linear
Test Type	No Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend
Trace	0	0	0	0
Max-Eig	0	0	0	0

example, Eichenbaum and Evans 1995; Walsh and Wilcox 1995). The time series examined have to be stationary. Each of the n endogenous variables in a VAR model is explained by past values of itself and of all remaining other $n-1$ variables that are considered in the model. More formally, let Y_t be a vector of $(n \times 1)$ endogenous variables that are included in the model:

$$Y_t = C + A_1 Y_{t-1} + A_2 Y_{t-2} + \ldots A_p Y_{t-p} + \varepsilon_t \quad (2)$$

In Eq. 2 A_i are $(n \times n)$ coefficient matrices, C is a $(n \times 1)$ vector of constants and ε_t is a $(n \times 1)$ vector of random errors. A VAR model of this type can be used to analyze the possibly dynamic relationships among government bond yield spreads and the short term interest rate that is used as main monetary policy variable in the European Monetary Union. At this point it is important to note again, that all variables examined here seem to be integrated of order 1. Moreover, no cointegration among the short term interest rate and the different yield spreads can be found. Therefore, a VAR model in first differences should be estimated (see, for example, Ibrahim 2005; Fodha and Zaghdoud 2010).

4 Empirical Analysis

Six bivariate VAR models are estimated to examine the relationship between the government bond yield spreads in France, Italy and Spain relative to Germany (10 year respectively 30 year interest rate differentials) and the monetary policy rate in the European Monetary Union. All variables examined are differenced once. The number of time lags to be considered in the models is determined using the HQ information criterion. In all six cases three time lags are included. Then techniques of impulse response analysis are used to examine the dynamic interactions between the endogenous variables in the VAR models. This approach is a very popular way to interpret the results from a VAR model (see, for example, Eichenbaum and Evans 1995; Sims 1998). The impulse response framework is based on the idea that a simulated exogenous shock to one endogenous variable is generated. Then the impact of this shock to the other variables is evaluated. In order to avoid the well-known problem that the results generated using this technique depend on the

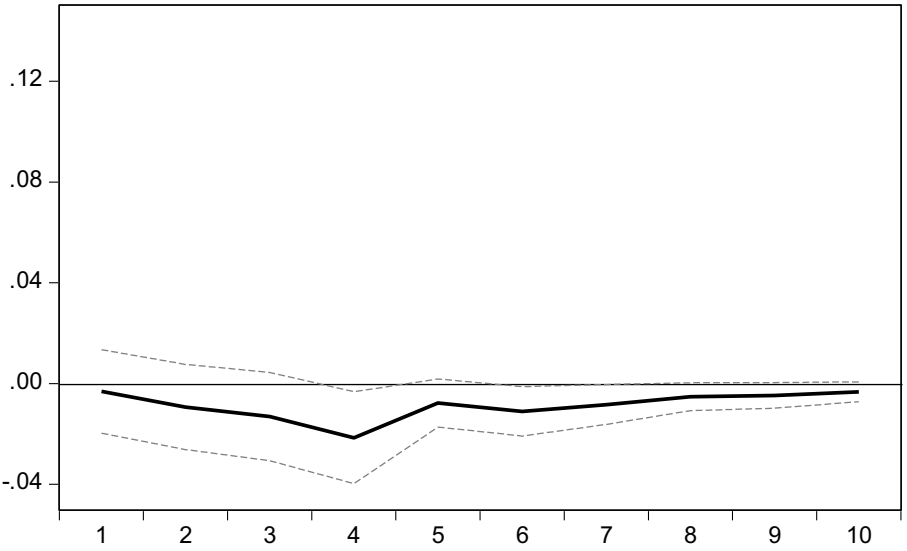


Fig. 1 Reaction of the monetary policy rate to a shock to the interest rate differential (France and Germany, 10 Years)

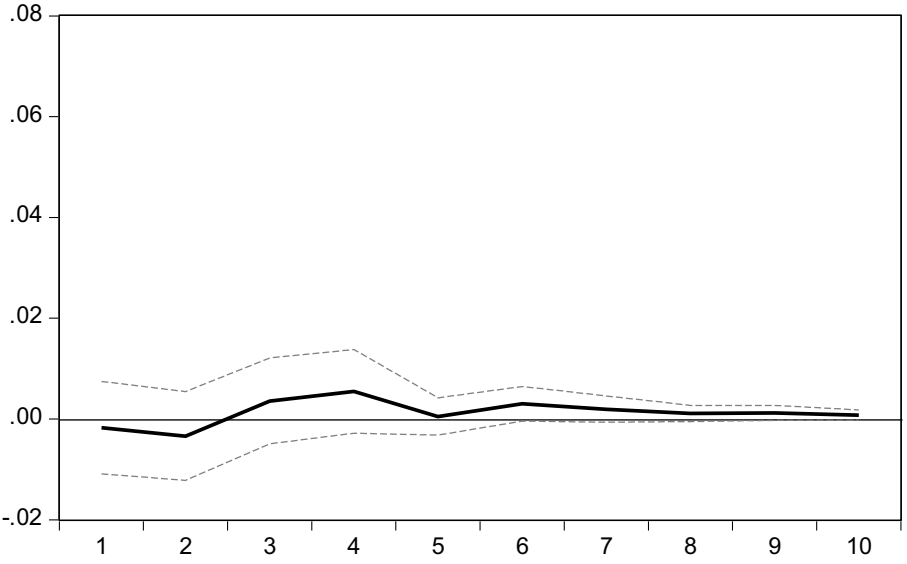


Fig. 2 Reaction of the interest rate differential (France and Germany, 10 Years) to a shock to the monetary policy rate

ordering of the variables in the VAR model when the Cholesky decomposition is employed, the approach of generalized impulses is used instead to compute the impulse response functions (see, for example, Pesaran and Shin 1998; Basse and Reddemann 2010). These are displayed in Fig. 1 to 12. The solid lines denote the

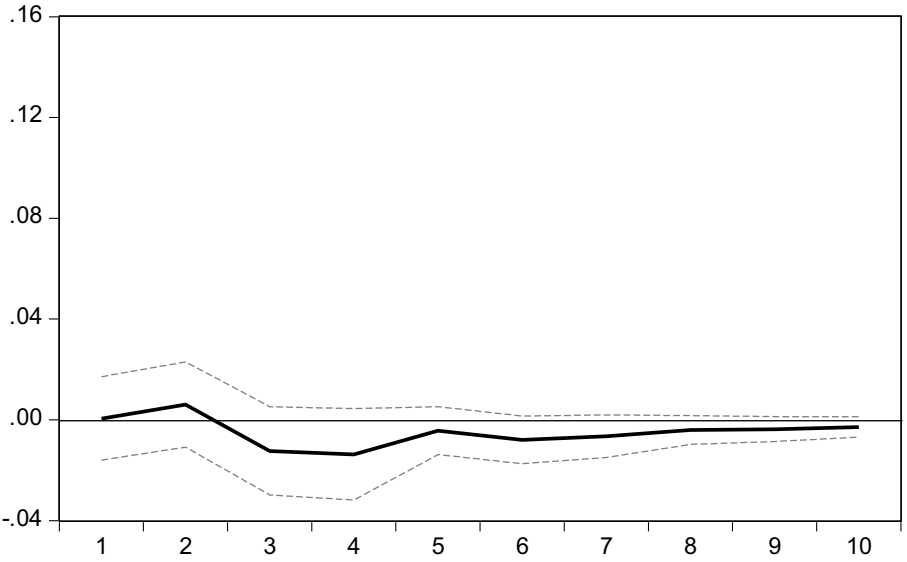


Fig. 3 Reaction of the monetary policy rate to a shock to the interest rate differential (France and Germany, 30 Years)

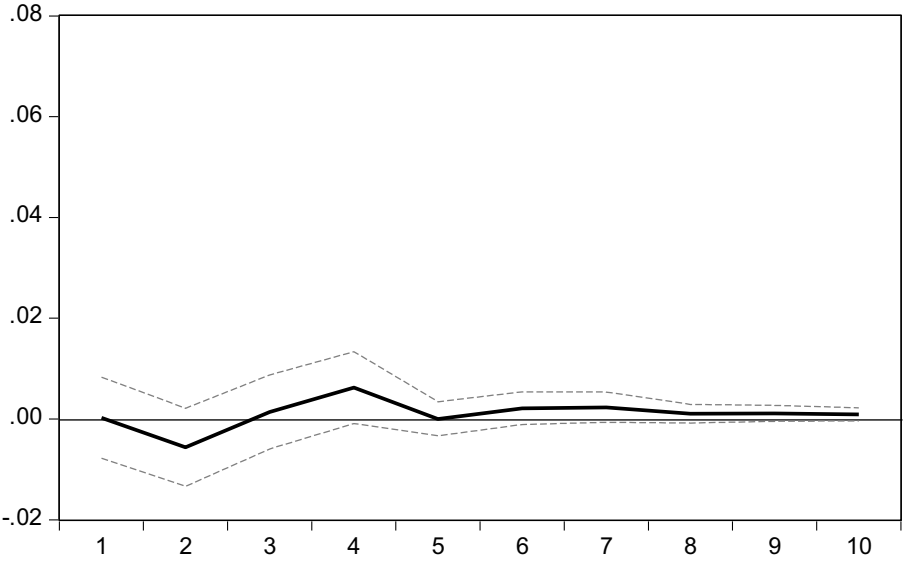


Fig. 4 Reaction of the interest rate differential (France and Germany, 30 Years) to a shock to the monetary policy rate

point estimates from the model. The dashed lines represent the ±2 standard deviation bands.

At this point is important to note again that the VAR models are estimated based on the first differences of the time series under investigation. Therefore, changes

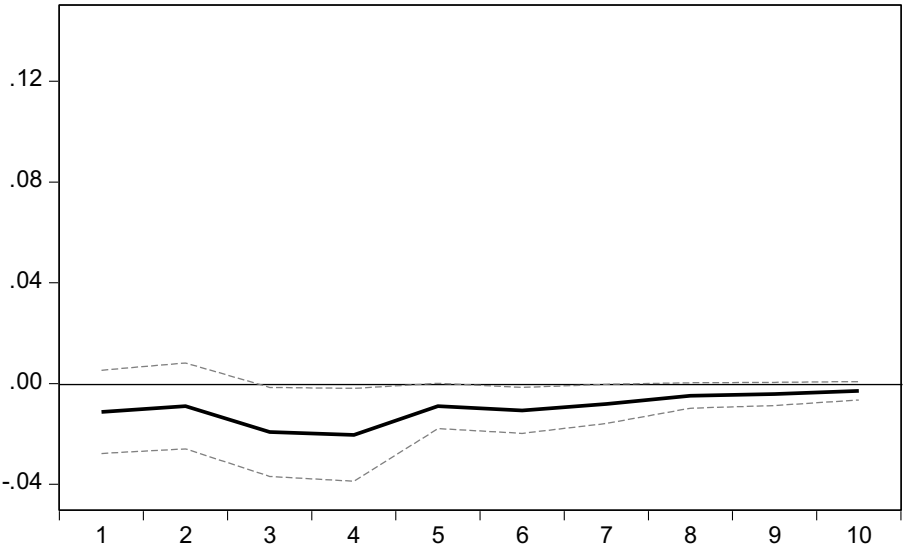


Fig. 5 Reaction of the monetary policy rate to a shock to the interest rate differential (Italy and Germany, 10 Years)

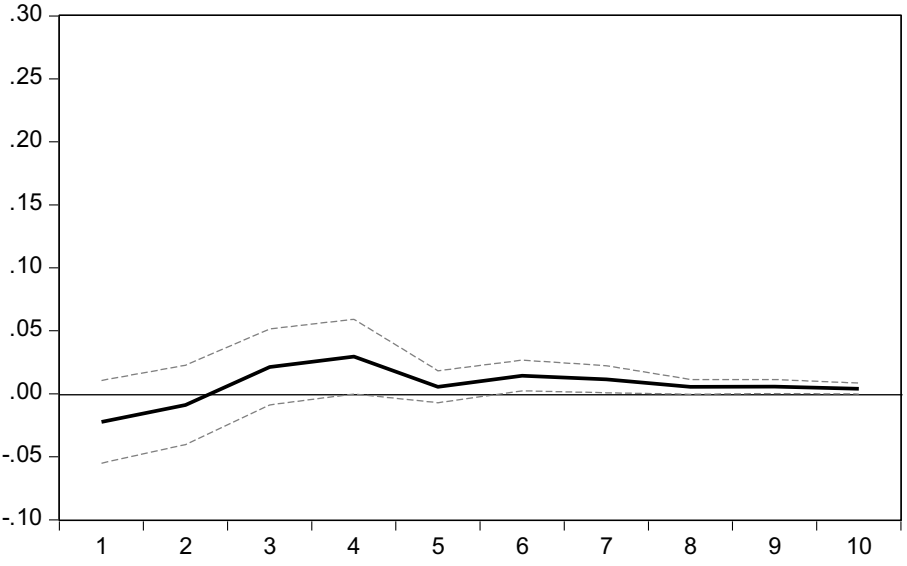


Fig. 6 Reaction of the interest rate differential (Italy and Germany, 10 Years) to a shock to the monetary policy rate

to the monetary policy rate respectively the bond yield spread are examined in the models. The impulse response functions show the reaction of one variable to an exogenous positive shock to the other variable included in the six bivariate VAR models. The results that are reported in the Figs. 2, 4, 6, 8, 10 and 12 should be

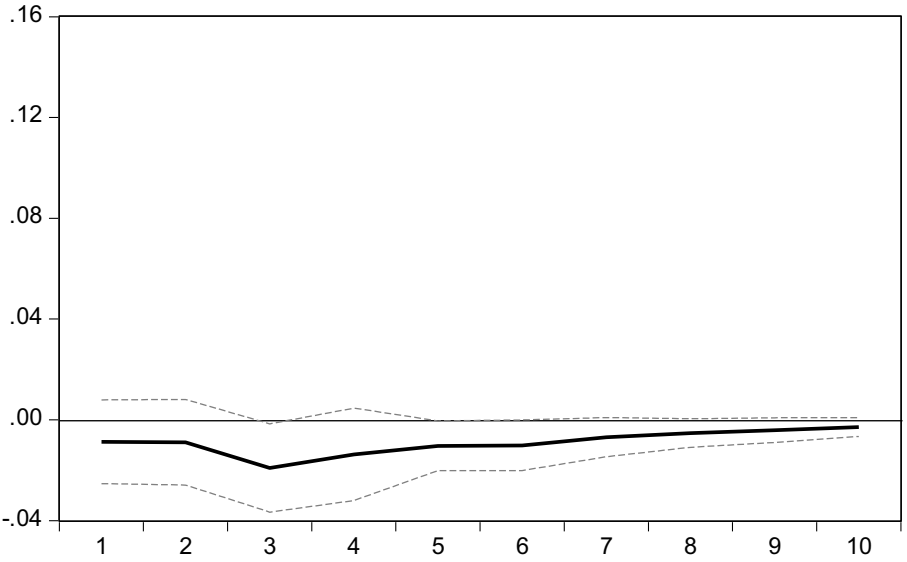


Fig. 7 Reaction of the monetary policy rate to a shock to the interest rate differential (Italy and Germany, 30 Years)

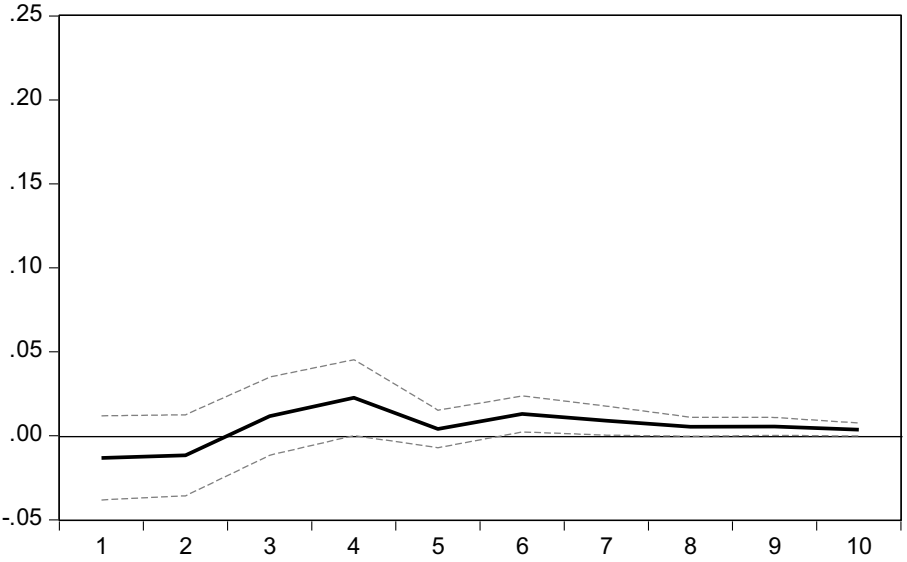


Fig. 8 Reaction of the interest rate differential (Italy and Germany, 30 Years) to a shock to the monetary policy rate

interpreted as a contractionary shock to monetary policy in the European Monetary Union. Phrased somewhat differently, the central bank is increasing the policy rate. In general, there seems to be no strong response of the interest rate differential to a shock to the monetary policy instrument. This is especially true for the first six

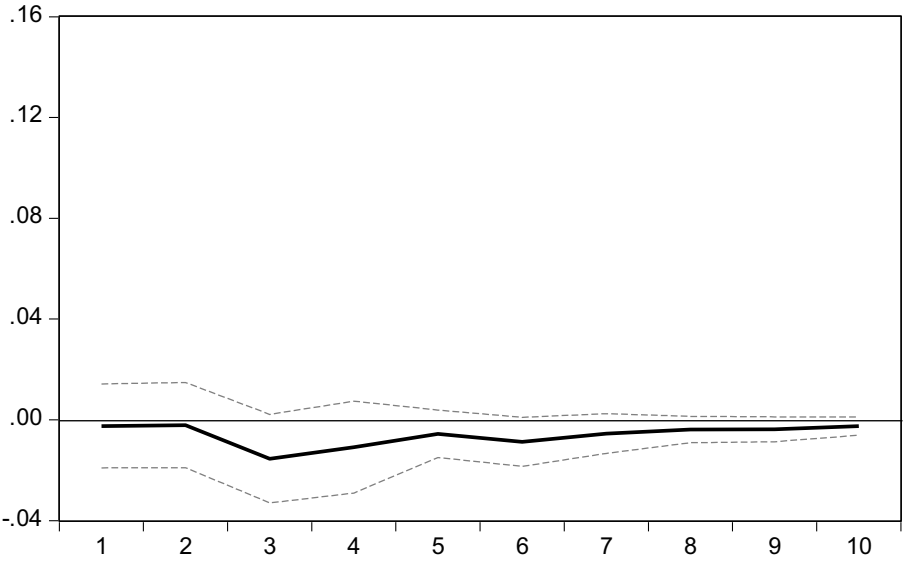


Fig. 9 Reaction of the monetary policy rate to a shock to the interest rate differential (Spain and Germany, 10 Years)

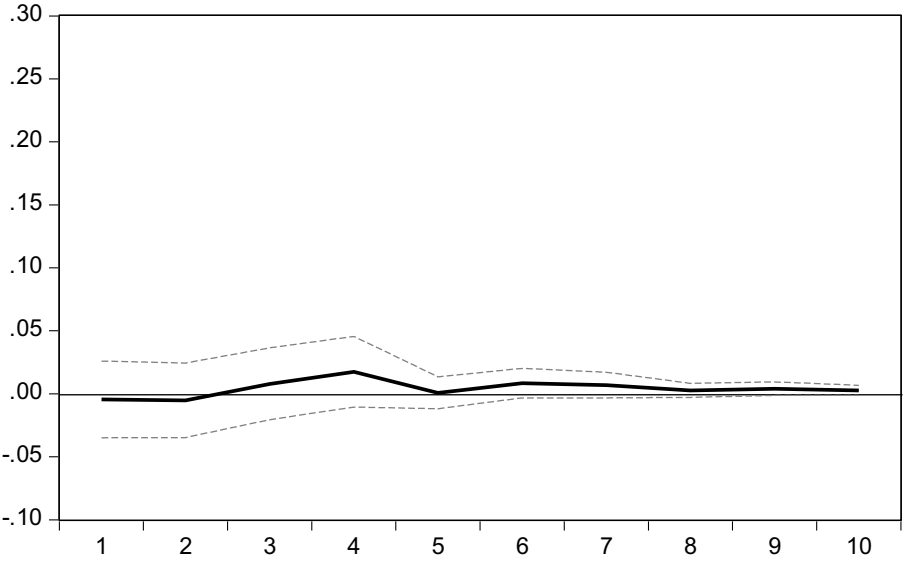


Fig. 10 Reaction of the interest rate differential (Spain and Germany, 10 Years) to a shock to the monetary policy rate

months after the monetary policy shock. After about half a year (as the response is slowly fading out) there is a slight and statistically significant reaction of the interest rate differentials to Germany in some cases. However, in general there is no strong positive reaction of the bond yield spreads to a contractionary monetary policy

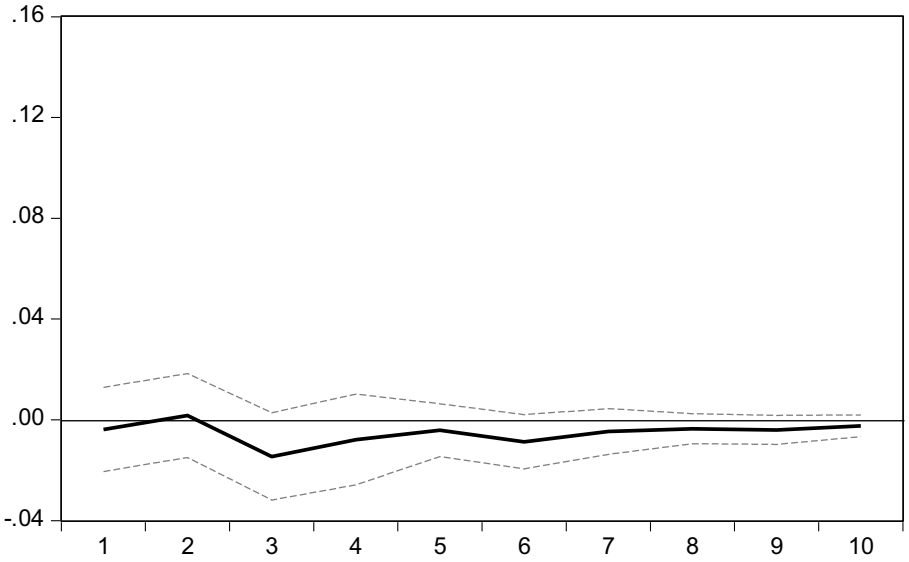


Fig. 11 Reaction of the monetary policy rate to a shock to the interest rate differential (Spain and Germany, 30 Years)

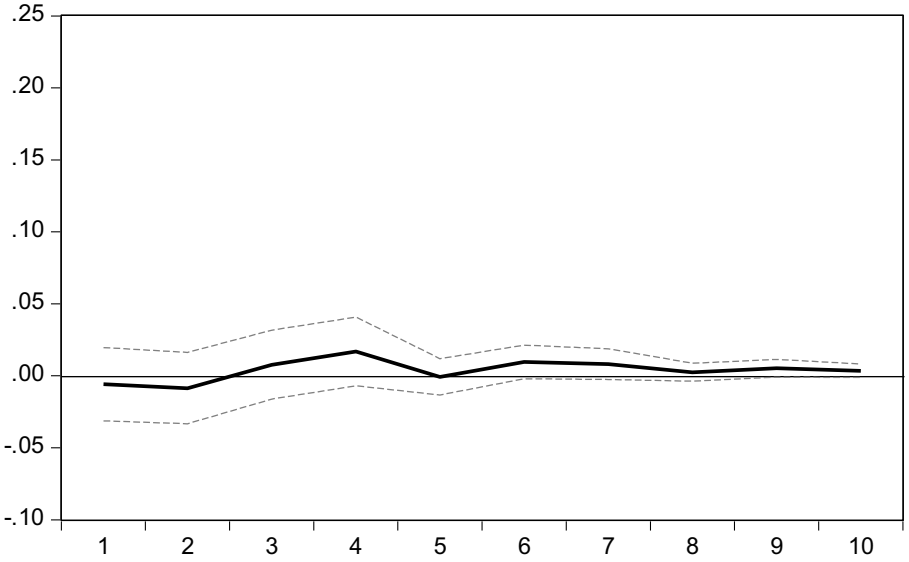


Fig. 12 Reaction of the interest rate differential (Spain and Germany, 30 Years) to a shock to the monetary policy rate

shock implemented by the European Central Bank. This empirical finding might be somewhat surprising. Moreover, the results reported above seem to imply that—in general—there is a negative reaction of the monetary policy rate to a positive shock to the government bond yield spread in the first months. In some cases this empirical

finding is statistically significant. This is especially true for the 10 year interest rate differential between France and Germany and between Italy and Germany. Examining Eq. 1 the shock could be a result from higher interest rates in France (respectively Italy), from lower interest rates in Germany or from a combination of both cases. Given the data problems discussed above one certainly should not over-interpret the results reported in the Figs. 1, 3, 5, 7, 9 and 11. However, some thoughts about conceivable explanations still should be discussed here. It is possible that the European Central Bank is reacting to news flow that is pushing down German interest rates. In fact, as already discussed, there have been "flight-to-quality" effects in the crisis that have increased the prices of German sovereign debt and—as a result—lowered the bond yields of these fixed income securities. However, this is most probably not the best explanation for the result reported in Figs. 1 and 5 because the monetary policy rate does not react in statistically significant way to shocks to the interest rate differential between Spanish and German 10 year government bond yields (see Fig. 12). Thus, the central bank seems to respond to changes to the risk premia France and Italy have to offer investors to make them buy debt instruments that have been issued by these countries. One possible reason for this behavior could be the idea that the European Central Bank wants to improve the ability of the two countries to fund their fiscal deficits. Monetary policymakers could also simply react to macroeconomic news that has an effect on government bond yields in France and Italy (for instance, a negative economic environment). In any case, the results reported above seem to be compatible with the European Central Bank trying to use its instruments of monetary policy to anchor Italian and French 10 year government bond yields at sufficiently low levels. This behavior probably could be a result of concerns with regard to the sustainability of government finances in these two economically very important member states of the European Monetary Union. The empirical evidence reported here clearly is interesting and should justify additional efforts to empirically analyze the relationship between government bond yield spreads and central bank actions in the European Monetary Union.

5 Conclusion

This paper focuses on the behavior of long term interest rates in France, Italy and Spain and analyses how government bond yield spreads relative to Germany react to traditional central bank actions (namely rate hikes) in the European Monetary Union. More specifically, fixed income securities with maturities of 10 and 30 years are examined. These long term bonds are of special importance for the European life insurance industry. Given that other central banks already have hiked rates and that financial markets now seem to be waiting for an increase to the Main Refinancing Operations Announcement Rate, the empirical evidence reported above is of some interest for financial markets. More specifically, techniques of time series analysis are used to gain new insights. The empirical evidence reported here should not only be interesting from the viewpoint of economic theory, but also has practical implications for asset managers working in European insurance companies. Given that there are some data problems, the results of this study probably should not be

over-interpreted. Nonetheless, the empirical findings documented in this paper seem to be compatible with the theory that the European Central Bank is trying to use its instruments of monetary policy to anchor Italian and French 10 year government bond yields at sufficiently low levels to help these countries fund their fiscal deficits. Additionally, there is no strong response of the interest rate differentials examined here to a rate hike by the European Central Bank.

References

Afonso, A., Arghyrou, M.G., Gadea, M.D., Kontonikas, A.: "Whatever it takes" to resolve the European sovereign debt crisis? Bond pricing regime switches and monetary policy effects. J. Int. Money Finance. **86**, 1–30 (2018)

Altmann, J.: Ist die Europäische Union ein optimaler Währungsraum? Wirtschaftsdienst **74**, 312–315 (1994)

Ang, A., Longstaff, F.A.: Systemic sovereign credit risk: lessons from the US and europe. J. Monet. Econ. **60**, 493–510 (2013)

Arghyrou, M.G., Kontonikas, A.: The EMU sovereign-debt crisis: fundamentals, expectations and contagion. J. Int. Financ Mark. Inst Money **22**, 658–677 (2012)

Basse, T.: Searching for the EMU core member countries. Eur. J. Polit. Econ. **34**, S32–S39 (2014)

Basse, T., Reddemann, S.: Variable-ordering induced problems of impulse-response analysis and other difficulties: the dividend policy of Austrian firms. Int. J. Comput. Econ. Econom. **1**, 278–293 (2010)

Basse, T., Friedrich, M., Kleffner, A.: Italian government debt and sovereign credit risk: an empirical exploration and some thoughts about consequences for European insurers. Z. Ges. Versicherungswiss. **101**, 571–579 (2012)

Basse, T., Friedrich, M., Kleffner, A., v. d, S.J.-M.: Are interest rates too low? Empirical evidence and implications for German life insurers. Z. Ges. Versicherungswiss. **103**, 31–43 (2014)

Basse, T., Kunze, F., Krampen, B., Schwarzbach, C.: German bond markets and US monetary policy. Z. Ges. Versicherungswiss. **106**, 265–276 (2017)

Basse, T., Wegener, C., Kunze, F.: Government bond yields in Germany and Spain—empirical evidence from better days. Quant. Finance **18**, 827–835 (2018)

Bayoumi, T., Eichengreen, B.: Optimum currency areas and exchange rate volatility: theory and evidence compared. In: Cohen, B.J. (ed.) International trade and finance: new frontiers for research, pp. 184–215. Cambridge University Press, Cambridge (1997)

Beetsma, R., Giuliodori, M.: The macroeconomic costs and benefits of the EMU and other monetary unions: an overview of recent research. J. Econ. Lit. **48**, 603–641 (2010)

Beine, M., Hecq, A.: Asymmetric shocks inside future EMU. J. Econ. Integr. **12**, 131–140 (1997)

Beine, M., Candelon, B., Sekkat, K.: EMU membership and business cycle phases in Europe: Markov-switching VAR analysis. J. Econ. Integr. **18**, 214–242 (2003)

Berdin, E., Gründl, H.: The effects of a low interest rate environment on life insurers. Geneva Pap. Risk Insur. **40**, 385–415 (2015)

Bernoth, K., v. Hagen, J., Schuknecht, L.: Sovereign risk premiums in the European government bond market. J. Int. Money Finance. **31**, 975–995 (2012)

Boreiko, D.: EMU and accession countries: Fuzzy cluster analysis of membership. Int. J. Finance Econ. **8**, 309–325 (2003)

Calomiris, C.W.: The impending collapse of the European Monetary Union. Cato J. **18**, 445–452 (1999)

Codogno, L., Favero, C., Missale, A.: Yield spreads on EMU government bonds. Econ. Policy **18**, 503–532 (2003)

Curdia, V., Woodford, M.: The central-bank balance sheet as an instrument of monetary policy. J. Monet. Econ. **58**, 54–79 (2011)

Dimson, E., Marsh, P., Staunton, M.: Global evidence on the equity risk premium. J. Appl. Corp. Finance **15**, 27–38 (2003)

Eichenbaum, M., Evans, C.L.: Some empirical evidence on the effects of shocks to monetary policy on exchange rates. Q. J. Econ. **110**, 975–1009 (1995)

Ejsing, J., Lemke, W.: The Janus-headed salvation: sovereign and bank credit risk premia during 2008–2009. Econ. Lett. **110**, 28–31 (2011)

Eling, M., Schmeiser, H.: Insurance and the credit crisis: Impact and ten consequences for risk management and supervision. Geneva Pap. Risk Insur. **35**, 9–34 (2010)

Fawley, B.W., Neely, C.J.: Four stories of quantitative easing. Fed. Reserve Bank St. Louis Rev. **95**, 51–88 (2013)
Feroli, M., Greenlaw, D., Hooper, P., Mishkin, F.S., Sufi, A.: Language after liftoff: fed communication away from the zero lower bound. Res. Econ. **71**, 452–490 (2017)
Fodha, M., Zaghdoud, O.: Economic growth and pollutant emissions in Tunisia: an empirical analysis of the environmental Kuznets curve. Energy Policy **38**, 1150–1156 (2010)
Gaspar, V., Perez-Quiros, G., Sicilia, J.: The ECB monetary policy strategy and the money market. Int. J. Finance Econ. **6**, 325–342 (2001)
Goodhart, C.A.: The two concepts of money: implications for the analysis of optimal currency areas. Eur. J. Polit. Econ. **14**, 407–432 (1998)
Graboyes, R.F.: The EMU: forerunners and durability. Fed. Reserve Bank Richmond Econ. Rev. **76**, 8–16 (1990)
De Grauwe, P., Schnabl, G.: Nominal versus real convergence–EMU entry scenarios for the new member states. Kyklos **58**, 537–555 (2005)
Gruppe, M., Lange, C.: Spain and the European sovereign debt crisis. Eur. J. Polit. Econ. **34**, S3–S8 (2014)
Gruppe, M., Basse, T., Friedrich, M., Lange, C.: Interest rate convergence, sovereign credit risk and the European debt crisis: a survey. J. Risk Finance **18**, 432–442 (2017)
Gürtler, M., Neelmeier, P.: Empirical analysis of the international public covered bond market. J. Empir. Finance **46**, 163–181 (2018)
v. Hagen, J., Fratianni, M.: German dominance in the EMS: evidence from interest rates. J. Int. Money Finance. **9**, 358–375 (1990)
v. Hagen, J., Schuknecht, L., Wolswijk, G.: Government bond risk premiums in the EU revisited: the impact of the financial crisis. Eur. J. Polit. Econ. **27**, 36–43 (2011)
Hardouvelis, G.A., Malliaropulos, D., Priestley, R.: EMU and European stock market integration. J. Bus. **79**, 365–392 (2006)
Herz, B., Röger, W.: The EMS is a greater Deutschmark area. Eur. Econ. Rev. **36**, 1413–1425 (1992)
Holder, M.: The Euro impact on European financial markets. Manag. Finance **25**, 27–34 (1999)
Holtemöller, O.: Uncovered interest rate parity and analysis of monetary convergence of potential EMU accession countries. Int. Econ. Econ. Policy **2**, 33–63 (2005)
Ibrahim, M.H.: Sectoral effects of monetary policy: evidence from Malaysia. Asian Econ. J. **19**, 83–102 (2005)
Johansen, S.: Statistical analysis of cointegration vectors. J. Econ. Dyn. Control. **12**, 231–254 (1988)
Kenen, P.: The theory of optimum currency areas: an eclectic view. In: Mundell, R.A., Swoboda, A. (eds.) Monetary problems of the international economy, pp. 41–60. University of Chicago Press, Chicago (1969)
Kouparitsas, M.A.: Is the EMU a viable common currency area? A VAR analysis of regional business cycles. Fed Reserve Bank Chicago Econ Perspect **23**, 2–20 (1999)
Krampf, A.: From transparency to ambiguity: The impact of the ECB's unconventional policies on the EMU. J. Eur. Integr. **38**, 455–471 (2016)
Krishnamurthy, A., Nagel, S., Vissing-Jorgensen, A.: ECB policies involving government bond purchases: impact and channels. Rev. Financ. **22**, 1–44 (2018)
Laopodis, N.T.: Government bond market integration within European Union. Int. Res. J. Finance Econ. **19**, 56–76 (2008)
Linderkamp, T., Pollmer, S., Schmidt, P., Siefert, P., Schwalba, M.: Neue Wege in der Kapitalanlage: Die Symbiose zwischen Banken und Versicherungen im Bereich der 'Alternative Assets. Z. Ges. Versicherungswiss. **102**, 273–289 (2013)
Ludwig, A.: Credit risk-free sovereign bonds under Solvency II: a cointegration analysis with consistently estimated structural breaks. Appl. Financial Econ. **24**, 811–823 (2014)
MacKinnon, J.G.: Numerical distribution functions for unit root and cointegration tests. J. Appl. Econom. **11**, 601–618 (1996)
McKinnon, R.I.: Optimum currency areas. Am. Econ. Rev. **53**, 717–725 (1963)
Mundell, R.A.: A theory of optimum currency areas. Am. Econ. Rev. **51**, 657–665 (1961)
Niedrig, T.: Optimal asset allocation for interconnected life insurers in the low interest rate environment under solvency regulation. J. Insur. Issues **38**, 31–71 (2015)
Paniagua, J., Sapena, J., Tamarit, C.: Sovereign debt spreads in EMU: The time-varying role of fundamentals and market distrust. J. Financial Stab. **33**, 187–206 (2017)
Pesaran, H.H., Shin, Y.: Generalized impulse response analysis in linear multivariate models. Econ. Lett. **58**, 17–29 (1998)
Phillips, P.C., Perron, P.: Testing for a unit root in time series regression. Biometrika **75**, 335–346 (1988)

Pollard, P.S.: EMU: will it fly? Fed. Reserve Bank St. Louis Rev. **77**, 3–16 (1995)
Pollard, P.S.: A look inside two central banks: the European Central Bank and the Federal Reserve. Fed. Reserve Bank St. Louis Rev. **85**, 11–30 (2003)
Quaglia, L., Royo, S.: Banks and the political economy of the sovereign debt crisis in Italy and Spain. Rev. Int. Polit. Econ. **22**, 485–507 (2015)
Reddemann, S., Basse, T., v. d, S.J.-M.: On the impact of the financial crisis on the dividend policy of the European insurance industry. Geneva Pap. Risk Insur. **35**, 53–62 (2010)
Ricci, O.: The impact of monetary policy announcements on the stock price of large European banks during the financial crisis. J. Bank. Finance **52**, 245–255 (2015)
Rodriguez Gonzalez, M., Kunze, F., Schwarzbach, C., Dieng, C.: Asset liability management and the euro crisis: sovereign credit risk as a challenge for the German life insurance industry. J. Risk Finance **18**, 466–483 (2017)
Sibbertsen, P., Wegener, C., Basse, T.: Testing for a break in the persistence in yield spreads of EMU government bonds. J. Bank. Finance **41**, 109–118 (2014)
Sims, C.A.: Macroeconomics and reality. Econometrica **48**, 1–48 (1980)
Sims, C.A.: Role of interest rate policy in the generation and propagation of business cycles: what has changed since the '30s? In: Fuhrer, J.C., Schuh, S. (eds.) Beyond shocks: what causes business cycles? pp. 121–175. Federal Reserve Bank of Boston, Boston (1998)
van de Ven, R., Dabadghao, S., Chockalingam, A.: Assigning Eurozone sovereign credit ratings using CDS spreads. J. Risk Finance **19**, 478–512 (2018)
Walsh, C.E., Wilcox, J.A.: Bank credit and economic activity. In: Peek, J., Rosengren, E.S. (eds.) Is bank lending important for the transmission of monetary policy? pp. 83–125. Federal Reserve Bank of Boston, Boston (1995)

Module 10

Re-Investigating the Insurance-Growth Nexus Using Common Factors

Rodriguez Gonzalez, M. / Wegener, C. / Basse, T. (2021)

Published in:
Finance Research Letters. DOI: https://doi.org/10.1016/j.frl.2021.102231.

Finance Research Letters xxx (xxxx) xxx

Contents lists available at ScienceDirect

Finance Research Letters

journal homepage: www.elsevier.com/locate/frl

Re-investigating the insurance-growth nexus using common factors

Miguel Rodriguez Gonzalez [a,*], Christoph Wegener [b], Tobias Basse [c,d]

[a] Leibniz University Hannover, Otto-Brenner-Straße 7, 30159 Hannover, Germany
[b] Leuphana University Lüneburg, Universitätsallee 1, 21335 Lüneburg, Germany
[c] Norddeutsche Landesbank Girozentrale, Am Friedrichswall 10, 30159 Hannover, Germany
[d] Touro College Berlin, Am Rupenhorn 5, 14055 Berlin, Germany

ARTICLE INFO

JEL classification:
C12
C23
G22

Keywords:
Insurance-growth nexus
Panel cointegration
Cross-sectional dependence

ABSTRACT

This study re-investigates the linkage between insurance market activity and economic activity by using panel cointegration techniques. The methodology used here accounts for the presence of cross-sectional dependence. Considering nine panels formed from the data of 90 countries, we find evidence in favor of panel cointegration among real insurance market activity per capita and real GDP per capita.

1. Introduction

The theoretical effects of insurance activity on economic growth have been widely discussed in the academic literature. Ward and Zurbruegg (2000) mention three major ways in which insurance fosters economic development: risk transfer, indemnification, and role of the insurance industry as a financial intermediary. Additionally, insurance companies amplify competition and increase liquidity in financial markets. Further, risk-based prices for insurance products are incentives to diminish high-risk behavior. Given these points, these are arguments for potentially positive welfare effects due to insurance.

Fundamental empirical work on the linkage between economic activity and insurance activity originates from Ward and Zurbruegg (2000). Their analysis, as well as many follow-up studies, are based on the Sigma dataset provided by the Swiss Re with respect to gross premium income and OECD data concerning economic growth. They use time series methodology – in particular cointegration tests – to investigate the long-run relationship of insurance activity and economic growth in the period between 1961 and 1996. Ward and Zurbruegg (2000) report empirical evidence against the hypothesis of a long-run equilibrium relationship for Austria, Switzerland, the United Kingdom, and the United States, whereas they find empirical evidence favoring cointegration in the cases of Australia, Canada, France, Italy, and Japan.

In a similar manner, more recent studies mostly apply panel econometrics. For example, Lee (2013) applies panel unit root and cointegration tests. The authors report empirical evidence for long-run equilibria by considering 33 countries. Another study by Lee et al. (2013) uses the seemingly unrelated regression augmented Dickey–Fuller (SURADF) test to examine the stochastic trending behavior of both variables. Our statistical tests reveal that the variables under consideration are mixtures of stationary and integrated variables. Further, they report evidence in favor of cointegration between real GDP and real life insurance premiums per capita while allowing for the heterogeneous country effect. Generally speaking, unattended cross-sectional dependence may result in oversized cointegration tests. To our knowledge, these potential effects have been neglected by the literature on the insurance-growth nexus so far. Therefore, we use panel cointegration testing procedures that are robust against cross-sectional dependence. Further, we

* Corresponding author.
E-mail address: mr@ivbl.uni-hannover.de (M. Rodriguez Gonzalez).

https://doi.org/10.1016/j.frl.2021.102231
Received 13 November 2020; Received in revised form 2 June 2021; Accepted 8 June 2021
Available online 18 June 2021

Table 1
Definition of the analyzed panels depending on the OECD country risk classification 2020.

Sigma dataset on worldwide insurance premia					
Data processing		Country			
Data package		**Aggregated**: Advanced Asia-Pacific, Advanced EMEA, Africa (up to 2018), ASEAN, Asia (up to 2018), Eastern Europe (up to 2018), Emerging Asia-Pacific, Emerging EMEA, Europe (up to 2018), European Union 15 (27) countries, G7, Latin America and Caribbean, Middle East and Central Asia, NAFTA, North America, Oceania (up to 2018), OECD, South and East Asia (up to 2018), Western Europe (up to 2018), and World **Country basis**: Algeria Angola, Argentina, Australia, Austria, Bahamas, Bahrain, Bangladesh, Barbados, Belgium, Botswana, Brazil, Bulgaria, Canada, Cayman Islands, Chile, China, Colombia, Costa Rica, Croatia, Cyprus, Czech Republic, Denmark, Dominican Republic, Ecuador, Egypt, El Salvador, Estonia, Finland, France, Germany, Greece, Guatemala, Hong Kong, Hungary, Iceland, India, Indonesia, Iran, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kazakhstan, Kenya, Kuwait, Latvia, Lebanon, Liechtenstein, Lithuania, Luxembourg, Macao, Malaysia, Malta, Mauritius, Mexico, Morocco, Namibia, Netherlands, New Zealand, Nigeria, Norway, Oman, Pakistan, Panama, Peru, Philippines, Poland, Portugal, Qatar, Romania, Russia, Saudi Arabia, Serbia, Singapore, Slovakia, Slovenia, South Africa, South Korea, Spain, Sri Lanka, Sweden, Switzerland, Taiwan, Thailand, Trinidad and Tobago, Tunisia (up to 2018), Turkey (up to 2018), Ukraine, United Arab Emirates, United Kingdom, United States, Uruguay, Venezuela, Vietnam, and Zimbabwe			
Unsuitable data		i. all aggregated time series ii. $N < 20$: Angola, Barbados, Serbia, and Zimbabwe iii. no GDP/population data: Taiwan iv. no OECD classification: Barbados, Cayman Islands, Liechtenstein, and Singapore			
Panel structure					
Panel	OECD code	Country	Period	T_P	N_P
EU East	EU	Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, and Slovenia	1995–2018	24	8
EU North	EU	Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Luxembourg, Netherlands, Sweden, and United Kingdom	1973–2016	44	11
EU South	EU	Cyprus, Greece, Italy, Malta, Portugal, and Spain	1996–2018	23	6
OECD	OECD	Australia, Canada, Chile, Iceland, Israel, Japan New Zealand, Norway, South Korea, Switzerland, and United States	1979–2019	41	11
Risk I	Risk 2	China, Kuwait, Macao, Malaysia, and Saudi Arabia United Arab Emirates	1994–2019	26	6
Risk II	Risk 3	Bahamas, Botswana, Bulgaria, Hong Kong, India, Indonesia, Mauritius, Mexico, Morocco, Peru, Philippines, Qatar, Romania, Thailand, Trinidad and Tobago, and Uruguay	1996–2017	22	16
Risk III	Risk 4	Colombia. Costa Rica, Croatia, Dominican Republic, Guatemala, Panama, Russia, South Africa, and Vietnam	1997–2019	23	9
Risk IV	Risk 5	Algeria, Bahrain, Bangladesh, Brazil, Egypt, El Salvador, Kazakhstan, Oman, and Turkey	1994–2018	25	9
Risk V	Risk 6	Jamaica, Jordan, Kenya, Namibia, Nigeria, Sri Lanka, Tunisia, and Ukraine	1997–2017	21	8
Risk VI	Risk 7	Argentina, Ecuador, Iran, Lebanon, Pakistan, and Venezuela	1992–2014	23	6

consider life and non-life insurance data separately, as both insurance sectors have different economic functions — life insurance is often used for capital accumulation, while non-life insurance is mainly used for risk transfer.

The remainder of this paper is structured as follows. The next section contains the literature review. Section 3 presents the data, and Section 4 gives an overview of the methodology and reports the empirical results. Section 5 concludes.

2. The insurance-growth nexus

The insurance-growth nexus is an important subgroup of the literature examining the relationship between economic growth and finance, which originally seems to have focused more strongly on banks (see, e.g., Levine, 2003; Beck et al., 2014). General surveys of the literature analyzing the finance-growth nexus have been conducted by Trew (2006) and Ang (2008), amongst others.

Table 2
Pesaran CD test for cross-sectional dependence in panels. Superscript ^{r} stands for rejection of the null hypothesis on a 1% significance level and ^{r*} for the rejection on a 5% level.

Panel	Life Premiums (LC)	Non-Life Premiums (NC)	Gross Domestic Product
EU East	39.320^{r}	39.048^{r}	38.642^{r}
EU North	41.533^{r}	81.694^{r}	91.773^{r}
EU South	6.589^{r}	7.241^{r}	31.653^{r}
OECD	82.344^{r}	78.479^{r}	84.662^{r}
Risk I	29.560^{r}	12.826^{r}	2.188^{r*}
Risk II	53.383^{r}	47.446^{r}	56.819^{r}
Risk III	39.020^{r}	38.089^{r}	41.770^{r}
Risk IV	40.357^{r}	38.507^{r}	45.164^{r}
Risk V	31.773^{r}	28.030^{r}	31.644^{r}
Risk VI	30.821^{r}	17.035^{r}	31.778^{r}

As stated above, first studies on the connection between the insurance sector and growth followed the work by Ward and Zurbruegg (2000). Further research, for example by Haiss and Sümegi (2008), specifically focuses on the relevance of the insurance industry in contrast to other financial sectors. The authors back their research using a small sample from 1992 to 2004, and they investigate the linkage between the insurance sector and GDP for 29 OECD countries. Amongst others, they find a positive correlation between the life insurance market and GDP for Western European countries and a short-term relation between property insurance and GDP for countries that joined the European Union (within the scope of eastward enlargement).

Based on an OECD-Swiss Re dataset, Lee (2011) shows that the property insurance markets have a higher impact on GDP growth than life insurance markets do. The results in Lee (2011) imply a long-run relationship with economic growth for both classes of insurance. In a more recent follow-up study, Lee (2013) applies panel unit root and cointegration tests and vector error correction models to re-investigate the relationship between insurance and economic growth. The author investigates 33 countries regarding a long-run relationship between GDP and premiums and finds evidence for cointegration in all cases.

Besides, Chen et al. (2012) identify various factors influencing the association between the insurance market and economic growth for 60 countries in the period from 1976 to 2005. They show that the degree of development of financial sectors, income level, interest and savings rates, old-age dependency ratio, life expectancy, and geographic location as well as the design of the social security system affect this relation. Furthermore, they show that these determinants vary across countries. For instance, the insurance market-GDP relationship is enhanced with decreasing income levels.

Another study by Lee et al. (2013) confirms the hypothesis of a long-term equilibrium between life insurance market activity and economic activity, as long as one controls for different income levels between the countries. Moreover, they use the SURADF test for examining the trending behavior of both considered variables and report evidence for the mixture of stationary and integrated variables.

Furthermore, Law and Singh (2014) put the shape of the relation between economic and financial market development in question. The authors find a negative U-shaped relationship and, thus, are able to identify the specific threshold value above which further growth of the financial markets affects the overall economic development in a negative manner.

Overall, the majority of the most recent empirical literature confirms the existence of a long-term relationship between economic growth and insurance activity. For example, Pradhan et al. (2015) analyze 34 OECD countries from 1988 to 2012 to test for long-term Granger causality. Moreover, Liu et al. (2016) apply rolling vector autoregressions to examine G7 countries for the period of 1980–2011 and, thus, address the problem of structural breaks in the data. In addition, Hatemi-J et al. (2019) test for asymmetric causal impacts for G7 countries for 1980–2014. Nevertheless, there is still some evidence for a negative effect of insurance on growth, as stated, for example, by Lee et al. (2017) using a non-parametric panel framework for 38 countries for 1984–2009.

To conclude, using mostly the same data source, the empirical literature examining the link between economic growth and insurance activity documents a variety of contradictory results (see Haiss and Sümegi, 2008; Outreville, 2013, for a comprehensive literature review). Most of the studies known to us are subject to some kind of limitations, particularly with regard to test methods or the underlying data. Therefore, we re-investigate the insurance-growth nexus by using the most recent Sigma dataset on life and non-life direct premiums written (see Section 3) and an approach not yet applied to the data, to eliminate cross-sectional dependence (see Section 4), and to shed further light on this research issue.

3. Data

The majority of studies investigate the same dataset provided by the Swiss Re. This dataset contains information on nationally aggregated direct premiums written (local currency/USDm), real premium growth (in %), insurance density (direct domestic premiums per capita, USD), and insurance penetration (direct domestic premiums per GDP) for the insurance sectors life, non-life, and total. To get a comprehensive overview of the insurance market, this research, in comparison with many other studies, examines not only life insurance but also non-life insurance premiums. Apart from this, data on GDP (constant 2010 USD) and population for

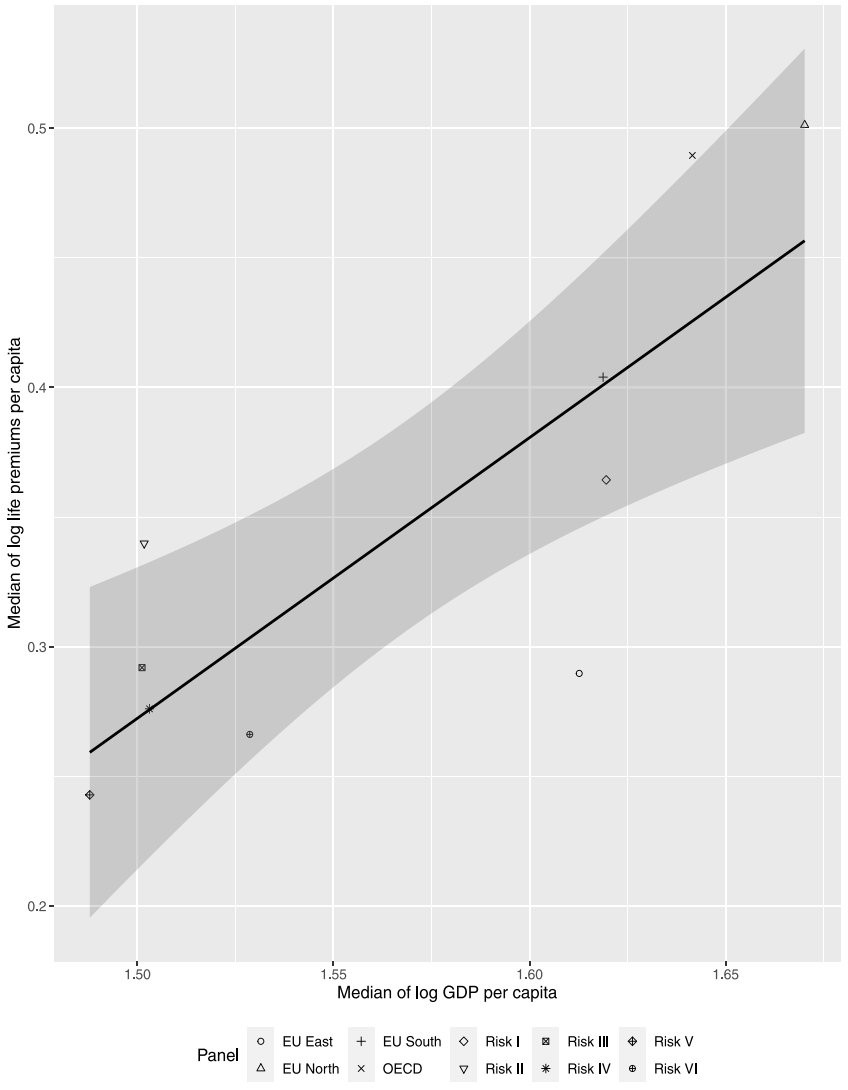


Fig. 1. Linear regression line describing the link between real GDP and life insurance activity per capita. The dark shaded areas indicate the 95% confidence interval.

the respective countries are taken from the World Bank national accounts data and OECD National Accounts data files.[1] Insurance premium data, on the other hand, are not publicly available and therefore had to be requested from the Swiss Re.

Table 1 provides a detailed overview of the cross-section of the Sigma dataset and shows the creation of our risk panel structure. As we are applying a methodology that requires balanced panels, the maximum amount of possible observations in the time dimension is 60, even though there are only few series with full data availability from 1960 to 2019. Accordingly, N_p denotes the maximum number of countries, and T_p the maximum number of observations, in the dimensions of our analyzed data after cutting the countries' time series within a risk class to a balanced panel. Therefore, countries under consideration were pre-selected mostly according to their data availability. All aggregated time series, with a maximum of 19 observations and/or missing GDP and/or population data are excluded from the analysis in the second step of our data processing (see also "unsuitable data" in Table 1). The remaining countries are classified into risk-related panels depending on the OECD Country Risk Classification.[2] This

[1] For GDP data, see https://data.worldbank.org/indicator/NY.GDP.MKTP.KD, and for population data, see https://data.worldbank.org/indicator/SP.POP.TOTL. In the case of Qatar, GDP data were obtained from FRED Economic Data of the Federal Reserve Bank of St. Louis (https://fred.stlouisfed.org/series/RGDPNAQAA666NRUG), since the World Bank does not provide data on this country before the year 2000.

[2] At the time of writing of this paper, the most recent OECD classification was the version from June 25, 2020. For the list, see: http://www.oecd.org/trade/topics/export-credits/documents/cre-crc-historical-internet-english.pdf.

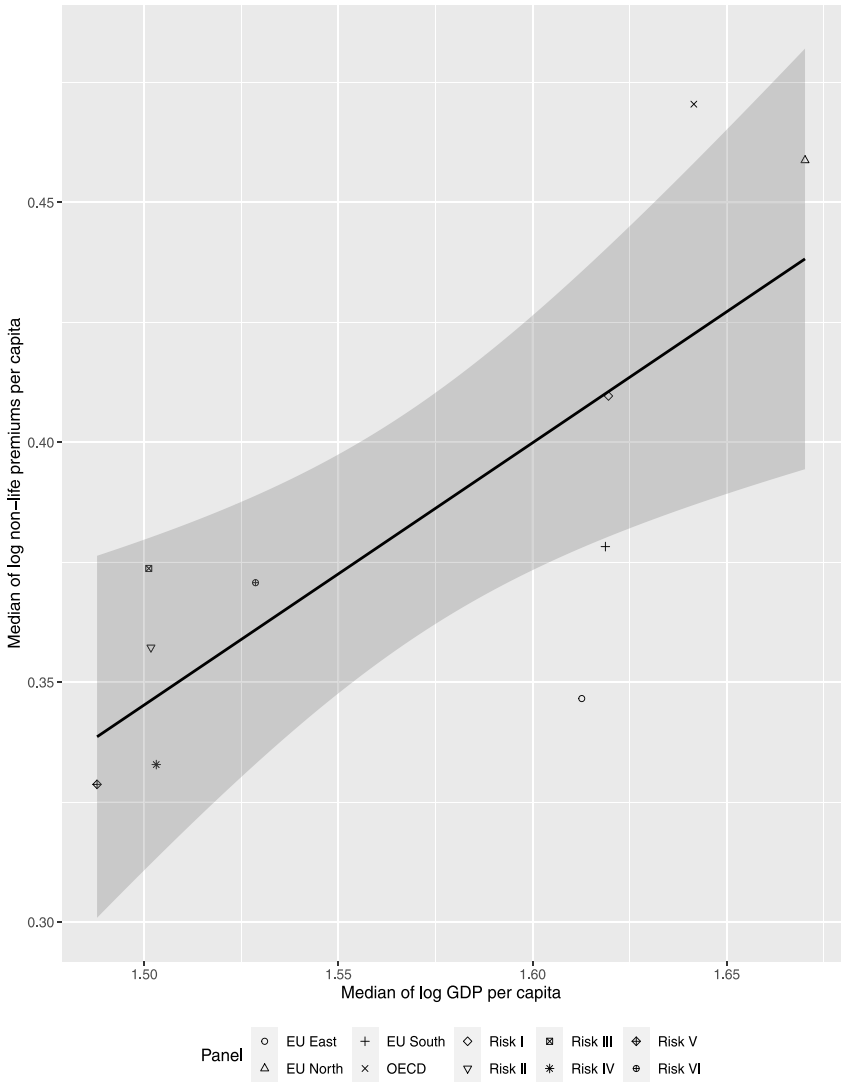


Fig. 2. Linear regression line describing the link between real GDP and non-life insurance activity per capita. The dark shaded areas indicate the 95% confidence interval.

rating is based on a quantitative and qualitative assessment of country credit risk, allowing a transparent classification of the panels into similar country risk groups. Therefore, countries without a classification are also excluded.

To provide the clearest possible picture about the long-run relationship between insurance activity and growth, the log time series are adjusted for inflation and population growth. First, the nominal direct premiums are converted into real direct premiums by using local consumer price inflation. The real premiums IP_{it} are determined recursively as

$$IP_{it+1} = IP_{it} \times (1 + g_{it+1}),$$

where IP_{i0} is set to one for all $i = 1, \ldots, N_p$, and g_{it} is the real growth rate for country i at time t. Thus, our data results from converting the nominal values into real insurance premiums by using the real growth rates that are provided in the Sigma dataset. Second, we divide both real premiums and real GDP (GDP_{it} for country i at time t) by the population series. Hence, per capita variables are used throughout the analysis. This is important as insurance market activity and GDP – in absolute terms – might share a common stochastic trend due to the population component in both variables. To avoid this common stochastic component leading to evidence in favor of cointegration, it is essential to account for population effects in both variables. According to Figs. 1 and 2 we see a positive linear relationship of real insurance activity and GDP per capita by considering our panel structure following the OECD Country Risk Classification (see on the other hand Lee et al., 2013, for a positive S-curve effect in the relationship between insurance activity and economic growth). To investigate this relationship, data from 1997 to 2014, which represents the commonly available observation period, were pooled and regressed. Hence, one could expect that real per capita GDP and insurance activity are

Table 3
Summary of countries for which each of the null hypotheses of the individual cointegration test by Saikkonen and Lütkepohl (2000) on a 5% significance level have to be rejected. All these countries have been removed from the corresponding panel.

Panel	Life Premiums (LC)	Non-Life premiums (NC)
EU East	(–)	Czech Republic Hungary Latvia Lithuania Slovakia
EU North	Netherlands	(–)
EU South	Cyprus Italy Malta	Malta Portugal
OECD	Japan	(–)
Risk I	Saudi Arabia	(–)
Risk II	(–)	(–)
Risk III	Colombia Guatemala Panama South Africa Vietnam	Croatia Russia South Africa Vietnam
Risk IV	Kazakhstan Oman	Algeria Bahrain Egypt El Salvador Oman
Risk V	Tunisia Ukraine	Jamaica Kenya Nigeria Tunisia
Risk VI	Pakistan	Argentina

homogeneously cointegrated among high- and low-risk countries, as more insurance activity might lead to lower (higher) economic risks, which then should lead to more (less) investment activity and, hence, higher (lower) income. The next section might also shed some light on this issue.

4. Methodology and empirical evidence

The methodology used here has been proposed by Örsal and Arsova (2017) and Arsova and Örsal (2018) and has, compared to methods used in previous studies on the insurance-growth nexus, the decisive advantage that it accounts for the presence of

Table 4
Results of the test statistics as suggested by Arsova and Örsal (2018). The methodology is applied to defactorized real insurance premia and real GDP per capita. Superscript ^{r} stands for rejection of the null hypothesis on a 5% significance level.

Panel	Premia	P_N^*		$P_{\phi^{-1}}^*$		PSL^J	
		$r=0$	$r=1$	$r=0$	$r=1$	$r=0$	$r=1$
EU East	LC	4.276^{r}	5.388^{r}	−3.633^{r}	−4.222^{r}	1.442	(–)
	NC	6.073^{r}	2.086^{r}	−3.961^{r}	−2.115^{r}	3.244^{r}	0.108
EU North	LC	8.557^{r}	0.467	−6.129^{r}	−0.599	4.282^{r}	−2.081
	NC	10.534^{r}	−1.437	−7.060^{r}	1.332	5.478^{r}	−3.438
EU South	LC	2.578^{r}	3.282^{r}	−2.392^{r}	−1.964^{r}	0.950	(–)
	NC	6.314^{r}	−0.371	−3.665^{r}	−0.186	5.182^{r}	−1.833
OECD	LC	9.793^{r}	1.289	−6.184^{r}	−0.059	4.963^{r}	−1.164
	NC	16.497^{r}	0.508	−8.614^{r}	−0.879	9.298^{r}	−2.223
Risk II	LC	13.299^{r}	−0.297	−6.301^{r}	0.513	9.087^{r}	−1.865
	NC	14.847^{r}	−0.645	−7.520^{r}	1.146	9.792^{r}	−2.189
Risk III	LC	13.416^{r}	0.246	−8.179^{r}	−0.837	6.837^{r}	−2.897
	NC	19.021^{r}	−0.302	−10.333^{r}	0.396	11.694^{r}	−3.149
Risk IV	LC	8.707^{r}	0.236	−4.264^{r}	−0.229	5.721^{r}	−1.301
	NC	8.135^{r}	1.359	−4.942^{r}	−1.599	4.142^{r}	−0.788
Risk V	LC	17.848^{r}	−0.947	−8.605^{r}	0.474	13.530^{r}	−2.669
	NC	11.824^{r}	1.763^{r}	−6.049^{r}	−1.905^{r}	6.565^{r}	−0.323
Risk VI	LC	5.073^{r}	−0.087	−3.531^{r}	0.962	2.043^{r}	−1.642
	NC	1.913^{r}	0.631	−2.121^{r}	−0.081	0.315	(–)
Risk VII	LC	12.516^{r}	0.414	−6.479^{r}	−0.202	8.023^{r}	−1.359
	NC	6.958^{r}	0.442	−4.726^{r}	−0.051	3.613^{r}	−1.306

cross-sectional dependence. Hence, we apply the CD test statistic by Pesaran (2015). All results are reported in Table 2 and indicate compelling empirical evidence for the existence of cross-sectional dependence in our data. Therefore, the use of robust procedures against cross-sectional dependence seems to be crucial for investigating the insurance-growth-nexus.[3]

The rationale behind the testing procedure by Örsal and Arsova (2017) and Arsova and Örsal (2018) is that the common factors are estimated by using the panel analysis of nonstationarity in idiosyncratic and common components (PANIC) as proposed by Bai and Ng (2004), and the factors are subtracted from the observed time series to obtain the estimated cross-sectionally independent idiosyncratic components of per capita real insurance premiums and GDP. These defactorized variables – $GDP_{it}^{(def)}$ and $IP_{it}^{(def)}$ – are used to test the following hypothesis:

$$H_0 : r_i = r, \quad \forall i, \quad \text{vs.} \quad H_1 : r_i > r, \quad \exists i,$$

where r_i is the cointegration rank for $i = 1, \ldots, N_p$ and $r \in 0, 1$. In particular, the PSL^J test statistic by Arsova and Örsal (2018) is computed as the standardized average of the individual likelihood ratio trace statistics of the test by Saikkonen and Lütkepohl (2000) applied to the defactored series. It has a standard normal limiting distribution under the null hypothesis, and the rejection region is in the right tail. Further, we use

$$P_{N_P}^* = \frac{-2\sum_{i=1}^{N_P} \ln\left(p_i^*\right) - 2N_P}{\sqrt{4N_P}} \quad \text{and} \quad P_{\Phi^{-1}}^* = \frac{\sum_{i=1}^{N_P} \Phi^{-1}\left(p_i^*\right)}{\sqrt{N_P}},$$

[3] To get an overview about the literature on cointegration in panels we would like to refer the reader to Breitung and Pesaran (2008).

proposed by Örsal and Arsova (2017). In this framework, p_i^* denotes the p-value of the test by Saikkonen and Lütkepohl (2000) applied to $GDP_{it}^{(def)}$ and $IP_{it}^{(def)}$. Further, Φ^{-1} denotes the cumulative distribution function of the standard normal distribution. These tests are also standard normally distributed, and the rejection region is in the left tail. Note that the tests are performed by including a linear trend.[4]

First, we remove all variables for which we have to reject each null hypotheses of the cointegration test by Saikkonen and Lütkepohl (2000) individually on the 5% significance level. Thereby, we consider that some per capita variables of the order zero might be integrated (see Lee et al., 2013). These countries are reported in Table 3.

Second, we compute the three test statistics PSL^J, $P_{N_P}^*$, and $P_{\Phi^{-1}}^*$ for the respective panels after removing the countries as reported in Table 3. The results are reported in Table 4.

We reject the null hypothesis of $r_i = 0\ \forall i$, and we do not reject the null hypothesis for $r_i = 1\ \forall i$ for EU North, OECD, Risk II, Risk III, Risk IV, and Risk VII for all test statistics used here and for both kinds of insurance. Further, we find evidence for cointegration for EU South in the case of non-life insurance and for Risk V and Risk VI in the case of life insurance for all used test statistics. We find ambiguous results in the cases of EU East and EU South for life insurance as well as Risk V and Risk VI for non-life insurance — but there is no clear evidence against cointegration.

5. Conclusion

To our knowledge, this is the first empirical study on the insurance growth nexus that accounts for unattended cross-sectional dependence. Further, we analyze updated data on the life and non-life insurance sectors and panels are formed by applying the OECD risk classification. The majority of the common literature (see, e.g., Lee et al., 2013) reports empirical evidence for long-run equilibria among these variables. Overall, we confirm these results, which is particularly important against the background that unattended cross-sectional dependence may result in oversized cointegration tests. Furthermore, we obtain overall homogeneous results for high- and low-risk countries.

Credit authorship contribution statement

Miguel Rodriguez Gonzalez: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Christoph Wegener**: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Tobias Basse**: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Supervision.

Acknowledgments

We would like to thank the editor Samuel Vigne, an anonymous associated editor and an anonymous referee for extremely valuable and profound comments. Their efforts have been essential in significantly improving this paper. We also have benefited greatly from comments made by J.-M. Graf von der Schulenburg and the participants of different international economics and finance conferences. The financial support of the German Association of Insurance Sciences (DVfVW) is also gratefully acknowledged. However, the sponsor had no involvement in study design; in the collection, analysis and interpretation of data; in the writing of the report; and in the decision to submit the article for publication.

References

Ang, J.B., 2008. A survey of recent developments in the literature of finance and growth. J. Econ. Surv. 22 (3), 536–576.
Arsova, A., Örsal, D.D.K., 2018. Likelihood-based panel cointegration test in the presence of a linear time trend and cross-sectional dependence. Econometric Rev. 37 (10), 1033–1050.
Bai, J., Ng, S., 2004. A panic attack on unit roots and cointegration. Econometrica 72 (4), 1127–1177.
Beck, R., Georgiadis, G., Straub, R., 2014. The finance and growth nexus revisited. Econom. Lett. 124 (3), 382–385.
Breitung, J., Pesaran, M.H., 2008. Unit roots and cointegration in panels. In: The Econometrics of Panel Data. Springer, pp. 279–322.
Chen, P.-F., Lee, C.-C., Lee, C.-F., 2012. How does the development of the life insurance market affect economic growth? Some international evidence. J. Int. Dev. 24 (7), 865–893.
Haiss, P., Sümegi, K., 2008. The relationship between insurance and economic growth in europe: A theoretical and empirical analysis. Empirica 35 (4), 405–431.
Hatemi-J, A., Lee, C.-C., Lee, C.-C., Gupta, R., 2019. Insurance activity and economic performance: Fresh evidence from asymmetric panel causality tests. Int. Finance 22 (2), 221–240.
Law, S.H., Singh, N., 2014. Does too much finance harm economic growth? J. Bank. Finance 41, 36–44.
Lee, C.-C., 2011. Does insurance matter for growth: Empirical evidence from OECD countries. B.E. J. Macroecon. 11 (1).
Lee, C.-C., 2013. Insurance and real output: The key role of banking activities. Macroecon. Dyn. 17 (02), 235–260.
Lee, C.-C., Lee, C.-C., Chiou, Y.-Y., 2017. Insurance activities, globalization, and economic growth: New methods, new evidence. J. Int. Financ. Mark. Inst. Money 51, 155–170.
Lee, C.-C., Lee, C.-C., Chiu, Y.-B., 2013. The link between life insurance activities and economic growth: Some new evidence. J. Int. Money Finance 32, 405–427.
Levine, R., 2003. More on finance and growth: More finance, more growth? Fed. Reserve Bank Saint Louis Rev. 85 (4), 31–46.

[4] See Örsal (2017) for another application of this methodology.

Liu, G.-C., Lee, C.-C., Lee, C.-C., 2016. The nexus between insurance activity and economic growth: A bootstrap rolling window approach. Int. Rev. Econ. Finance 43, 299–319.

Örsal, D.D.K., 2017. Analysing money demand relation for OECD countries using common factors. Appl. Econ. 49 (60), 6003–6013.

Örsal, D.D.K., Arsova, A., 2017. Meta-analytic cointegrating rank tests for dependent panels. Econom. Stat. 2, 61–72.

Outreville, J.F., 2013. The relationship between insurance and economic development: 85 empirical papers for a review of the literature. Risk Manag. Insur. Rev. 16 (1), 71–122.

Pesaran, M.H., 2015. Testing weak cross-sectional dependence in large panels. Econometric Rev. 34 (6–10), 1089–1117.

Pradhan, R.P., Arvin, M.B., Norman, N.R., 2015. Insurance development and the finance-growth nexus: Evidence from 34 OECD countries. J. Multinatl. Financ. Manag. 31, 1–22.

Saikkonen, P., Lütkepohl, H., 2000. Trend adjustment prior to testing for the cointegrating rank of a vector autoregressive process. J. Time Ser. Anal. 21 (4), 435–456.

Trew, A., 2006. Finance and growth: A critical survey. Econ. Rec. 82 (259), 481–490.

Ward, D., Zurbruegg, R., 2000. Does insurance promote economic growth? Evidence from OECD countries. J. Risk Insur. 489–506.

Module 11

Risks of the German Power Supply System Difference between Risk Assessments from the Insurance Industry and Energy Technicians

Wrede, D. / Linderkamp, T. / Rodriguez Gonzalez, M. (2017)

Published in:
Zeitschrift für Energiewirtschaft, Vol. 41, No. 2, pp. 105–117. DOI:
https://doi.org/10.1007/s12398-016-0191-6.

Z Energiewirtsch (2016) 41:105–117
DOI 10.1007/s12398-016-0191-6

Risks of the German Power Supply System

Difference between Risk Assessments from the Insurance Industry and Energy Technicians

Dirk Wrede[1] · Tim Linderkamp[2] · Miguel Rodriguez Gonzalez[1]

Published online: 16 December 2016

Abstract The German power supply system is experiencing a phase of radical change. The insurance industry designed this transformation not only as a property insurance donor, but also as an institutional investor. The emphasis of this commitment is based on their own assessment of the risks to which this supply system has been exposed. This study compares risk assessment designs from the insurance industry with that from technical network managers and shows in which the assessments significantly differ. For example, the insurance company's risk assessment of natural disasters and cyber-attacks is much greater in terms of probability of occurrence and the potential of damage than the assessment of energy experts.

Keywords Risk assessment · Energy risks · Energy industry · Insurance industry · Energy security · Power supply system · Risk management

✉ Dirk Wrede
dw@ivbl.uni-hannover.de

Tim Linderkamp
tl@kvw-hannover.de

Miguel Rodriguez Gonzalez
mr@ivbl.uni-hannover.de

[1] Institute for Risk and Insurance, Gottfried Wilhelm Leibniz Universität Hannover, Otto-Brenner-Straße 1, 30159 Hannover, Germany

[2] Center for Risk and Insurance, Otto-Brenner-Straße 1, 30159 Hannover, Germany

Die Risikosituation des deutschen Energieversorgungssystems

Eine vergleichende Einschätzung aus Perspektive der Versicherungs- und Energiewirtschaft

Zusammenfassung Das deutsche Energieversorgungssystem befindet sich in einem Umbruch. Die Versicherungswirtschaft gestaltet diese Transformation nicht nur als Risikoträger, sondern auch als institutioneller Investor entscheidend mit. Die Akzentuierung dieses Engagements beruht vielfach auf unternehmenseigenen Einschätzungen der das Energiesystem betreffenden Risiken.

In diesem Beitrag wird zunächst eine Risikoklassifikation für derartige Einzelrisiken entwickelt. Darauf aufbauend wird im Rahmen einer empirischen Expertenbefragung gezeigt, wie die Bewertung der einzelnen Risiken von den Spezialisten der Versicherungsindustrie im Vergleich zu den ingenieurtechnischen Sachverständigen der Energiewirtschaft ausgeprägt ist und in welchen Risikofeldern sich diese Einschätzungen signifikant unterscheiden. Es zeigte sich unter anderem, dass die Spezialisten der Versicherer sowohl das Risiko für Naturkatastrophen als auch für Cyberattacken deutlich höher einschätzen als die Experten der Energiewirtschaft.

Schlüsselwörter Risikobewertung · Energierisiken · Energiewirtschaft · Versicherungswirtschaft · Energiesicherheit · Energieversorgungssystem · Risikomanagement

1 Introduction

The German power supply system is undergoing transformation. In 2011, the federal government decided to abandon

nuclear energy and promote the development of renewable energy. This development, through the adjustment of energy mixes, facilitated a grid expansion.

The insurance industry is presently connected to the energy system in many ways. It functions as a risk carrier through the provision of insurance coverage for energy producers, network operators, and consumers, and additionally focuses on its role as an institutional investor. In particular, the provision of property insurance coverage is a precedent condition, which occurred to establish technology or systems in the market. Every insurance policy, or more precisely, every insurance premium, is based on a presumed claims distribution, which influences the premium level or the decision to grant insurance coverage. This study investigates the associated risks in terms of their probability and extent of damage. The German insurance industry is observed to influence the electric power system significantly and for the first time, has participated in the debate regarding the threat to the country's energy system. Our study contributes to three issues in existing literature:

- First, we provide a broad risk categorization, which covers all risk related to the German power supply system.
- Second, we present a risk assessment based on expert surveys from both the insurance and energy industries.
- Finally, we test if assessments from the insurance industry and from energy experts differ statistically in our risk categories.

This remainder of this paper is organized as follows: Sect. 2 provides a literature overview regarding existing risk classifications and assessments for energy systems and projects. Sect. 3 presents our data and applied methods. Sect. 4 shows our results, Sect. 5 is the discussion portion, and Sect. 6 concludes.

2 Literature Overview

The power supply system is one of Germany's basic technical infrastructures (Federal Ministry of the Interior 2009) and is classified as a one of the most critical infrastructures by its high degree of networking (Dai et al. 2014; Hao et al. 2014; Liu et al. 2013; Lukasik 2003). These infrastructures are considered critical because their failure would have extensive social and economic consequences in the affected geographical areas.[1] Kröger (2006, 2008) noted that a critical infrastructure's essential characteristics can pose a threat through different risks (technical-human, physical, environmental, and cyber-related).

The power supply system as a critical infrastructure is not only directly affected by risks, but can also produce risks (Johansson 2013a, 2013b). Energy risks[2] can be determined by external and internal factors, which are controlled by the energy companies (Crousillat 1989). Thus, Birkmann et al. (2010) and Kjølle et al. (2012) focused on an investigation of the power supply system's potential vulnerability from such various potential hazards as natural hazards, terrorism, and cyber-attacks. A growing importance has been placed on terrorist activity's potential threat to the power supply system as a result (Amin 2002, 2005; Toft et al. 2010).

Different approaches can be found in literature regarding the classification and categorization of energy supply risk and its relevant security. However, the collection of risk in this case is often limited by selected fossil fuels (Doukas et al. 2011; Gupta 2008; Weisser 2007), individual energy companies (Lomitschka 2009; Lomitschka and Schulten 2009), sectors (Gross et al. 2007, 2010; Liu et al. 2015, 2012), countries (Nikolić et al. 2011 for Serbia; Jin et al. 2014 for China; Bhattacharya and Kojima 2012 for Japan), or by electricity production from renewable energy sources (Aragonés-Beltrán et al. 2010, 2014; Francés et al. 2013; Montes and Martín 2007).

A recommendation for different energy risk classifications can be found in Checchi et al. (2009). This risk survey of Europe's energy supply security distinguished between geological, technical, economic, geopolitical, and environmental risk factors, whereas the Clingendael International Energy Programme (CIEP) (2004) and the United Nations Environment Programme (UNEP) (2004) focused primarily on economic risks.

Winzer (2012) and Colli et al. (2009) differentiated energy security risks as technical, human, or inherent risk sources. The European Commission (2000) divided energy security risks into physical, economic, social, and environmental risks.

Separate risk analyses exist for specific production technologies, which can be found in literature, in addition to

[1] For the effects of the 1998 ice storm in Canada, see Chang et al. (2007); for the consequences of the gas conflict between Russia and the Ukraine see, for example, Torres et al. (2009). Regarding the impacts of the United States and Canadian blackouts in 2003, see U.S.-Canada Power System Outage Task Force (2004); for the 2003 Italian blackout, see Union for the Co-ordination of Transmission of Electricity (UCTE) (2004); for the European Blackout in 2006, see van der Vleuten and Lagendijk (2010); for major blackouts from 2003 to 2015, see Veloza and Santamaria (2016).

[2] We use the term "energy risks" synonymously for all risks in this study, for those that threaten the German power supply system directly or indirectly, or result from the system itself.

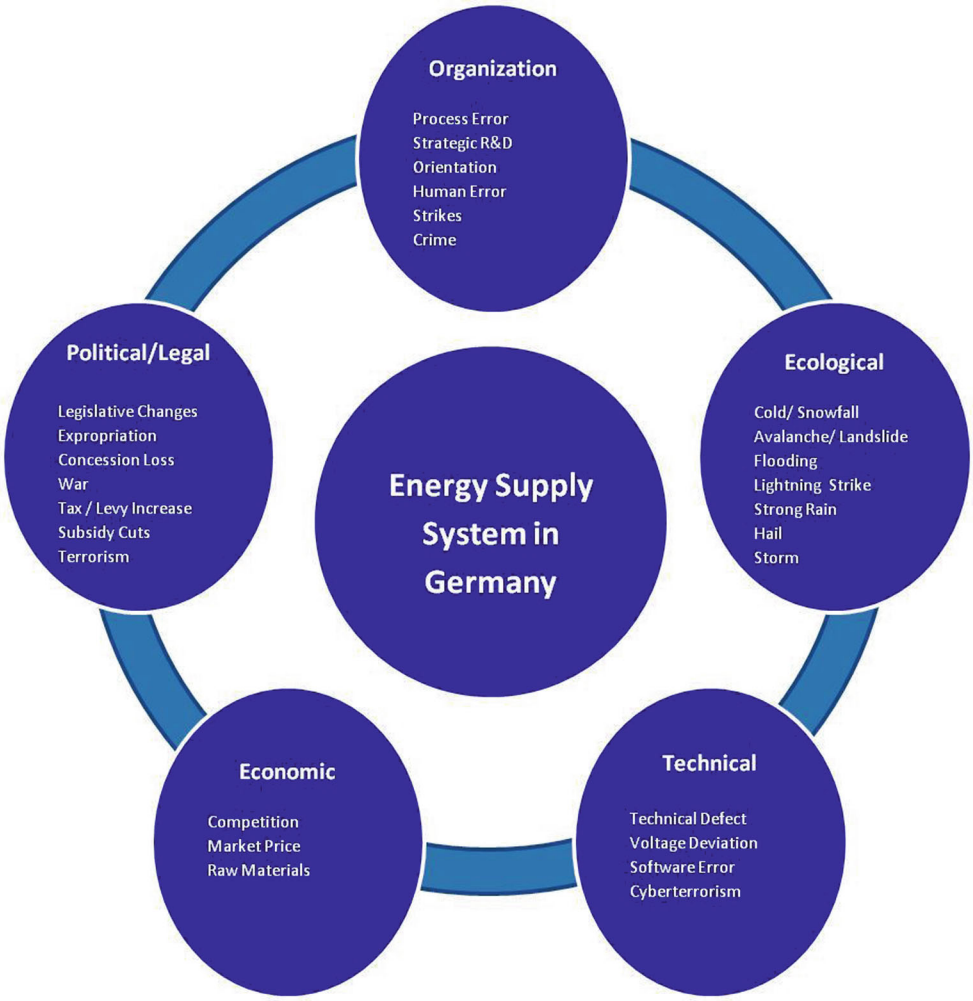


Fig. 1 Overview of the different risks and risk categories

project-related risk assessments (Chapman 2001; Perry and Hayes 1985; Tah and Carr 2001; Tah et al. 1993). For example, key risks regarding wind energy according to the European Wind Energy Association (EWEA) (2013), are changes in regulatory framework, technically faulty components, and financial key risks. The construction sector's key risks are inadequate availability and performance of the energy network's infrastructure, the economic situation, and contract logistics and assembly risks associated with the construction elements. Madlener et al. (2009) suggested that regarding offshore wind turbines, a subdivision exists between external (ecological, development, soil, technical, procurement price, weather, construction, and income risks) and internal project risks (repair costs, operating, and financial risks).

Torbaghan et al. (2015) follow a systemic approach, as in the present study; however, they focus on the risks in the context of an increase in transnational networking, and specifically, on the pan-European network that would arise with the inclusion of Great Britain. They also conduct a systematic literature review with an additional expert survey, and found social, technical, economic, ecological, and political risks.

In conclusion, it has been demonstrated thus far that there has not been a holistic risk assessment for the German energy supply system. Moreover, literature has inadequately provided expert assessments of risk analyses, and a comparative risk study completely lacks the insurance industry's perspective. We provide such a study in the following chapters.

3 Methodology and Data

An online survey was conducted to answer the aforementioned questions, as to whether the estimation of likelihood and selected risks' damage extent differ between risk managers in the insurance industry and power grid experts. This approach is necessary because no historical data is available to answer the issues raised in this study. To ensure a systematic and comprehensive assessment of the probability of occurrence and the extent of damage, we consulted experts

Table 1 Scale for the probability of occurrence and extent of damage for the assessment of the surveyed risks

Score	Probability	Extent of Damage
5	>80% (Relatively Certain)	Serious
4	60–80% (Probable)	Significant
3	30–60% (Possible)	Moderate
2	10–30% (Rare)	Minor
1	<10% (Unlikely)	Insignificant
0	Not Applicable	Not Applicable

Table 2 Overview of the respondents

Industry	Classification	Number of Participants
Insurance Industry	Primary Insurance Company	4
	Reinsurance Company	2
	Insurance Broker focusing on the Energy Industry	5
Energy Industry	Subarea of Network Technology	5
	Subarea of Risk Management	1
	Energy Management Consultancy	2
	Without Specifications	2
Research	Applied Research	2
Total Number of Participants		23

specifically addressing risk-related and technical expertise from the insurance and energy industries. We also consulted experts who specialize in technical and energy-economic issues. The study is not regarded as a random sample of representative character for this reason, but rather, it represents an expert survey. The survey is based on a specially developed risk catalog for the German energy supply system. The elaboration of material risks is based on a systematic review of appropriate literature.[3] The PESTEL Analysis[4] has been modified for the classification of risks in five major categories, in light of the German power supply system's complexity. Our risk catalog is divided into political/legal, economic, technical, ecological, and organizational risks, or PETEO. Each category contains various risks with descriptions[5], which were evaluated by the respondents regarding their probability of occurrence, and the potential extent of damage through risk realization. Although the risk differentiation is precise, the results of risk realization, the damages, manifest their selves mostly in a similar way. Mostly the stakeholder are affected in an economic way (economic burdens) or in a physical way (damage to business assets). Therefore we define damages as negative impacts in general on the considered stakeholder. A risk overview is shown in Fig. 1.

The assessment was conducted for different stakeholders in the electric power supply system, depending on the concern. A distinction was drawn between power producers (PP), transmission grid operators (TGO), distribution grid operators (DGO), and electricity consumers (Con). Sherman Kent's rating scale was used to assess the damage's likelihood and extent, as it subdivides these into five levels.[6] Table 1 displays a precise subdivision of the assessment of likelihood and extent of damage, and the corresponding verbal explanations from the experts' interviews.

The choices for the probability of occurrence are limited by one category, while multiple selections have been approved for the extent of damage. Therefore, uncertainty regarding the different possible damage patterns in the risk implementation has been considered. As a time frame for the risk assessments, respondents were asked using a moderate time frame, which lasts from three to five years.

Questionnaire responses were submitted online. A pretest was conducted before the survey could commence, to ensure the questionnaire's comprehensibility. A total of 46 experts were contacted from both the insurance industry and from the network technology and research field, and 23 completed the questionnaire in its entirety, which corresponds with a 50% return rate. A detailed breakdown of the respondents can be found in Table 2.

The analyses of survey results are divided into two parts. First, it is descriptively noted how risks are assessed. For this purpose damage probability and extent are regarded. Second, the risks' standard deviations (SD) also with respect to the different groups are noted. They are regarded as an indicator of which risk assessments present the highest uncertainty.

Subsequently, two sample t-tests were conducted for the two surveyed groups:[7] the insurance industry and technical experts. We tested to determine whether the two groups' assessments differ significantly in terms of both the probability of occurrence and extent of damage in the queried risks.

[3] See Section 2.

[4] The PESTEL analysis is the standard model to scan a company's environment. PESTEL covers political, economic, social, technological, ecological, and legal risks. See also Johnson et al. (2013). For the PESTEL analysis as a risk analysis method, see Burt et al. (2006); Gassner (2009); Sachs et al. (2008).

[5] The descriptions of the risks from the survey are listed in the appendix, in Table 10.

[6] Regarding Sherman Kent's rating scale and its recommendation, see also Meyer and Booker (1991).

[7] For the evaluation, the respondents who indicated themselves as active in application-oriented research are included in the energy engineers' group. This is for two reasons: the low-quantity research group ($n = 2$) has no meaningful results; second, it can be assumed that application-oriented researchers assess energy system risks from a more technical perspective.

Table 3 Overview of the averages of the probability of occurrence (Prob.) and extent of damage for selected risks

	Averages of the Probability of Occurrence				Averages of the Extent of Damage			
	Top 5 Risks		Bottom 5 Risks		Top 5 Risks		Bottom 5 Risks	
	Risk	Prob	Risk	Prob	Risk	Damage	Risk	Damage
Insurance Industry	Market Price (PP)	4.5455	War (Con)	0.8182	Expropriation (PP)	4.2097	Strike (TGO)	1.9091
	Concession Loss (DGO)	4.2126	War (DGO)	0.9091	Expropriation (TGO)	4.2097	Strike (DGO)	2.0000
	Expropriation (TGO)	4.2125	War (TGO)	1.0000	Expropriation (DGO)	4.2097	Strike (PP)	2.0909
	Concession Loss (TGO)	4.2096	War (PP)	1.0909	Concession Loss (PP)	4.2066	Process Error (DGO)	2.2727
	Expropriation (DGO)	4.2095	Terrorism (DGO)	1.3636	Concession Loss (TGO)	4.2066	Process Error (TGO)	2.2727
Energy Industry	Legislative Changes (DGO)	4.5748	Concession Loss (TGO)	0.4545	Legislative Changes (TGO)	4.5717	Concession Loss (TGO)	0.8636
	Flooding (Con)	4.5689	War (Con)	0.7500	Strategic R&D Orientation (PP)	4.5717	Concession Loss (PP)	1.2222
	Lightning Strike (DGO)	4.5689	War (DGO)	0.8333	Lightning Strike (Con)	4.5689	Technical Defect (Con)	1.5909
	Storm (TGO)	4.5689	Concession Loss (PP)	0.8889	Competition (PP)	4.2219	Hard Rain (TGO)	1.8750
	Cyberterrorism (TGO)	4.5689	War (TGO)	0.9167	Legislative Changes (DGO)	4.2127	Terrorism (Con)	1.9091
Overall	Market Price (PP)	4.3636	War (Con)	0.7826	Cyberterrorism (PP)	3.7826	Concession Loss (TGO)	1.9545
	Legislative Changes (PP)	4.1304	War (DGO)	0.8696	Legislative Changes (PP)	3.7174	War (Con)	2.0000
	Tax/Levy Increase (Con)	3.8261	War (TGO)	0.9565	Flooding (PP)	3.7174	War (DGO)	2.0238
	Competition (PP)	3.6818	War (PP)	1.0000	Cyberterrorism (TGO)	3.6739	Concession Loss (PP)	2.1136
	Legislative Changes (Con)	3.6522	Expropriation (DGO)	1.2273	Market Price (PP)	3.6429	War (TGO)	2.1521

A distinction between the two-sample t-tests was necessary to determine whether the two different groups' variances could be compared. Therefore, we used Levene's test to ascertain equal variance. The null hypothesis, in which no present difference exists between the two groups' variance, is rejected if the test statistic is less than the predetermined significance level ($\alpha = 0.05$).

Subsequent t-tests are performed under the null hypothesis, in which no underlying significant difference exists between the two surveyed groups. The null hypothesis is rejected if the test statistic is less than the required significance level. The t-test in each case is required for both equal and unequal variances.

Table 4 Overview of standard deviation (SD) for the probability of occurrence (Prob.) and the extent of damage for selected risks

	SD of the Probability of Occurrence				SD of the Extent of Damage			
	Top 5 Risks		Bottom 5 Risks		Top 5 Risks		Bottom 5 Risks	
	Risk	Prob	Risk	Prob	Risk	Damage	Risk	Damage
Insurance Industry	Storm (PP)	1.6011	Subsidies (PP)	0.6467	War (PP)	2.0111	Terrorism (DGO)	0.7746
	Heavy Rain (TGO)	1.5783	Market Price (PP)	0.6876	Concession Loss (PP)	1.9551	War (Con)	0.8312
	Heavy Rain (DGO)	1.5725	Legislative Changes (PP)	0.7006	War (TGO)	1.9551	Cold/Snow (PP)	0.8312
	Heavy Rain (PP)	1.5551	Tax/Levy Increase (PP)	0.7508	War (Con)	1.8488	Terrorism (Con)	0.8739
	Lightning Strike (DGO)	1.446	Resources (PP)	0.7746	War (DGO)	1.7581	War (TGO)	0.9045
Energy Industry	Tax/Levy Increase (DGO)	1.4434	Terrorism (DGO)	0.4924	Expropriation (PP)	2.4008	Strike (DGO)	0.4830
	Tax/Levy Increase (PP)	1.3114	War (Con)	0.6216	Expropriation (TGO)	2.3160	Strike (TGO)	0.5798
	Legislative Changes (TGO)	1.3027	Cold/Snow (PP)	0.6686	Expropriation (DGO)	2.2401	Cold/Snow (TGO)	0.7217
	Voltage Deviations (Con)	1.3027	Terrorism (Con)	0.6686	Avalanche/ Landslide (Con)	1.9909	Flooding (PP)	0.7355
	Expropriation (PP)	1.2881	War (TGO)	0.6686	Avalanche/ Landslide (TGO)	1.9482	Competition (PP)	0.7930
Overall	Heavy Rain (PP)	1.3644	Terrorism (DGO)	0.6473	Heavy Rain (PP)	2.0853	Competition (PP)	0.7661
	Storm (DGO)	1.3644	War (Con)	0.7359	Storm (DGO)	2.0290	Subsidies (PP)	0.8646
	Concession Loss (TGO)	1.3593	War (PP)	0.7385	Concession Loss (TGO)	2.0129	Resources (PP)	1.0165
	Heavy Rain (TGO)	1.3366	War (TGO)	0.7674	Heavy Rain (TGO)	1.9875	Concession Loss (DGO)	1.0477
	Voltage Deviations (DGO)	1.3366	Subsidies (PP)	0.7964	Voltage Deviations (DGO)	1.9853	Cold/Snow (TGO)	1.0515

4 Results

4.1 Descriptive Analysis

Table 3 displays the averages of the probability of occurrence and extent of damage for the top five risks and the lowest five risks.

Respondents attributed the highest probability of occurrence to the market price changes risk, which lead to the situation that power producers cannot profitably operate.[8] Similarly, the risk resulting from an increase in competition between power producers is given a high probability. The dominant risk, from the risk class with the highest probability of occurrence, is primarily political/legal and economic

[8] This estimation could result from the current merit-order system, because the respondents were asked to use a time frame, which lasts from three to five years. In the long run non-profitable power plants will leave the market and the price for electricity will stabilize.

risks, which affects the power generators (market prices and legislative changes) or the consumer (tax/levy increase).

The insurance managers' group attributes the risk of market price fluctuations to the power producers, which also has a high probability of occurrence. Additionally, risks of expropriation and the concession loss affect both transmission and distribution grid operators. Conversely, the network engineers' group considers changes in the law to have a higher probability to affect distribution grid operators. Natural disasters and cyberterrorism are considered more probable risks.

Regarding the risks with the lowest probability of occurrence, the results are relatively homogeneous. The risk of war is considered as having low probability not only for the population of correspondents, but also for both subgroups. Overall, the risk of expropriation for distribution grid operators is estimated as relatively unlikely; the insurance industry also notes a low probability of terror risk for distribution network operators. Concession loss risks for transmission grid operators are considered unlikely by the surveyed network engineers.

Regarding the extent of damage, cyberterrorism is considered as a risk with the highest extent of damage, and especially for power producers and distribution grid operators. They also consider flood, fluctuation in market prices, and legislative changes to have serious consequences on power producers. The insurance industry attributes the risk for producers and network operators to be expropriated, and for the concession loss risk for power generators and transmission system operators as the highest extent of damage. Energy experts' estimations, in terms of risks with high loss effects, are heterogeneous; legislative changes are of great importance for both transmission network operators (first place) and distribution grid operators (fifth place), and

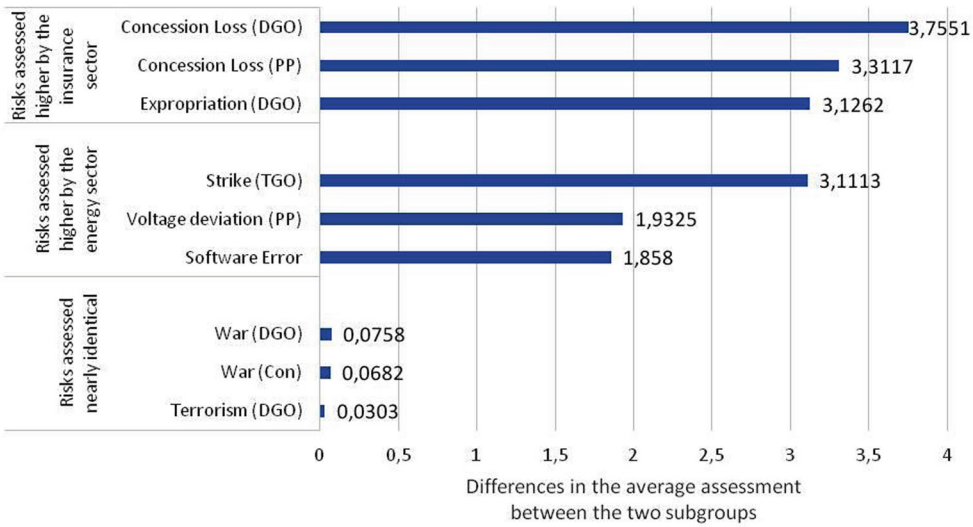


Fig. 2 Differences in the assessment of the probability of occurrence

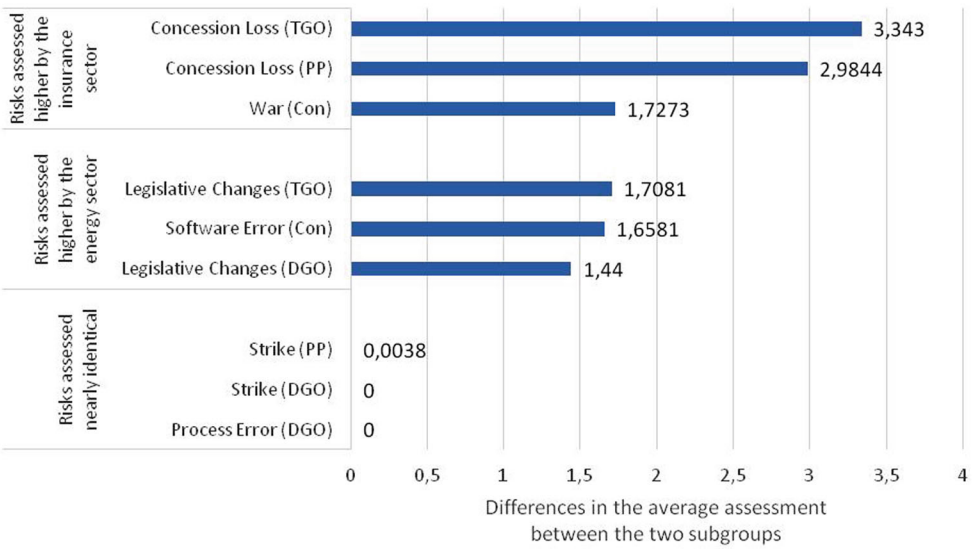


Fig. 3 Differences in the assessment of the extent of damage

Table 5 Significant differences in the assessment of political/legal risks

Political/Legal Risks	
Probability	Extent of Damage
Legislative Changes (DGO)**	Legislative Changes (PP)**
Concession Loss (PP)**	Concession Loss (PP)**
Concession Loss (TGO)***	Concession Loss (TGO)***
Concession Loss (DGO)**	War (Con) **
–	Terrorism (Con) **

*** ≙ 1% significance level
** ≙ 5% significance level
* ≙ 10% significance level

Table 6 Significant differences in the assessment of economic risks

Economic Risks	
Probability	Extent of Damage
Competition (PP)*	Market Price (PP)*
Resources (PP)*	–

*** ≙ 1% significance level
** ≙ 5% significance level
* ≙ 10% significance level

Table 7 Significant differences in the assessment of ecological risks

Ecological Risks	
Probability	Extent of Damage
Cold/Snow (PP)*	Cold/Snow (TGO)**
Cold/Snow (Con)*	Cold/Snow (Con)**
Flood (PP)***	Flood (PP)**
Flood (TGO)***	Flood (TGO)*
Flood (DGO)**	Flood (DGO)**
Flood (Con)**	Flood (Con)**
Lightning Strike (Con)**	Lightning Strike (Con)**
Hail (PP)**	Storm (TGO)*
Storm (TGO)***	Storm (DGO)*
Storm (DGO)***	Storm (Con)*
Storm (Con)**	–

*** ≙ 1% significance level
** ≙ 5% significance level
* ≙ 10% significance level

strategic risk is significant for power generators, to set incorrect or outdated technologies. Additionally, the risk of being struck by lightning for electricity consumers, and the risk of increasing competition between power producers, were also considered.

Insurance and other industries awarded low loss potential to the risk of a network operator strike. Similarly, errors that network operators apply to their processes are a manageable risk for the insurance industry in terms of impact. However, the energy sector estimates that risks of technical defects and terrorism among consumers have a relatively low potential for damage. The impact of a concession loss

Table 8 Significant differences in the assessment of technical risks

Technical Risks	
Probability	Extent of Damage
Technical Defect (PP)**	Technical Defect (Con)*
Technical Defect (TGO)*	Cyberterrorism (TGO)*
Cyberterrorism (PP)*	Cyberterrorism (DGO)**
Cyberterrorism (TGO)**	–
Cyberterrorism (DGO)**	–

*** ≙ 1% significance level
** ≙ 5% significance level
* ≙ 10% significance level

Table 9 Significant differences in the assessment of organizational risks

Organizational Risks	
Probability	Extent of Damage
Human Error (PP)*	Crime (DGO)*
Crime (DGO)*	–

*** ≙ 1% significance level
** ≙ 5% significance level
* ≙ 10% significance level

for producers and transmission system operators was also rated as low by the energy sector.

The insurance industry rates transmission network operators' concession loss as having a relatively high potential for damage. The standard deviation in the evaluation of the probability of occurrence is to be construed as an indicator for risks' predictability (as shown in Table 4).

It is noteworthy that natural disaster risks have a high standard deviation on the whole, and especially in the group of insurance representatives. This is also true for the insurance industry's assessment of heavy rainfall risk. The assessment of probability of occurrence by the surveyed energy technicians demonstrates that political or legal risks, and particularly regarding the risk of tax or levy increases, are considered to have a relatively high degree of diversification.

No major discrepancies exist between the entire group and network technicians in the assessment of the probability of occurrence, regarding the risk of terrorism for distribution grid operators and the risk of armed conflicts. The insurance industry rated political/legal and economic risks as comparatively homogeneous.

The risk of armed conflicts is overall and from the energy technicians' perspective rated differently in assessing risks' damage effects. In addition, the surveyed experts of the insurance industry have rated the risk of an avalanche and of expropriation with relatively high heterogeneity.

The lowest valuation differences exist between the entire group and the energy company, regarding the competition risks for power generators. The insurance industry assesses

the impact of network operators' strike actions as relatively heterogeneous.

4.2 Statistical Results

The tests' results tend to demonstrate significantly different risk assessments between the insurance industry and the energy sector. Figs. 2 and 3 give an overview of the differences in absolute figures. Both figures show in an exemplary way the three risks, which are assessed higher by the insurance industry, higher by the energy sector or assessed nearly equal.

The Tables 5, 6, 7, 8 and 9 show which risk assessments differ significantly. The results are sorted by risk classes, and the significance level is indicated by stars: the 1% significance level is represented by three stars, the 5% level by two stars, and the 10% level by one star.

As Table 5 indicates, the insurance industry and technical experts' estimates differ, and particularly regarding the risk of concession loss. Additionally, this reveals the differences in assessing the probability of law changes, which affect distribution grid operators and, regarding the extent of damage from armed conflicts and terrorism, the consumers.

Different assessments exist regarding economic risks, and particularly regarding the probability of both competition and commodity risks. The extent of changing market prices is also differently evaluated by both subgroups, but only at the 10% level.

There is a significant difference between the subgroups regarding the risks of flooding and storms. Moreover, the extent of damage for transmission grid operators and consumers regarding cold exposure risks, and the probability of hail risk for electricity producers, are differently assessed.

There is only a slight difference in the assessments for technical risks. This applies to the probability of a technical fault for power generators and transmission system operators (on a 10% level) and, conversely, the risk of cyberterrorism, in which the estimates differ significantly.

The risk assessments seem to be similar regarding organizational risks. A difference at the 10% level is evident only regarding crime risk for distribution grid operators. The probability for human errors in power producing plants is assessed differently but also occurs at the 10% level.

5 Discussion

As detailed in Section 4, partly significant differences exist in the evaluation of certain risks between the insurance industry and energy technicians, and this is true for evaluations regarding both the probability of occurrence and the extent of damage. This is particularly noteworthy because the assessments made regarding seminal risks have significant differences; the insurance industry usually rates the risks much higher compared to the energy engineers' group.

The insurance industry significantly overestimates the risks of concession losses for both producers and network operators. They also estimate the risks' aftermath at a much higher level. This could be due to insufficient information in the insurance industry regarding the concession award procedure. Similarly, the ratings for the extent of damage to electricity consumers in wars and terrorist attacks are significantly higher in the insurance industry than the network engineers' group. We assume here that the insurance industry has a higher level of expertise, because the abstract political risks are in a non-core area of expertise for the network engineers.

The significant differences in estimates of flood and storm risks must be prioritized. Natural disaster risks and manmade disasters are considered major risk drivers in property insurance companies. The insurance industry again estimates both the probability of occurrence and the potential extent of damage at a significantly higher level. It can be noted that in terms of the probability of occurrence, the insurance industry has a higher assessment skill because they normally have their own weather models; however, the estimation of the extent of damage remains doubtful. The difference between the energy technicians' and insurance industry's estimations can be based on the insurance industry's overestimation of the extent of damage. This could imply non-risk-based estimations, and subsequently, excessively high premiums for storm and flood insurance.

Additionally, risks of cyber-attacks have been more significant in recent technical literature (Biener et al. 2015; Haas et al. 2015; Kosub 2015; Young et al. 2016). The insurance industry estimates cyber risks as more likely, with a higher extent of damage. This assessment is seen as critical because technical managers should be aware of their own cyber vulnerability, and specifically regarding electrical generators and network operators. On the other hand, it is possible that the insurance industry already include different scenarios within its assessment, which are currently still situated outside the technical managers' expectations.

Few to no significant differences were found in the technical risks. The insurance industry's risk managers had a more economic approach to technical risks compared to the network engineers, who had a more technical perspective. Therefore, the technical risks' assessments were expected to differ. Excluding the cyberterrorism risk, the only difference in the assessment of probability of a technical defect's occurrence is whether it pertains to either the electricity producers or the transmission network operators. This could provide a distorted technical picture of the German power supply system to the insurance industry.

However, the organizational risks' assessments do not differentiate significantly at the 5% level. Organizational risks could obviously be classified as relatively homogenous. Additionally, organizational risks are considered to be unspecific to the electric power supply system; however, they must be managed in an adaptable form for all large organizations.

Naturally, the chosen research approach is fraught with various limitations. The relatively small sample size indicated the results' limited representation and validity. This problem arises in surveys that require both a large number of participants and special expertise. Furthermore, it is doubtful as to whether the respondents maintained a predetermined separation of content between assessing the damage probability and extent throughout. The studies reveal that these subjects were mixed in the two risk dimensions (Ulbig et al. 2009). The respondents' different assessments of the probability for an external event had unexpected results, for example, the natural disaster results. This could also indicate that the respondents had a mix of dimensions of probability and the extent of damage. The assessment of the probability of loss dimension is exacerbated because the risks can be realized to various degrees. This means that claims are processed in a highly individual manner, and should be partially moderated by the possibility of mitigating the range in terms of the extent of damage.

6 Conclusion

Certain risks were assessed within an expert survey framework for the probability of occurrence and the potential extent of losses by both risk managers in the insurance industry and energy technicians. Our risk catalog was prepared based on literature, and the risk classification based on the PESTEL analysis led to a new categorization, named PETEO. The descriptive analysis indicated that overall, political/legal and economic risks have the highest probability of occurrence and that cyberterrorism risk has the highest damage potential. However, the two subgroups' assessments differed considerably.

The test of the risk estimates' equality displayed a significant difference between surveyed experts from the insurance and energy industries. The insurance industry highly rated both the probability of occurrence and the potential of damage, particularly for such natural disasters as storms and flooding, which are expected to be volatile. The same applies to risk assessments for effects on electricity consumers in the event of wars, terrorism, and cyberterrorism. However, an important question arises as to whether the insurance industry's assessments were based on the insurance companies' risk models. This leads to the question as to whether these models are properly calibrated, and whether these were used to calculate premiums adequately. Ideally this is not the case, at least for the technical risk field, due to varying assessments between the insurance and energy industries. On the other hand our results indicate that the insurance industry overestimate miscellaneous risks. Such inaccurate estimations might lead to excessively high premiums for the corresponding insurance products.

Funding This work was supported by the Federal Ministry of Education and Research, Germany (grant number 13N12332).

Appendix

Table 10 Description of risks according to the PETEO classification

Political/legal risks	
Legislative Changes	Economic burden due to legislative changes
Expropriation	Loss of ownership of company assets by expropriation
Concession Loss	Economic burden or end of business activity due to a concession loss
War	Interruption or end of business activity or destruction of business assets due to armed conflicts
Increase in Taxes and Levies	Economic burden due to increasing taxes and/or duties
Subsidy Cuts	Economic burden due to subsidy cuts
Terrorism	Damage/destruction of business assets or business interruption due to terrorist acts
Economic risks	
Competition	Loss of market shares or financial losses due to an intensification of the competitive situation
Market Prices	Decommissioning of power plants due to falling market prices for electricity
Raw Materials	Increasing procurement costs due to a supply shortage of raw materials
Technical risks	
Technical Defect	Economic burden/business interruption due to damage of technical infrastructure as a result of a technical disruption or defect
Voltage Deviation	Economic burden/business interruption due to damage of technical infrastructure as a result of high voltage deviations outside the tolerance
Software Error	Economic burden/business interruption due to damage of technical infrastructure as a result of software errors
Cyberterrorism	Economic burden/business interruption due to damage of technical infrastructure as a result of cyberterrorism
Ecological risks	
Cold/Snowfall	Economic burden/business interruption due to damage of technical infrastructure as a result of heavy cold/snowfall
Avalanche/Landslide	Economic burden/business interruption due to damage of technical infrastructure as a result of an avalanche/landslide
Flooding	Economic burden/business interruption due to damage of technical infrastructure as a result of flooding
Lightning Strike	Economic burden/business interruption due to damage of technical infrastructure as a result of a lightning strike
Strong Rain	Economic burden/business interruption due to damage of technical infrastructure as a result of strong rain
Hail	Economic burden/business interruption due to damage of technical infrastructure as a result of hail
Storm	Economic burden/business interruption due to damage of technical infrastructure as a result of storm
Organizational risks	
Process Error	Disruption or business interruption due to process errors
Strategic R&D Orientation	Economic burden/consequences due to an incorrect alignment of R&D policy
Human Error	Economic burden/Disruption or business interruption due to human errors
Strikes	Disruption or business interruption due to strikes
Crime	Damage/destruction of business assets or business interruption due criminal activities like sabotage, (data-)robbery

References

Amin SM (2002) Toward secure and resilient interdependent infrastructures. J Infrastruct Syst 8(3):67–75

Amin SM (2005) Scanning the technology: energy infrastructure defense systems. Proc IEEE 93(5):861–875

Aragonés-Beltrán P, Chaparro-González F, Pastor-Ferrando JP, Rodríguez-Pozo F (2010) An ANP-based approach for the selection of photovoltaic solar power plant investment projects. Renew Sustain Energy Rev 14(1):249–264

Aragonés-Beltrán P, Chaparro-González F, Pastor-Ferrando JP, Pla-Rubio A (2014) An AHP (Analytic Hierarchy Process)/ANP (Analytic Network Process)-based multi-criteria decision approach for the selection of solar-thermal power plant investment projects. Energy 66:222–238

Bhattacharya A, Kojima S (2012) Power sector investment risk and renewable energy: a Japanese case study using portfolio risk optimization method. Energy Policy 40:69–80

Biener C, Eling M, Wirfs JH (2015) Insurability of cyber risk: an empirical analysis. Geneva Pap Risk Insur Issues Pract 40(1):131–158

Birkmann J, Bach C, Guhl S, Witting M, Welle T, Schmude M (2010) State of the Art der Forschung zur Verwundbarkeit Kritischer Infrastrukturen am Beispiel Strom/Stromausfall. Forschungsforum Öffentliche Sicherheit. Working Paper. Schriftenreihe Sicherheit Nr. 2. http://www.sicherheit-forschung.de/publikationen/schriftenreihe_neu/sr_v_v/sr_2.pdf. Accessed 1. Feb 2016

Burt G, Wright G, Bradfield R, Cairns G, van der Heijden K (2006) The role of scenario planning in exploring the environment in view of the limitations of PEST and its derivatives. Int Stud Manag Org 36(3):50–76

Chang SE, McDaniels TL, Mikawoz J, Peterson K (2007) Infrastructure failure interdependencies in extreme events: power outage consequences in the 1998 Ice Storm. Nat Hazards 41(2):337–358

Chapman RJ (2001) The controlling influences on effective risk identification and assessment for construction design management. Int J Proj Manag 19(3):147–160

Checchi A, Behrens A, Egenhofer C (2009) Long-term energy security risks for Europe: a sector-specific approach. CEPS Working Document No. 309. http://www.exeter.ac.uk/energysecurity/documents/publications/Checchi_et_al_2009.pdf. Accessed 1. Feb 2016

Clingendael International Energy Programme (CIEP) (2004) Study on energy supply security and geopolitics – final report. Institute for international relations 'Clingendael'. http://www.clingendaelenergy.com/inc/upload/files/Study_on_energy_supply_security_and_geopolitics.pdf. Accessed 1. Feb 2016

Colli A, Vetere Arellano AL, Kirchsteiger C, Ale BJM (2009) Risk characterisation indicators for risk comparison in the energy sector. Saf Sci 47(1):59–77

Crousillat EO (1989) Incorporating risk and uncertainty in power system planning. Industry and Energy Department working paper. Energy series paper No. 17. Working paper of the World Bank. http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/1999/08/15/000009265_3960930085410/Rendered/PDF/multi_page.pdf. Accessed 1. Feb 2016

Dai Y, Chen G, Dong Z, Xue Y, Hill DJ, Zhao Y (2014) An improved framework for power grid vulnerability analysis considering critical system features. Physica A 395:405–415

Doukas H, Flamos A, Psarras J (2011) Risks on the security of oil and gas supply. Energy Sources Part B 6(4):418–422

European Commission (2000) Towards a European strategy for the security of energy supply. Green paper. COM (2000) 769 final. http://aei.pitt.edu/1184/1/enegy_supply_security_gp_COM_2000_769.pdf. Accessed 1. Feb 2016

European Wind Energy Association (EWEA) (2013) Where's the money coming from? Financing offshore wind farms. Report by the European Wind Energy Association. http://www.ewea.org/fileadmin/files/library/publications/reports/Financing_Offshore_Wind_Farms.pdf. Accessed 1. Feb 2016

Federal Ministry of the Interior (2009) National strategy for critical infrastructure protection (CIP strategy). http://www.bmi.bund.de/SharedDocs/Downloads/EN/Broschueren/cip_stategy.pdf?__blob=publicationFile. Accessed 1. Feb 2016

Francés GE, Marín-Quemada JM, González ESM (2013) RES and risk: renewable energy's contribution to energy security. A portfolio-based approach. Renew Sustain Energy Rev 26:549–559

Gassner M (2009) PESTEL – Strategie zur Beherrschung externer Risiken?. In: Becker L (ed) Digitale Fachbibliothek Management und Führungspraxis. Symposion Publishing, Düsseldorf, pp 117–124

Gross R, Heptonstall P, Blyth W (2007) Investment in electricity generation: the role of costs, incentives and risks. A report produced by Imperial College Centre for Energy Policy and Technology (ICEPT) for the Technology and Policy Assessment Function of the UK Energy Research Centre. http://www.ukerc.ac.uk/asset/E6BB633F%2D17D3%2D4FD6%2DB5B709A3ED26FFAA/. Accessed 1. Feb 2016

Gross R, Blyth W, Heptonstall P (2010) Risks, revenues and investment in electricity generation: why policy needs to look beyond costs. Energy Econ 32(4):796–804

Gupta E (2008) Oil vulnerability index of oil-importing countries. Energy Policy 36(3):1195–1211

Haas A, Haas M, Weinert M (2015) The Internet of things is already here, but who bears the risks? – A model to explain coverage disputes in a world of interconnected, autonomous devices. Working Paper. July 2015. http://www.wriec.net/wp-content/uploads/2015/07/6J3_Haas.pdf. Accessed 1. Feb 2016

Hao J, Kang E, Jackson D, Sun J (2014) Adaptive defending strategy for smart grid attacks. Proceedings of the 2nd Workshop on Smart Energy Grid Security. SEGS 2014, Scottsdale, pp 23–30

Jin X, Zhang Z, Shi X, Ju W (2014) A review on wind power industry and corresponding insurance market in China: Current status and challenges. Renew Sustain Energy Rev 38:1069–1082

Johansson B (2013a) A broadened typology on energy and security. Energy 53:199–205

Johansson B (2013b) Security aspects of future renewable energy systems – A short overview. Energy 61:598–605

Johnson G, Whittington R, Scholes K, Angwin D, Regnér P (2013) Exploring strategy: text & cases, 10th edn. Pearson Education, London

Kjølle GH, Utne IB, Gjerde O (2012) Risk analysis of critical infrastructures emphasizing electricity supply and interdependencies. Reliab Eng Syst Saf 105:80–89

Kosub T (2015) Components and challenges of integrated cyber risk management. Z Versicherungswiss 104(5):615–634

Kröger W (2006) Critical infrastructures at risk: securing electric power supply. Int J Crit Infrastruct 2(2–3):273–293

Kröger W (2008) Critical infrastructures at risk: a need for a new conceptual approach and extended analytical tools. Reliab Eng Syst Saf 93(12):1781–1787

Liu L, Ye J, Zhao Y, Zhao E (2015) The plight of the biomass power generation industry in China – a supply chain risk perspective. Renew Sustain Energy Rev 49:680–692

Liu X, Ye M, Pu B, Tang Z (2012) Risk management for jatropha curcas based biodiesel industry of Panzhihua Prefecture in Southwest China. Renew Sustain Energy Rev 16(3):1721–1734

Liu X, Ren K, Yuan Y, Li Z, Wang Q (2013) Optimal budget deployment strategy against power grid interdiction. Proc IEEE Infocom 2013:1160–1168

Lomitschka M (2009) Integriertes Risiko-/Chancenmanagement als instrument der Unternehmenssteuerung. In: Hilz-Ward RM, Everling O (eds) Risk Performance Management: Chancen für ein besseres Rating. Gabler, Wiesbaden, pp 277–291

Lomitschka M, Schulten R (2009) Aufbau des Risikomanagementsystems der MVV Energie AG. In: Scholz F, Schuler A, Schwintowski H-P (eds) Risikomanagement der Öffentlichen Hand. Physica, Heidelberg, pp 289–305

Lukasik SJ (2003) Vulnerabilities and failures of complex systems. Int J Eng Educ 19(1):206–212

Madlener R, Siegers L, Bendig S (2009) Risikomanagement und -controlling bei Offshore-Windenergieanlagen. Z Energiewirtsch 33(2):135–146

Meyer MA, Booker JM (1991) Eliciting and analyzing expert judgment: a practical guide. Academic Press, London

Montes GM, Martín EP (2007) Profitability of wind energy: short-term risk factors and possible improvements. Renew Sustain Energy Rev 11(9):2191–2200

Nikolić DM, Jednak S, Benković S, Poznanić V (2011) Project finance risk evaluation of the electric power industry of Serbia. Energy Policy 39(10):6168–6177

Perry JH, Hayes RW (1985) Risk and its management in construction projects. Proc Inst Civ Eng Part I 78(1):499–521

Sachs T, Dalla Rosa A, Tiong RLK (2008) Case study on quantifying the impact of political risks on demand and pricing in a power project. J Struct Financ 14(2):77–84

Tah JHM, Carr V (2001) Knowledge-based approach to construction project risk management. J Comput Civil Eng 15(3):170–177

Tah JHM, Thorpe A, McCaffer R (1993) Contractor project risks contingency allocation using linguistic approximation. Comput Sys Eng 4(2–3):281–293

Toft P, Duero A, Bieliauskas A (2010) Terrorist targeting and energy security. Energy Policy 38(8):4411–4421

Torbaghan ME, Burrow MPN, Hunt DVL (2015) Risk assessment for a UK pan-European supergrid. Int J Energy Res 39(11):1564–1578

Torres JM, Alvarez A, Laugé A, Sarriegi JM (2009) Russian-Ukrainian gas conflict case study. Proceedings of the 27th International conference of the System Dynamics Society, Albuquerque. http://www.systemdynamics.org/conferences/2009/proceed/papers/P1240.pdf. Accessed 1. Feb 2016

Ulbig E, Hertel RF, Böl G-F (eds) (2009) Evaluierung der Kommunikation über die Unterschiede zwischen „risk“ und „hazard“: Abschlussbericht. Federal Institute for Risk Assessment. http://www.bfr.bund.de/cm/350/evaluierung_der_kommunikation_ueber_die_unterschiede_zwischen_risk_und_hazard.pdf. Accessed 1. Feb 2016

Union for the Co-ordination of Transmission of Electricity (UCTE) (2004) Final report of the investigation committee on the 28 September 2003 blackout in Italy. https://www.entsoe.eu/fileadmin/user_upload/_library/publications/ce/otherreports/20040427_UCTE_IC_Final_report.pdf. Accessed 1. Feb 2016

United Nations Environment Programme (UNEP) Division of Technology, Industry, and Economics (DTIE) (2004) Financial risk management instruments for renewable energy projects: summary document. http://www.unep.org/pdf/75_Risk_Management_Study.pdf. Accessed 1. Feb 2016

U.S.-Canada Power System Outage Task Force (2004) Final report on the August 14, 2003 blackout in the United States and Canada: causes and recommendations. http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/BlackoutFinal-Web.pdf. Accessed 1. Feb 2016

Veloza OP, Santamaria F (2016) Analysis of major blackouts from 2003 to 2015: classification of incidents and review of main causes. Electr J 29(7):42–49

van der Vleuten E, Lagendijk V (2010) Transnational infrastructure vulnerability: the historical shaping of the 2006 European “Blackout”. Energy Policy 38(4):2042–2052

Weisser H (2007) The security of gas supply – a critical issue for Europe? Energy Policy 35(1):1–5

Winzer C (2012) Conceptualizing energy security. Energy Policy 46:36–48

Young D, Lopez Jr. J, Rice M, Ramsey B, McTasney R (2016) A framework for incorporating insurance in critical infrastructure cyber risk strategies. Int J Crit Infrastruct Prot 14:43–57