New Insights from Behavioral Economics in Developing Countries

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ZUSAMMENFASSUNG

Es wird im Allgemeinen angenommen, dass verhaltensökonomische Eigenschaften und risikobehaftete Managemententscheidungen für die Erklärung chronischer Armut in Entwicklungsländern eine wichtige Rolle spielen. Die Literatur besagt, dass Haushalte, die in ihrem Einkommen und ihrer Vermögensausstattung begrenzt, und somit anfällig gegenüber Schocks sind, mit hoher Wahrscheinlichkeit dazu neigen, Investitionen mit geringem Risiko und geringer Rendite vorzunehmen und damit ihre Chance der Armut zu entfliehen, verfehlen. Gleichermaßen ist die Wahrscheinlichkeit gering, dass diese Haushalte auf einen Teil ihres gegenwärtigen Konsums verzichten, um diesen in langfristige Investitionen anzulegen, die sich erst zu einem zukünftigen Zeitpunkt auszahlen und ihre Lebensbedingungen verbessern könnten. Somit sind Risiko- und Zeitpräferenzen zwei wichtige verhaltensökonomische Eigenschaften, die risikobehaftete Entscheidungen beeinflussen.

Sowohl individuelle Risiko- und Zeitpräferenzen als auch Risikomanagement bilden den Kern dieser Arbeit. Ziel ist es, unser Verständnis über den Zusammenhang zwischen Präferenzen, Risikomanagement und Armut in Entwicklungsländern anhand von Daten zu ökonomischen Feldexperimenten und umfangreichen Haushaltsbefragungen aus Westafrika und Südostasien zu verbessern. Die spezifischen Ziele dieser Arbeit sind: (1) individuelle Risiko- und Zeitpräferenzen zu bewerten und deren Relation mit beobachtbaren Eigenschaften zu untersuchen, insbesondere den Zusammenhang zwischen Risikoaversion, Ungeduld und Armut; (2) die Auswirkungen von Risiko- und Zeitpräferenzen auf die Effizienz des individuellen Risikomanagements zu messen; und (3) die zeitliche Stabilität von Risikopräferenzen sowie die Auswirkungen von negativen Schocks zu analysieren.

Die ersten beiden Zielstellungen wurden anhand eines Datensatzes zu 211 Kleinbauern aus abgeschiedenen Gebieten in Mali und Burkina Faso untersucht. Der Datensatz umfasst sozioökonomische Informationen zu Viehhaltungsproduktion- und Management, die innerhalb von zwei Erhebungswellen in 2007 und 2011 gesammelt wurden. Zusätzlich

wurden in der zweiten Welle ökonomische Feldexperimente durchgeführt, um später Risiko- und Zeitpräferenzen eruieren zu können.

Zur Bearbeitung der dritten Zielstellung wurde ein umfangreicher Paneldatensatz, bestehend aus demographischen und sozioökonomischen Informationen über 2812 Familienvorständen aus ländlichen Gebieten Thailands und Vietnams, angewandt. Diese Daten wurden 2008 und 2010 erhoben. Zusätzlich wurden im Jahr 2010 Informationen zu Infrastruktur und Institutionen auf Dorfebene gesammelt. Um die Risikoeinstellung des Familienvorstandes zu messen, wurde er/sie gebeten, auf einer Skala zwischen null und zehn sein/ihr Risikoverhalten selbst einzuschätzen, wobei null "keine Bereitwilligkeit ein Risiko einzugehen" und zehn "völlige Bereitwilligkeit ein Risiko einzugehen" implizierte.

Methodisch trägt diese Arbeit zum gegenwärtigen Forschungsstand in der Verhaltensökonomie in Entwicklungsländern auf verschiedene Weise bei. Erstens findet ein Modell des "Diskontierten Nutzens" seine Anwendung, wobei die Nutzenfunktion im Sinne der "Prospect"-Theorie und die Diskontierungsfunktion als quasi-hyperbolisch spezifiziert wurde. Die Maximum-Likelihood-Schätzung des Modells bekundet empirisch den Zusammenhang zwischen Risikoaversion, Ungeduld und Armut für Kleinbauern in Westafrika – eine Region, die lange Zeit wenig Beachtung in ökonomisch-experimentellen Feldstudien gefunden hat. Zweitens wird in dieser Arbeit ein bio-ökonomisches Modell entwickelt, das das Managementverhalten der Kleinbauern, die dem Risiko ausgesetzt sind, dass ihre Rinder an einer Seuche erkranken, abbildet. Dieses Modell stellt eine Erweiterung in der ökonomischen Literatur infektiöser Krankheiten dar. Zum einen finden die Externalität der Resistenzbildung in Medikamenten, verursacht durch Fehlverhalten des Kleinbauern, und zum anderen verhaltensökonomische Parameter wie Risiko- und Zeitpräferenzen im Modell Berücksichtigung. Drittens wird die zeitliche Variation der Risikopräferenzen durch die geschätzte Variation im Konsum als exogenes Maß für Schockerfahrung erklärt. Hierbei werden mit Hilfe eines hierarchischen Modells die verschiedenen Auswirkungsebenen von Schocks berücksichtigt, nämlich idiosynkratische Schocks auf individueller Ebene und kovariate Schocks auf Makroebene.

Die Ergebnisse dieser Arbeit liefern neue Erkenntnisse in der Entwicklungs- und Verhaltensökonomie. Die simultane Schätzung der Risiko- und Zeitpräferenzen zeigt die erwarteten Ergebnisse nur teilweise. Kleinbauern aus abgeschiedenen Gebieten in Westafrika, die anfällig gegenüber zahlreichen Risiken sind, sind im Durchschnitt risikoavers und (überraschenderweise) geduldig. Im Vergleich zu Kleinbauern aus Asien scheint der durchschnittliche westafrikanische Kleinbauer risikoaverser und geduldiger zu sein. Möglicherweise ist dieses Ergebnis mit der Natur der traditionellen Rinderzucht in Westafrika verbunden. Kontrolliert man für andere beobachtbare Eigenschaften, so zeigt sich die erwartete positive Korrelation zwischen Risikoaversion, Ungeduld und Armut. Die Ergebnisse betonen, welche wichtige Rolle verhaltensökonomische Eigenschaften in der Erklärung chronischer Armut spielen und unterstreichen die Notwendigkeit ihrer Berücksichtigung in der Gestaltung von Entwicklungsinterventionen. Entwicklungsstrategien, die sich zum Beispiel in Asien als erfolgreich erwiesen haben, können nicht 1:1 in Afrika angewendet werden. Stattdessen wird ein indigener Entwicklungspfad empfohlen, der kulturelle und sozioökonomische Charakteristika der Zielgruppe bedenkt.

Im bio-ökonomischen Modell werden die eruierten Risiko- und Zeitpräferenzen zur Abbildung des Risikomanagementprozesses integriert. Die Simulationsergebnisse zeigen, dass das Risikomanagement eines risikoaversen und geduldigen Kleinbauern ineffizient ist. Die Übernahme der optimalen Managementstrategie würde Verluste in Höhe von 5% des jährlichen Einkommens eines durchschnittlichen Bauern vermeiden. Wenn es möglich wäre die Risikoaversion des Bauern zu verringern, so könnte er seine Verluste um US$130 pro Jahr reduzieren. Diese Ergebnisse implizieren die Notwendigkeit Anreize zu schaffen, die den Kleinbauern veranlassen, sein gegenwärtiges Risikomanagement zu verbessern. Zum Beispiel könnten spezielle Feldschulen dazu beitragen, Fehlverhalten in der Tierzucht zu korrigieren. Das hohe Maß an Risikoaversion ließe sich durch Versicherungen reduzieren. Somit könnte möglicherweise das Entscheidungsverhalten des Kleinbauern geändert, und damit Verluste vermieden werden.

Die Überprüfung der zeitlichen Stabilität von Risikopräferenzen anhand des Paneldatensatzes aus Thailand und Vietnam zeigt signifikante Veränderungen in der Risikoeinstellung. Die Veränderungen in der Risikoeinstellung werden durch verschiedene

Schockarten ausgelöst. Idiosynkratische Schocks verändern die Risikoeinstellung in Thailand, während kovariate Schocks die Risikoeinstellung in Vietnam beeinflussen. Eine mögliche Erklärung ist in den unterschiedlichen politischen Systemen und der damit verbundenen Ausrichtung sozialpolitischer Maßnahmen zu finden. Die Ergebnisse deuten darauf hin, dass sich Vietnamesen besser gegenüber idiosynkratischen Schocks versichern können, zum Beispiel indem sie Sicherheitsnetze bilden, in denen sie sich gegenseitig unterstützen. Allerdings sind diese Mechanismen gegenüber kovariaten Schocks weniger effektiv. In Thailand scheint die gegenseitige Unterstützung weniger gut zu funktionieren, was wiederum auf ein Problem des sozialen Zusammenhalts hinweisen könnte.

Stichworte: Armut, Risiko- und Zeitpräferenzen, Risikomanagement, Schocks, Südostasien, Westafrika

ABSTRACT

Behavioral-economic attitudes and decisions under risk are assumed to play a fundamental role in the explanation of persistent poverty in developing countries. The literature suggests that households, who are constrained in income and assets, and hence in their ability to cope with shocks, are more likely to invest in low-risk options with low returns, thereby failing to escape from poverty. In addition, poor households are less likely to forego part of their current consumption to invest in long-term investments with higher returns in the distant future that might improve their livelihoods. Therefore, risk and time preferences are two important behavioral attitudes that affect the management decisions under risk.

Individual attitudes towards risk and time and individual's risk management are the core of this thesis. Overall, it is aimed to improve our understanding of the interrelation between risk and time preferences, risk management and poverty in developing countries using data from economic field experiments and comprehensive household surveys collected in West Africa and Southeast Asia. The specific objectives are to (1) evaluate individual risk and time preferences and examine the relation between preferences and observable characteristics, in particular the relation between risk aversion, impatience and poverty; (2) assess the extent to which risk and time preferences impact the efficiency of individual management decisions under risk; and (3) analyze the temporal stability of risk preferences and the impact of adverse shocks.

The first two objectives are investigated using data from 211 small-scale cattle farmers living in remote areas of Mali and Burkina Faso. The data set consists of socio-economic information on cattle herd production and management collected during two waves in 2007 and 2011. In addition to the second survey wave, economic field experiments were conducted with the household head in order to elicit his risk and time preferences.

A comprehensive panel data set containing demographic and socio-economic information of 2812 household heads from rural areas in Thailand and Vietnam collected in 2008 and 2010 is used to address the third objective. In addition, information on village infrastructure

and institutions is available from 2010. Individual risk preferences are measured by a survey-based item on individuals' willingness to take risk. Respondents were asked to classify themselves on a scale between zero and ten, where zero indicated an "unwillingness to take risk" and ten implied "being fully prepared to take risk".

Methodologically, the thesis contributes to current research of behavioral economics in developing countries in different ways. First, a discounted utility model is applied that specifies the utility function in accordance to prospect theory and the discounting function in accordance to quasi-hyperbolic discounting. The maximum likelihood estimation of the discounted utility model provides empirical evidence on the relation between risk aversion, impatience and poverty for cattle farmers that live in risky environments in West Africa – a region that has long been unrecognized in economic experimental studies. Second, a bio-economic model is developed that portrays cattle farmers' management under the risk of a livestock disease. The model extends the economic literature on infectious diseases by the integration of the externality of drug resistance caused by farmers' mismanagement and the consideration of behavioral parameters such as farmers' risk and time preferences. Third, temporal variation in risk attitudes is explained by an exogenous measure of shocks, namely estimated variation in consumption. Hereby, multilevel modeling allows taking into account the different impact levels of shocks: idiosyncratic shocks at the individual level and covariate shocks that are correlated across individuals at the aggregate level.

The results obtained in this thesis contribute to existing knowledge and help improve on theories of development economics and behavioral economics. The simultaneous estimation of cattle farmers' risk and time preferences shows only partly the expected results. Cattle farmers from remote areas in West Africa, vulnerable to miscellaneous risks, are on average risk-averse and (surprisingly) patient. In comparison to farmers from Asia, the average West African farmer appears more risk-averse and shows longer time horizons. Possibly, this result is connected to the nature of traditional cattle farming in West Africa. Allowing for individual heterogeneity and analyzing the correlation between poverty and preferences shows the expected result, i.e. poverty is positively associated with risk

aversion and impatience. However, the findings highlight the importance of behavioral attitudes in the explanation of persistent poverty and suggest their consideration into the design of development interventions. Development strategies that were proven to be successful in Asia may not be easily transferred to Africa. Instead, pursuing indigenous development paths and considering cultural and socio-economic characteristics is recommended.

Having obtained cattle farmers' risk and time preferences, they are integrated into the bio-economic model of a livestock disease in order to portray farmers' disease management process. Simulation results show that the disease management of a risk-averse and patient farmer is not efficient. The adoption of the optimal strategy would avoid losses of approximately 5% of farmer's annual income. In addition, if the same farmer would be less risk-averse, he could reduce losses by US$130 per year. The results call for incentives that induce farmers to improve current risk management. For example, livestock field schools may reduce disease management failures and livestock insurances may lead to a reduction in farmers risk aversion, thereby increasing the efficiency of the management process.

Testing the temporal stability of risk attitudes using the panel data set from rural Thailand and Vietnam shows significant changes in risk attitudes over time. The changes in risk attitudes over time are caused by different kind of shocks. Idiosyncratic shocks alter risk attitudes in Thailand, whereas covariate shocks affect risk attitudes in Vietnam. A possible explanation is the difference in political systems and consequently the focus of socio-political measures. The results suggest that Vietnamese respondents may be better in insuring idiosyncratic risks for example through safety nets. However this mechanism is less effective to cope with correlated risks. In Thailand, mutual insurance across individuals does not seem to work well and may point to a problem of social cohesion.

Keywords: Attitudes towards risk and time, poverty, risk management, shocks, Southeast Asia, West Africa

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AAT	African Animal Trypanosomosis
ABM	Agent-Based Model
AEL	German Economic Association
CRRA	Constant Relative Risk Aversion
DFG	German Research Foundation
FAO	Food and Agriculture Organization of the United Nations
FCFA	Franc Communauté Financière Africaine
GeWiSoLa	Gesellschaft für Wirtschafts- und Sozialwissenschaften des Landbaues e.V.
HIV	Human Immunodeficiency Virus
i.e.	id est
ifw	Kiel Institute for the World Economy
ILO	International Labor Organization
IMF	International Monetary Fund
ILRI	International Livestock Research Institute
ML	Maximum-Likelihood
N	Number of Observations
N.a.	Not available
ODE	Ordinary Differential Equations
PEGNet	Poverty Reduction, Equity and Growth Network
PPP	Purchasing Power Parity
sMPL	Switching Multiple Price List
THB	Thai Baht
US$	US Dollar
VD	Vietnamese Dong
WTR	Willingness to Take Risk

1.1 Motivation

Attitudes towards risk and the ability to manage risk are assumed to be two important elements in the vicious cycle of poverty for rural households in developing countries (Mosley and Verschoor 2005). These two elements characterize a self-reinforcing mechanism that may cause poverty to persist (Azariadis and Stachurski 2005; Barrett and Carter 2013). Following Mosley and Verschoor (2005), the hypothesis of the vicious cycle of poverty can be described as follows: The poorer the household, the less means are available to cope with risks and the larger is the risk aversion. In turn, risk-averse farmers are more likely to invest in low risk and low return investments. As a consequence, abilities to manage risks further deteriorate and increase the likelihood that the farm household remains poor (Figure 1.1).

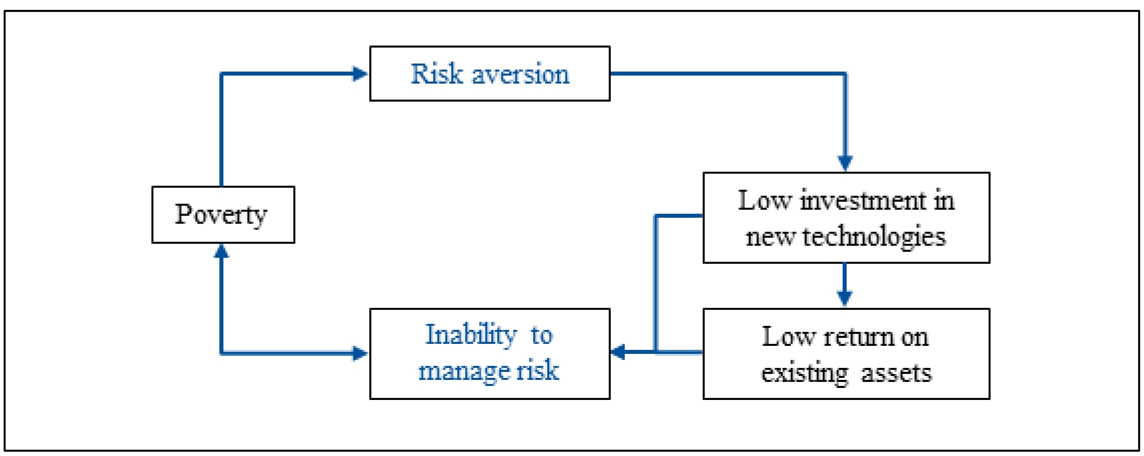

Figure 1.1 Vicious cycle of poverty

Source: Mosley and Verschoor (2005)

Empirical evidence from rural India (Rosenzweig and Binswanger 1993), West Africa (Carter 1997) and East Africa (Yesuf and Bluffstone 2009) support this hypothesis. Hence, small-scale farmers that live in risky environments without access to functioning insurance and credit markets practice a 'survival algorithm' (Lipton 1968: 337), preserving the livelihood of the household at the cost of an efficient allocation of resources, thereby perpetuating poverty (Dercon and Christiaensen 2011).

The practice of a survival algorithm does not mean to blame the poor for their own misfortune. It rather means that there are structural mechanisms that may alter individuals' risk attitudes in ways that lead to management decisions that sustain their lives in poverty (Barrett and Carter 2013). Although the temporal variability of risk attitudes is controversially discussed in the literature (e.g. Love and Robison 1984; Malmendier and Nagel 2011), Barrett and Carter (2013) suggest one mechanism, among others, that may cause risk attitudes to change, i.e. the impact of negative shocks as a key driver of poverty. For example, individuals exposed to violence in Afghanistan (Callen et al. 2014) or to a natural disaster like the tsunami in Thailand (Cassar, Healy, and Kessler 2011) were found to increase risk aversion.

Recent literature considers not only attitudes towards risk as an important behavioral parameter in poverty dynamics, but also attitudes towards time (Lybbert and McPeak 2012; Barrett and Carter 2013). Laajaj (2012) shows that pessimistic future prospects induce asset poor farmers in Mozambique to decrease their time horizons, thereby worsening future consumption and increasing their likelihood to remain poor. Voors et al. (2012) find a similar pattern, namely that individuals that experienced the civil war in Burundi have shorter time horizons than individuals that were not exposed to war. They follow that exposure to violence can hence alter savings behavior and investment decisions.

Taking into account the findings from the recent literature may suggest adding two components to the vicious cycle of poverty as described by Mosley and Verschoor (2005), namely (i) time preferences as a another important attitude that influences management decisions and (ii) shocks as one key driver of poverty and assumed to change individual preferences. The adjusted vicious cycle is illustrated in Figure 1.2.

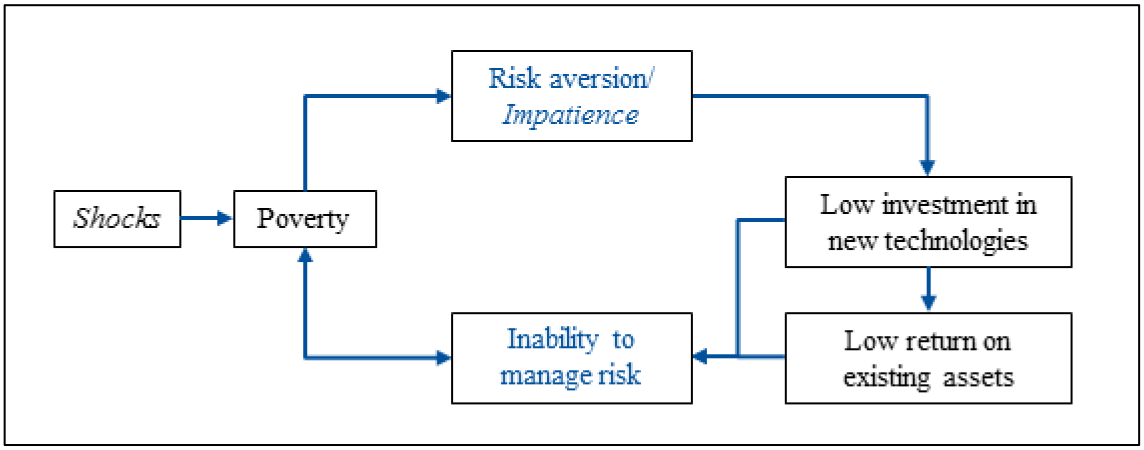

Figure 1.2 Adjusted vicious cycle of poverty

Source: Mosley and Verschoor (2005), modified

In this thesis, individual preferences, in particular attitudes towards risk and time, and individual risk management take center stage. The overall objective of the thesis is to derive new insights on the interrelation between risk and time preferences, risk management and poverty using data from economic field experiments and comprehensive household surveys conducted in West Africa and Southeast Asia. The thesis consists of three essays, each addressing a central question inside the framework described above:

Essay 1: How risk-averse and impatient are poor farmers from West Africa and how much do their preferences differ from Asian farmers?

Essay 2: Do risk and time preferences affect the efficiency of management decisions under risk and if yes, to what extent?

Essay 3: Are risk attitudes variable over time and if yes, to what extent are they affected by adverse shocks?

The main focus of each essay and their interrelationships are illustrated in Figure 1.3.

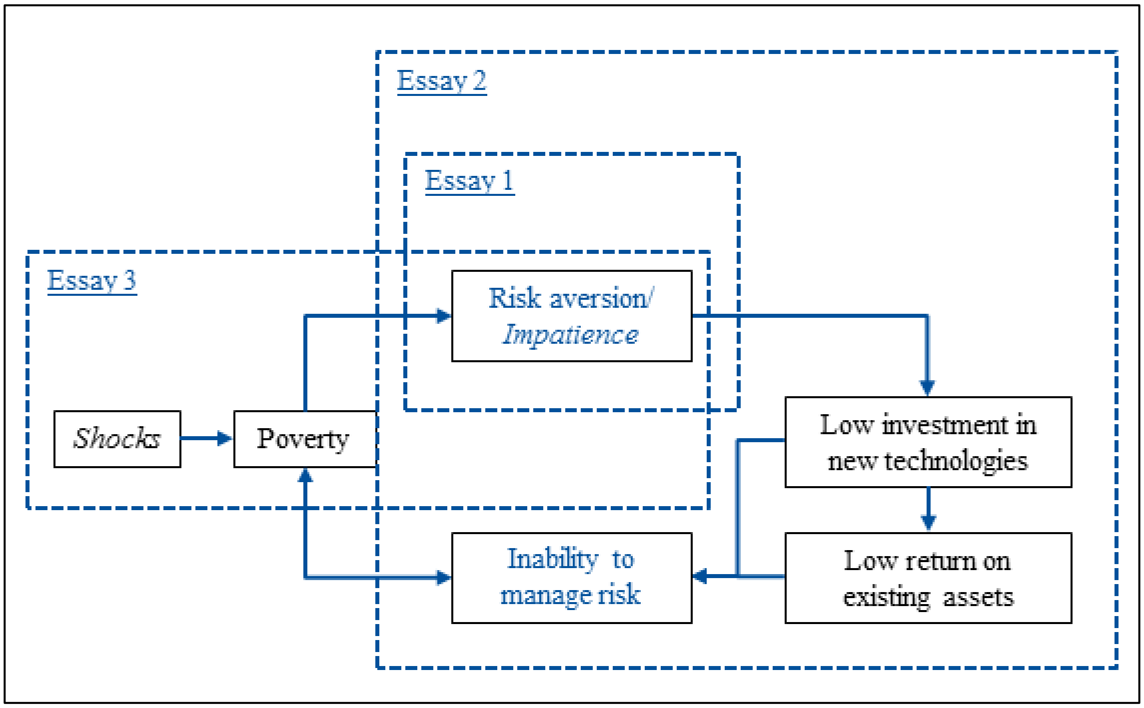

Figure 1.3 Overview and interrelation of essay topics

Source: Mosley and Verschoor (2005), modified

In the next section, the objectives of each essay are introduced in more detail, followed by a depiction of methodologies in section three. Section four describes the data sets, and section five summarizes the results. Conclusions and prospects for future research are derived in section six, and finally section seven presents the outline of the overall thesis.

1.2 Objectives

The **first essay** focuses on individual risk and time preferences of small-scale cattle farmers from remote areas in West Africa. Small cattle herds are farmers' major asset - often exposed to many kinds of negative shocks such as drought, pests or diseases. Following the literature, one would expect that these farmers, who are asset poor and living in risky environments, are risk-averse and impatient (Rosenzweig and Binswanger 1993; Yesuf and

Bluffstone 2009; Laajaj 2012). The objective of the first essay is to analyze if this expectation is true. Therefore, it is aimed to evaluate farmers' risk and time preferences and improve our understanding of the relation between preferences and individual characteristics such as low standards of living. In addition, since most studies that simultaneously measure time and risk preferences were conducted in Asia (Tanaka, Camerer, and Nguyen 2010; Nguyen 2011), the essay intends to extend existing knowledge of risk and time preferences to Africa. The specific objectives of the first essay are to:

(i) simultaneously assess both the risk and time preferences of small-scale cattle farmers in Mali and Burkina Faso;

(ii) examine how demographic and socio-economic characteristics are correlated with farmers' risk and time preferences; and

(iii) compare the findings with the results of few existing studies that were mostly conducted in Asia.

In the **second essay**, the focus is on the relation between cattle farmers' preferences and their management decision given the risk that their cattle might become infected with one of the major livestock diseases in sub-Saharan Africa (Cecchi and Mattioli 2009), namely African animal trypanosomosis (AAT). Disease management options are few and the most common are prophylactic and curative drug treatment (Holmes 1997). An additional problem is the emergence of drug resistance in AAT pathogens that arises mainly because farmers do not correctly apply drugs (Grace et al. 2009; Clausen et al. 2010).

In this essay, we develop a bio-economic model combining ecological aspects, i.e. the spread of AAT infections and the development of resistance, with economic aspects, i.e. farmers' management decision given the elicited risk and time preferences from the first essay and the resulting costs and benefits. The second essay contributes to the dearth of literature that integrates economic and ecological aspects (Ceddia et al. 2013) in two ways. First, the study considers the externality of pathogen resistance to drugs and second, it portrays the decision making process of farmers with observed individual risk and time preferences. In particular, the second essay aims to:

(i) identify the privately optimal allocation of curative and preventive drug control that minimizes the present discounted value of total disease losses from AAT;

(ii) examine if, and to what extent, losses could be avoided if farmers would reduce drug misuse; and

(iii) analyze if, and to what extent, losses could be avoided if specific circumstances would enable changes in farmers' risk and time preferences.

The **third essay** focuses on the temporal stability of risk preferences. In this respect, the literature can be divided into studies (mostly from developed countries) that confirm risk attitudes are constant over time (Vlaev, Chater, and Stewart 2009; Wölbert and Riedl 2013; Lönnqvist et al. 2014) and studies (mostly from developing countries) that show variability over time (Doss, McPeak, and Barrett 2008; Voors et al. 2012; Callen et al. 2014). The second strand of literature finds that covariate shocks such as natural disasters (Cassar, Healy, and Kessler 2011) or exposure to war (Callen et al. 2014) alter risk attitudes over time, while idiosyncratic shocks show no significant impact (Doss et al. 2008).

The objective of this essay is to test the temporal stability of risk attitudes for rural households in Southeast Asia and analyze if this 'pattern' that covariate shocks affect risk attitudes, but idiosyncratic shocks do not affect risk attitudes can be confirmed for these households. In addition, we aim to analyze the relation between risk attitudes, shocks and poverty. The contribution of this essay is to explain temporal variation in risk attitudes by using an exogenous measure of shocks in the absence of a natural experiment. In order to obtain such an exogenous measure of shocks, we follow Günther and Harttgen (2009) and estimate a multilevel model of consumption variation. In particular, the third essay intends to:

(i) investigate, if and to what extent, risk attitudes alter over time in rural Thailand and Vietnam;

(ii) analyze the impact of idiosyncratic and covariate shocks on changes in individual risk attitudes over time; and

(iii) explore whether the impact of shocks is different for poor and non-poor individuals.

1.3 Methodologies

The underlying thesis applies a number of theoretical and empirical methodologies that are shortly introduced in what follows.

In the **first essay**, we apply a discounted utility model to identify the risk and time preferences of West African cattle farmers. This model allows us to explain dynamic decision making behavior under uncertainty. As Mosley and Verschoor (2005) suggest, in order to check for the existence of the survival algorithm of poor farmers, one should go beyond the dominant economic decision theories such as expected utility theory and exponential discounting. Therefore, we specify farmers' utility function in accordance with prospect theory (Kahneman and Tversky 1979; Tversky and Kahneman 1992) to capture risk in both gain and loss situations along with respondents' weightings of probabilities. In order to identify farmers' discounting function, we use a quasi-hyperbolic specification. We simultaneously estimate the risk and time preference parameters of the discounted utility model, using the maximum likelihood technique suggested by Nguyen (2011). The corresponding maximum likelihood program was written in Stata 11.

In the **second essay**, we study cattle farmers' management decision given the risk of AAT infection in cattle. We develop a bio-economic model in which we simulate economic outputs, such as production losses, based on the epidemiological interactions among vector, host, and farmers' disease management. We apply the dynamic optimization framework provided by Gersovitz and Hammer (2005) and adjust it to our case of AAT. Both ecological and economic aspects are integrated in the model. From the ecological perspective, the spread of AAT infection and the development of drug resistance through farmers' drug misuse are considered. The economic side takes into account farmers' disease management and related costs and benefits. In order to better portray farmers' disease management the discounted utility framework from the first essay is incorporated. Hence, it is possible to reflect farmers' valuation of disease losses and their disease management behavior towards risk and time. The corresponding simulation procedure was specified as a system of ordinary differential equations (ODE) in Matlab R2013b.

The **third essay** aims to analyze if and to what extent negative shocks as a key driver of poverty lead to a temporal variation in risk attitudes. The analysis is conducted in a three-step framework. First, we exogenously measure the impact of shocks, because the use of self-reported shocks may generate biased results, since they are likely to be interrelated with risk attitudes. Therefore, we follow Günther and Harttgen (2009) and estimate variation in consumption in a multilevel model, where variation in consumption at the individual level serves as a proxy for idiosyncratic shocks and variation in consumption at the aggregate level is used as a measure for covariate shocks. Second, we use the two estimated idiosyncratic and covariate shock proxies to exogenously explain changes in individual risk attitudes over time. Third, we compare the estimated impact of shocks on risk attitudes among individuals that we categorized according to their poverty status as chronically poor, transient poor or non-poor. The multilevel analysis was conducted in Stata 13.

1.4 Data

The measurement of behavioral attitudes, the assessment of risk management strategies and the examination of interdependencies with individual and household characteristics is based on economic field experiments and socio-economic household surveys.

The data used in the **first essay** and in the **second essay** come from the project "Economics of African Animal Trypanosomosis (AAT) Management Strategies under Risk and Time Preferences" funded by the German Research Foundation (DFG WA 1002/8 - 1). We conducted a household survey in two waves, the first wave in 2007 and the second wave in 2011. The study included only households that owned cattle within the last twelve months. We collected demographic information and detailed economic data on cattle herd production such as herd structure, inputs used, outputs produced and selling prices from the household head. From the two surveys, we obtained data from 211 small-scale cattle farmers; 107 farmers living in ten villages in the circle around Sikasso in southeastern Mali and 104 farmers from five villages in the province of Kénédougou in southwestern Burkina Faso (Figure 1.4). We also obtained data on AAT prevalence and drug resistance from an epidemiological study in the same area (Clausen et al. 2010).

During the 2011 household survey, we also conducted economic field experiments to elicit farmers' risk and time preferences. The design of experiments followed Tanaka et al. (2010), calibrated to the local conditions in Mali and Burkina Faso. In the risk experiment respondents had the choice between paired lotteries; one constant lottery with a likely, but small payoff and the other lottery with an unlikely, but large payoff that was increased in every round. The time experiment was constructed as a choice between a smaller payoff promised in the near future and a larger payoff promised in the distant future. Both experiments were played with real money to assure that participants show their true preferences (Andersen et al. 2006).

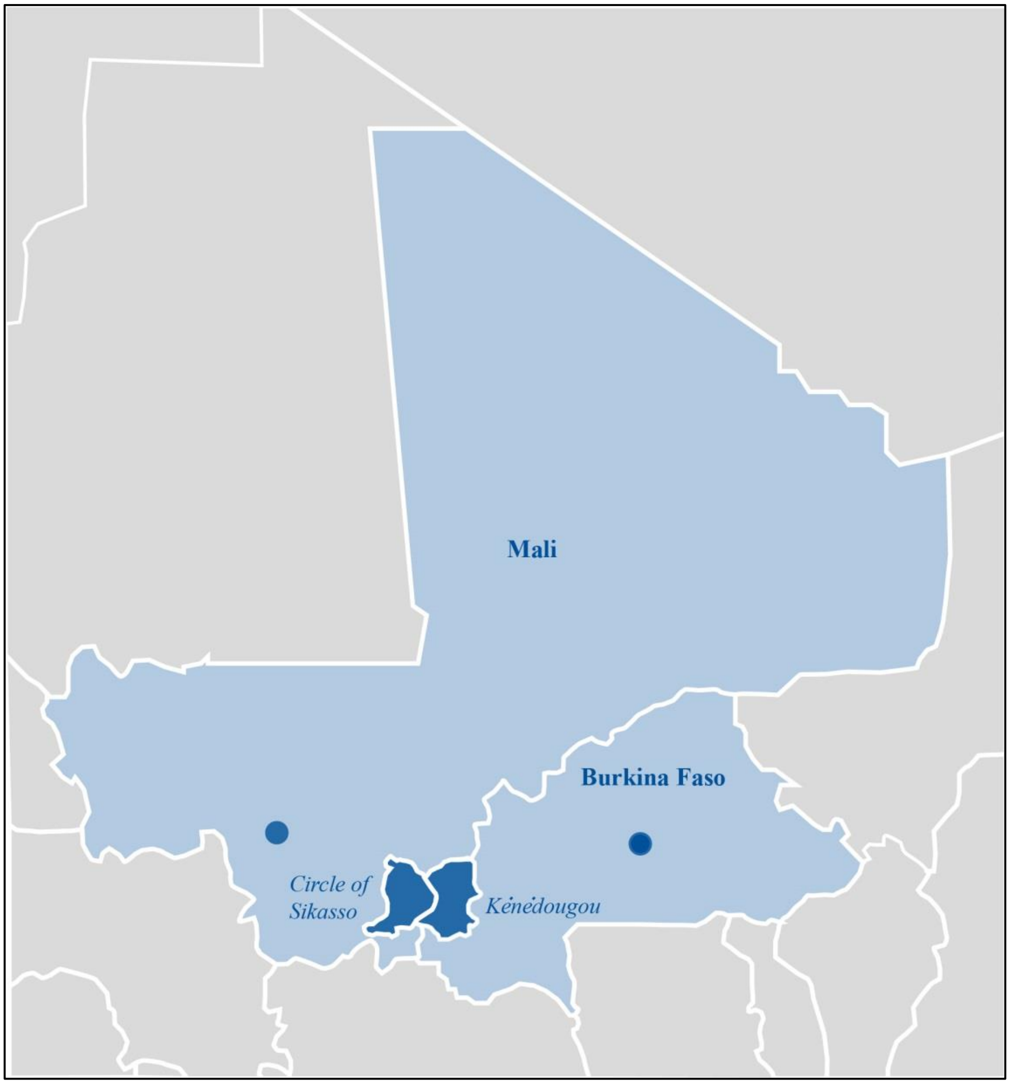

Figure 1.4 Study area in West Africa

Source: Own illustration based on Google Maps (2014)

In the **third essay** the stage changes location from Mali and Burkina Faso to Thailand and Vietnam (Figure 1.5). The data in the third essay comes from the project "Impact of Shocks on the Vulnerability to Poverty: Consequences for Development of Emerging Southeast Asian Economies", funded by the German Research Foundation (FOR 756). We use demographic and socio-economic information of 2812 heads and decision-makers of rural households in Thailand and Vietnam that were collected in 2008 and 2010. Information on income, consumption, education and health are available at the individual level and at the household level. In addition to the household survey in 2010, the village head was interviewed about infrastructure and institutions in the village. We use the information from the village head at the aggregate level in our multilevel model.

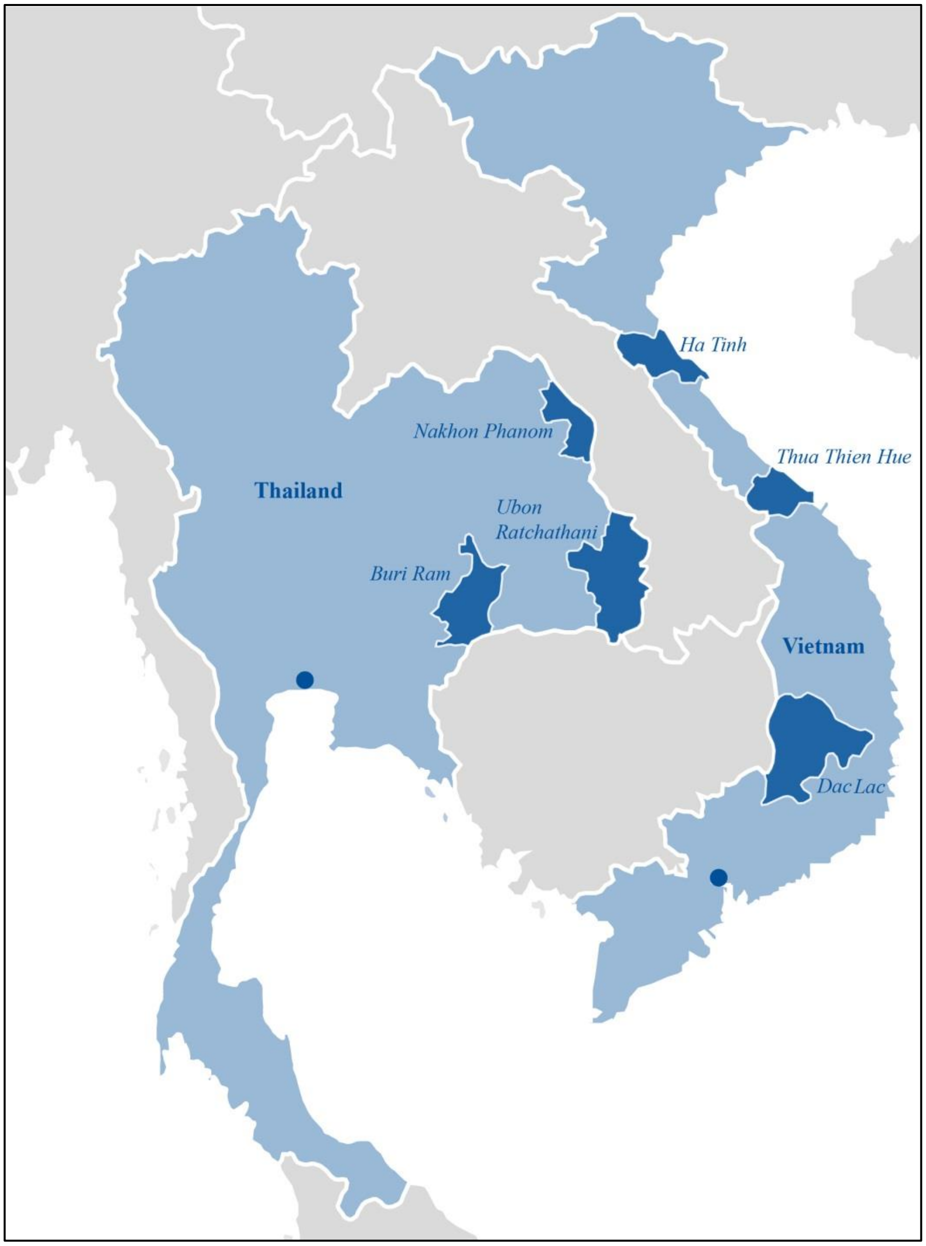

Figure 1.5 Study area in Southeast Asia
Source: Hardeweg, Klasen and Waibel (2013), modified

In order to elicit individual risk attitudes, we do not use experimental data like in the first essay, but we rely on a survey-based measure that was originally developed by Dohmen et al. (2011). In this survey-based measure respondents were asked to classify themselves on an eleven-point Likert scale, where zero indicated unwillingness to take risk and ten implied being fully prepared to take risk. Although the survey-based measure is not sufficient to reflect the shape of the utility function, several studies have shown that it can predict the outcome of an experimental measure (Hardeweg, Menkhoff, and Waibel 2013; Lönnqvist et al. 2014; Chuang and Schechter 2014).

The next section presents the results of each essay.

1.5 Results

In the **first essay** we expected the poor small-scale cattle farmers from West Africa that are exposed to numerous adverse events to be risk-averse and impatient. However, results confirm only expected risk aversion. The estimates on discount rates and present biasedness indicate longer time horizons. Furthermore, in comparison to farmers from Asia (Nguyen and Leung 2010; Tanaka et al. 2010; Liu 2013), the average West African farmer appears more risk-averse and more patient. One possible explanation is the different livelihood strategy of traditional cattle farming in West Africa; one that is a long-term and low-return investment.

Examining correlations between preferences and individual characteristics show that farmers who are more constrained in income and assets are likely to be more risk-averse and impatient. The result suggests that poverty is associated with larger risk aversion and impatience, which is consistent with other studies on risk preferences in Africa (Wik et al. 2004; Yesuf and Bluffstone 2009) and time preferences in Africa (Holden, Shiferaw, and Wik 1998; Nielsen 2001) and in Asia (Pender 1996; Tanaka et al. 2010; Nguyen 2011). This finding also provides empirical evidence on the first part of the vicious cycle of poverty-hypothesis.

The **second essay** aimed to examine the relation between cattle farmers' preferences and the efficiency of their disease management decisions. The integration of farmers' elicited risk and time preferences from the first essay into the bio-economic model of AAT shows that the disease management of the average farmer who is risk-averse and patient is not efficient. Results suggest that an efficient disease management consists of maximizing prophylaxis in order to protect animals from the risk of AAT infection supported by a small number of curative treatments for those animals where prophylaxis was not effective. Compared to observed disease management practices, a farmer that adopts the optimal strategy would avoid losses of US$125 per year – an amount that approximately corresponds to 5% of farmer's income from cattle production.

In addition, results show that a reduction in drug misuse that leads to a decrease in the incidence of resistance scales down the need for treatment, specifically the need for prophylactic treatment. The avoidance of every second treatment failure would save a farmer US$128 per year.

Results also demonstrate that a reduction in farmers' risk aversion would be associated with higher treatment rates that reduce losses and save treatment expenditures in the future. Assuming that the average farmer is risk-taking and patient, he could save approximately US$130 per year.

The **third essay** intended to test the temporal stability of risk attitudes and the relation between risk attitudes, shocks and poverty in rural areas of Thailand and Vietnam. Following the findings of studies that use long-term panel data from developing countries (Doss et al. 2008; Voors et al. 2012; Callen et al. 2014), it was expected that risk attitudes change over time through the impact of covariate shocks. Results confirm variability of risk attitudes over time in Thailand and Vietnam. However, the impact of shocks on risk attitudes is different in the two countries. In Vietnam, we find that covariate shocks increase risk aversion, whereas idiosyncratic shocks increase risk aversion in Thailand. We argue that this country-specific difference may be explained by political differences, especially with respect to differences in socio-political measures in the past.

In addition, separating the impact of shocks for poor and non-poor respondents, we find that the magnitude of the covariate shock impact is larger for poor than for non-poor respondents in Vietnam. Following the hypothesis of the vicious cycle of poverty, poor respondents may perceive the shock impact to be larger and thereby, increase their risk aversion. Results also suggest that respondents living in persistent poverty in Vietnam perform better in coping with idiosyncratic shocks possibly by supporting each other in informal safety nets (Dercon 2002; De Weerdt 2005; De Weerdt and Dercon 2006). In contrast, such safety nets seem not to function well in Thailand.

1.6 Conclusion and future research

Based on the empirical evidences on the relation between risk attitudes, risk management and poverty from West Africa and Southeast Asia we submit the following important implications for development interventions.

The main finding from the **first essay** that the average West African cattle farmer is risk-averse and patient suggests that development interventions should take into account such specific behavioral attitudes of poor people. In many cases, development projects are of short-term nature and designed to produce quick results, which does not correspond to the time horizon of cattle farmers in West Africa. In general, more attention should be focused on pursuing indigenous development paths that consider the specific cultural and socio-economic characteristics, including risk and time preferences, of the target population.

However, this conclusion is based on the estimation of a discounted utility model that we specified under prospect theory and quasi-hyperbolic discounting. Although we are able to derive more information than under the dominant theories of expected utility theory and exponential discounting, one could test the robustness of this result by a non-parametric estimation without specifying any functional form a priori (Hey and Orme 1994; Harrison and Rutström 2008).

The main finding from the **second essay** that the survival algorithm of the average West African cattle farmer in managing the risk of AAT infection is not efficient implies the need for generating incentives to optimize current risk management. For example, livestock field schools could provide special training in drug management to reduce treatment failures and the risk of drug resistance development (Grace et al. 2008). In addition, specific livestock insurance mechanisms that reduce farmers risk aversion could increase the efficiency of farmers' disease management. Other interventions might include treatment subsidies to encourage farmers to make higher investments in prophylaxis in order to reduce the probability of infection.

One could extend the current bio-economic model and test the usefulness of such interventions by implementing other scenarios. However, the current model specification as an ODE system is able to identify the efficient risk management strategy of the average farmer. Alternatively, an agent-based model (ABM) would allow the analysis of the disease management efficiency of heterogeneous agents with unique characteristics such as individual risk and time preferences (Matthews et al. 2007; Schlüter et al. 2012).

From the **third essay** we conclude that risk attitudes are not a stable function over time and we confirm the existence of a structural mechanism as suggested by Barrett and Carter (2013) that negative shocks cause risk attitudes to change. However, the country-specific differences in the kind of shocks that cause risk attitudes to change suggest that there are well-functioning mutual insurance mechanisms that enable the poor to cope with idiosyncratic shocks in Vietnam. In contrast, such mechanisms, where individuals support each other seem not to work well in Thailand. We conclude that this finding possibly indicates a lack of social cohesion in Thailand.

However, it remains unclear if the increase in risk aversion indeed translates into low risk investments with low returns as hypothesized by Mosley and Verschoor (2005). Creating a long-term panel data set that consists of three consecutive survey waves would allow investigations into what extent changes in risk attitudes over time triggered by idiosyncratic and covariate shocks lead to changes in real investment behavior.

1.7 Outline

The three essays are organized in the following three chapters. Chapter 2 contains the **first essay** “Simultaneous Estimation of Risk and Time Preferences among Small-scale Farmers in West Africa” that was published in the American Journal of Agricultural Economics in 2014. Sabine Liebenehm collected data, estimated the model and wrote the first essay, while Hermann Waibel performed the supervisory role and provided suggestions on different aspects of the manuscript.

Chapter 3 contains the **second essay** “Optimal Drug Control under Risk of Drug Resistance – The Case of African Animal Trypanosomosis” that was submitted to Journal of Agricultural Economics. In the second essay, Sabine Liebenehm collected primary and secondary data, developed the model and wrote the essay. Bernard Bett, Cristobal Verdugo and Mohamed Said advised on the set up of the model and commented on essay content.

The **third essay** titled “Changes in Risk Attitudes and Vulnerability to Idiosyncratic and Covariate Shocks – Evidence from Panel Household Data in Thailand and Vietnam” is organized in Chapter 4. A former version of this essay has been presented at the PEGNet Conference and at the AEL Conference in 2014. Sabine Liebenehm used the DFG FOR 756 data of Thailand and Vietnam from 2008 and 2010, estimated the multilevel model and wrote the manuscript. Lukas Menkhoff and Hermann Waibel took a supervisory role and provided suggestions on different aspects. Table 1.1 provides an overview of the history of the manuscripts.

Table 1.1 Overview of essays

	Title	Authors	Presented/ Submitted/ Published
Chapter 2	Simultaneous Estimation of Risk and Time Preferences among Small-scale Farmers in West Africa	S. Liebenehm and H. Waibel	Published in: *American Journal of Agricultural Economics* 2014, 96(5): 1420- 1438 Earlier versions presented at: GeWiSoLa Conference 2013, September 25-27, Berlin, Germany PEGNet Conference 2011, September 07-09, Hamburg, Germany
Chapter 3	Optimal Drug Control under Risk of Drug Resistance – The Case of African Animal Trypanosomosis	S. Liebenehm; B. Bett; C. Verdugo and M. Said	Submitted to: *Journal of Agricultural Economics* 2015
Chapter 4	Changes in Risk Attitudes and Vulnerability to Idiosyncratic and Covariate Shocks – Evidence from Panel Household Data in Thailand and Vietnam	S. Liebenehm; H. Waibel and L. Menkhoff	Presented at: PEGNet Conference 2014; September 18-19, Lusaka, Zambia AEL Verein für Socialpolitik Conference 2014; June 27-28, Passau, Germany

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CHAPTER 2: SIMULTANEOUS ESTIMATION OF RISK AND TIME PREFERENCES AMONG SMALL-SCALE CATTLE FARMERS IN WEST AFRICA

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CHAPTER 3: OPTIMAL DRUG CONTROL UNDER RISK OF DRUG RESISTANCE – THE CASE OF AFRICAN ANIMAL TRYPANOSOMOSIS

This chapter is an extended version of

Liebenehm, S., B. Bett, C. Verdugo and M. Said. "Optimal Drug Control under Risk of Drug Resistance Development – the Case of African Animal Trypanosomosis in West Africa"

Submitted to *Journal of Agricultural Economics*

Abstract

In this paper, we examine two widely used treatment strategies for African animal trypanosomosis (AAT) in West Africa, namely, preventive drug control *ex ante* AAT infection and curative drug control *ex post* AAT infection, to investigate which combination of these alternative strategies is economically optimal for cattle farmers.

We develop a bio-economic model to simulate the economic consequences of treatment strategies in a dynamic scenario that takes into account the interactions among vector, host, and livestock farmers. In this model, we allow for the evolution of drug-resistant trypanosomes through trypanocide misuse and aim to simulate the observed behavior of cattle farmers by including the elicited risk and time preferences of a sample of 202 cattle farmers in Mali and Burkina Faso.

The results show that the private optimal mix of treatment strategies involves preventive treatment until a maximum number of susceptible cattle are protected from the risk of AAT infection. In addition, preventive treatment must be supported by a small number of curative treatments for infected cattle. Compared to treatment strategies observed in the field, this optimal mix of treatment strategies would save 5% of the annual income of a

livestock farmer in the study areas. We also demonstrate that the improvement of AAT treatment practices reduces the prevalence of AAT and saves approximately US$128 per farmer. Finally, we show that farmer's risk aversion behavior costs him approximately US$130.

Keywords: African animal trypanosomosis, bio-economic model, risk preference, time preference, West Africa.

3.1 Introduction

The link between economics and epidemiology offers considerable potential to improve our understanding how infectious diseases evolve and spread (Gersovitz and Hammer 2003). On the one hand, epidemiology provides dynamic mathematical models that can describe how diseases are transmitted either between hosts or between vectors and hosts. Economics, on the other hand, can assess the costs and benefits of disease interventions by considering the externalities and behavioral aspects of decision making and can thus help to allocate scarce resources.

The economic literature on infectious diseases is nevertheless in its infancy (Gersovitz and Hammer 2004; Klein et al. 2007; Ceddia et al. 2013). Previous studies focus either on one specific disease, i.e., HIV/Aids (Geoffard and Philipson 1996; Kremer 1996; Lakdawalla, Sood, and Goldman 2006), or on one specific treatment, i.e., vaccination (Brito, Sheshinski, and Intriligator 1991; Geoffard and Philipson 1997; Francis 1997; 2004; Barrett and Hoel 2007; Houy 2013). However, most studies do not consider externalities, and they insufficiently model behavioral aspects.

One exception is Gersovitz and Hammer (2004), which is among the first studies to explicitly consider two types of externalities, i.e., (i) the spread of infections through infectious hosts and (ii) treatment actions of one agent that affect the probability of other agents becoming infected.

This paper contributes to this body of literature in two ways. First, we consider the externality of pathogen resistance to both therapeutic and prophylactic drugs. Second, to reflect the decision making of farmers, we incorporate a discounted utility function for optimizing treatment strategies with observed individual risk and time preferences.

In particular, we aim to investigate the optimal control of tsetse-transmitted African animal trypanosomosis (AAT) in cattle from an individual livestock farmer's point of view. Cattle farmers' major control strategy for AAT is the application of drugs, namely, trypanocides, as either a preventive or a curative treatment. Trypanocides are commonly available to farmers living in remote areas and, at approximately US$1 per treated animal, are generally affordable (McDermott and Coleman 2001). However, frequent cases of misuse cause resistance in pathogens to trypanocides and reduce their effectiveness (Grace et al. 2009; Clausen et al. 2010). Therefore, our research aims to identify the optimal allocation of curative and preventive drug treatment given the potential for drug-resistant trypanosomes.

To answer this research question, we develop a bio-economic model in which we simulate economic outputs, such as production losses, based on the epidemiological interactions among vector, host, and treatment regimen. In so doing, we allow for the evolution of resistance through trypanocide misuse. In addition, we incorporate a discounted utility function to consider the individual valuation of disease losses and the resulting behavior toward risk and time. The simulation is based on socio-economic and epidemiological data on 202 cattle-dependent small-scale farmers in West Africa. We aim to identify the privately optimal allocation of curative and preventive drug control that minimizes the present discounted value of total disease losses from AAT.

In the next section, we introduce the impact of AAT in West Africa and the study region. In section three, we describe the bio-economic model, which is followed by a detailed model specification. In section five, we discuss the main findings. Finally, in section six, we draw conclusions and provide policy recommendations.

3.2 African animal trypanosomosis in West Africa

AAT has been considered one of the most important constraints to livestock and crop-livestock production in sub-Saharan Africa (Kristjanson et al. 1999). Estimated total losses from AAT are in the range of US$1.3-4.5 billion annually, depending on whether direct or indirect impacts are considered (Swallow 2000). Further, AAT reduces physical outputs such as milk offtake and draft power by up to 40%. Thus, in a country that is largely affected by AAT, total agricultural production is reduced by up to 10% (Agyemang et al. 1991; McDermott and Coleman 2001).

Disease management strategies for AAT in cattle include (i) the application of trypanocidal drugs to control the parasites (trypanosomes); (ii) the control of the vector of the disease, namely, the tsetse fly, by spraying insecticides or by utilizing screens and fly traps that are more environmentally friendly; and (iii) the breeding of trypanotolerant cattle breeds, such as the N'Dama or Baoulé, which are able to ward off the infection to some degree (Holmes 1997).

The application of trypanocidal drugs is the only strategy that is widely applied by individual farmers because the drugs are commonly available and, at approximately US$1 per treated animal, generally affordable (McDermott and Coleman 2001). The drugs can be applied either as a curative treatment *ex post* AAT infection once symptoms are observed or as a preventive measure *ex ante* AAT infection on a regular basis.

However, farmers lack knowledge about the correct use of drugs. For example, farmers incorrectly dilute the drugs with water, disregard the bodyweight of the animal in administering the drugs, or inject the drugs in the wrong place. In other cases, farmers use expired or poorly stored drugs, which are less effective. Such misuse of trypanocides has led to the widespread development of drug-resistant AAT parasites (Grace et al. 2009; Clausen et al. 2010).

In this paper, we study AAT treatment strategies in West Africa, particularly in southeastern Mali and southwestern Burkina Faso, where the prevalence of AAT and trypanocide resistance is high (Clausen et al. 2010).

Both epidemiological and socio-economic data are available for this area and will be used in our bio-economic model.

The data come from a multi-disciplinary research project led by the International Livestock Research Institute (ILRI) to ensure the future efficacy of trypanocides as one component of integrated AAT control. Within this project, epidemiologists assessed the prevalence of AAT and identified specific “hot spots” of drug resistance (Clausen et al. 2010). Economists simultaneously collected demographic and socio-economic data on cattle farmers to understand how AAT and trypanocide resistance are managed (Liebenehm, Affognon, and Waibel 2011a; Liebenehm, Affognon, and Waibel 2011b).

In addition, economists re-visited the study site in 2011 and conducted a socio-economic survey of a random sub-sample of farmers. In particular, the survey aimed to improve the understanding of farmer decision-making behavior. Therefore, economic field experiments were conducted to identify farmers’ subjective probabilities of AAT and trypanocide resistance and to elicit farmers’ preferences regarding risk and time (Liebenehm and Waibel 2014).

We calibrate our bio-economic model with observed data from 202 small-scale cattle farmers collected over the course of the inter-disciplinary research project from 2002 to 2007 and the follow-up project in 2011. Table 3.1 presents an overview of the observed statistics.

Table 3.1 Descriptive statistics

	Value	Standard deviation	Source
Epidemiological data			
Mean prevalence of AAT	0.664	0.473	Epidemiological survey 2002-2007
Mean prevalence of trypanocide resistance	0.707	0.458	
Socio-economic data			
General			
Total number of cattle	4027		Socio-economic survey 2011
Total number of cattle affected by AAT	843		
Total number of cattle affected by AAT with no response to treatment	219		
Total number of cattle that died from AAT	71		
AAT disease management			
Percentage of farmers that administer drugs	51.485		Socio-economic survey 2007
Percentage of farmers that apply *curative* drugs	76.289		
Percentage of farmers that apply *preventive* drugs	28.767		
Percentage of farmers that report treatment failure with *curative* drugs	18.421		
Percentage of farmers that report treatment failure with *preventive* drugs	27.273		
Behavioral attitudes			
Mean estimated risk aversion	0.112	0.006	Socio-economic survey 2011
Mean estimated loss aversion	1.351	0.262	
Mean estimated time preference	0.001	0.0001	
Mean subjective probability of AAT infection	28.962	10.48	
Mean subjective probability of sensitive AAT infection	16.644	7.868	
Mean subjective probability of resistant AAT infection	12.464	6.091	

Note: N = 202.

The epidemiological statistics indicate that 66% of farmers live in an area in which AAT is prevalent and that 70% of farmers live in an area in which resistance to trypanocides is evident.

Furthermore, from the recent socio-economic survey, we know that the 202 surveyed farmers possessed 4027 cattle in total. On average, each farmer kept 20 animals, which is below the average of 38 heads in sub-Saharan countries (Otte and Chilonda 2002). The farmers reported that approximately 20% of cattle were infected with AAT and that every fourth infected animal did not effectively respond to trypanocidal treatment. In other words, 25% of the infected animals showed signs of trypanocide resistance. However, the fatality rate was less than 10%.

In addition, the AAT management statistics indicate that every second farmer treated his animals without veterinary support. Further, approximately 75% of the farmers administered curative drugs upon the emergence of disease symptoms, whereas approximately 30% applied preventive drugs. Although preventive treatment is relatively low, the reported treatment failure rate is almost 10% higher than the curative treatment failure rate. One explanation for this result might be that preventive treatment strategies involve frequent application of the drugs at fixed intervals, which increases the potential for misuse or misapplication.

Finally, the average estimated risk and time preferences indicate that the farmers were risk-averse and that they had relatively low discount rates (Liebenehm and Waibel 2014). On average, the farmers assumed that the probability that their animals would be infected with AAT is approximately 30%, whereas the joint probability of a sensitive infection was 16.64%, and the joint probability of a resistant infection was 12.5%.

Some of the observed statistics will serve as inputs for the bio-economic model, which will be introduced in the following section.

3.3 A bio-economic model of African animal trypanosomosis

We use bio-economic modeling to analyze optimal drug control of AAT under the risk of drug resistance development. Figure 3.1 illustrates our bio-economic model, which consists of (i) a biological component that simulates the transmission of the disease and the impact of curative and preventive treatment intervention while allowing for the evolution of drug resistance and (ii) an economic component that identifies the optimal allocation of curative and preventive treatments that minimizes the value of total losses from AAT. In the following, we detail the two model components.

3.3.1 Biological component

The first component (Figure 3.1a), i.e., the biological-epidemiological component, simulates the transmission of AAT from vector to host, and vice versa, and the impact of two alternative drug treatment strategies.

Rogers (1988) and Milligan and Baker (1988) develop mathematical models of tsetse-transmitted trypanosomosis, where the transmission of trypanosomosis is a function of the tsetse feeding rate, proportion of infected tsetse, tsetse-host ratio, and probability of an infective bite causing infection in the host. In addition, they assume constant populations and consider multiple host tsetse and trypanosome species. Milligan and Baker (1988) specify a *SEIR* compartmental model, where the host population is differentiated by health states. For example, a healthy animal moves from the susceptible state (S) to the exposed state (E) if it is bitten by an infected fly. After incubation, the host moves to the infectious state (I), and finally, through natural recovery, the infection is cleared, and the removed state is reached (R).

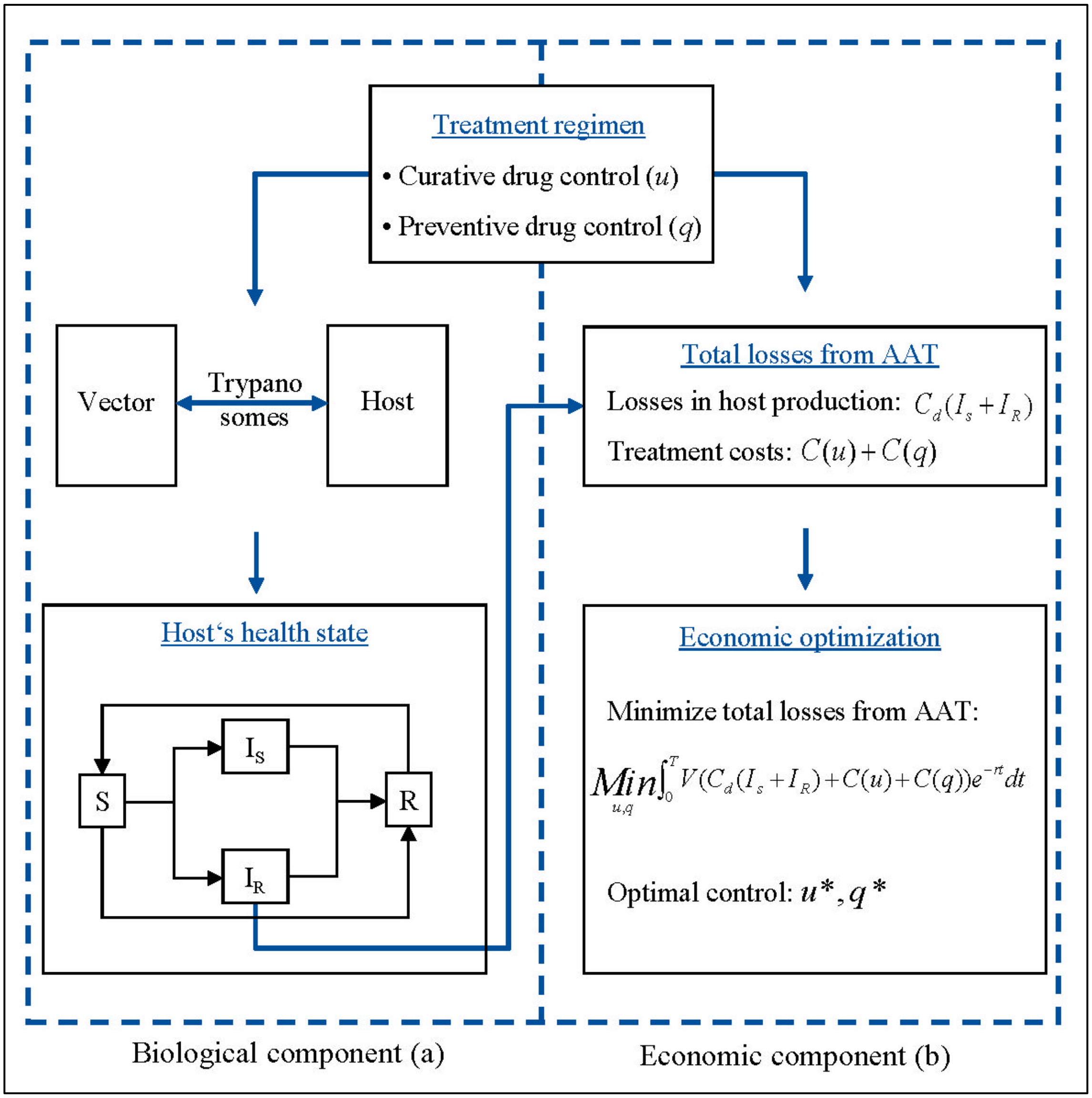

Figure 3.1 Bio-economic model of AAT control

Source: Own illustration

In this study, we adopt the modeling strategy developed by Milligan and Baker (1988). As in their paper, we assume constant host and vector populations and therefore set death rates equal to birth rates.

However, we make the following adjustments. We simplify the model and consider only one host species (domestic cattle), one tsetse species (G. m. morsitans), and one trypanosome species (T. congolense). Further, we ignore the exposed state and allow individual cattle to move between susceptible (*S*), infected (*I*), and removed (*R*) classes in the host population and between susceptible (S_V) and infected (I_V) classes in the tsetse population.[1] We extend the Milligan and Baker (1988) model by allowing for the development of drug resistance through treatment failure. Figure 3.2 illustrates the basic specification of the AAT model.

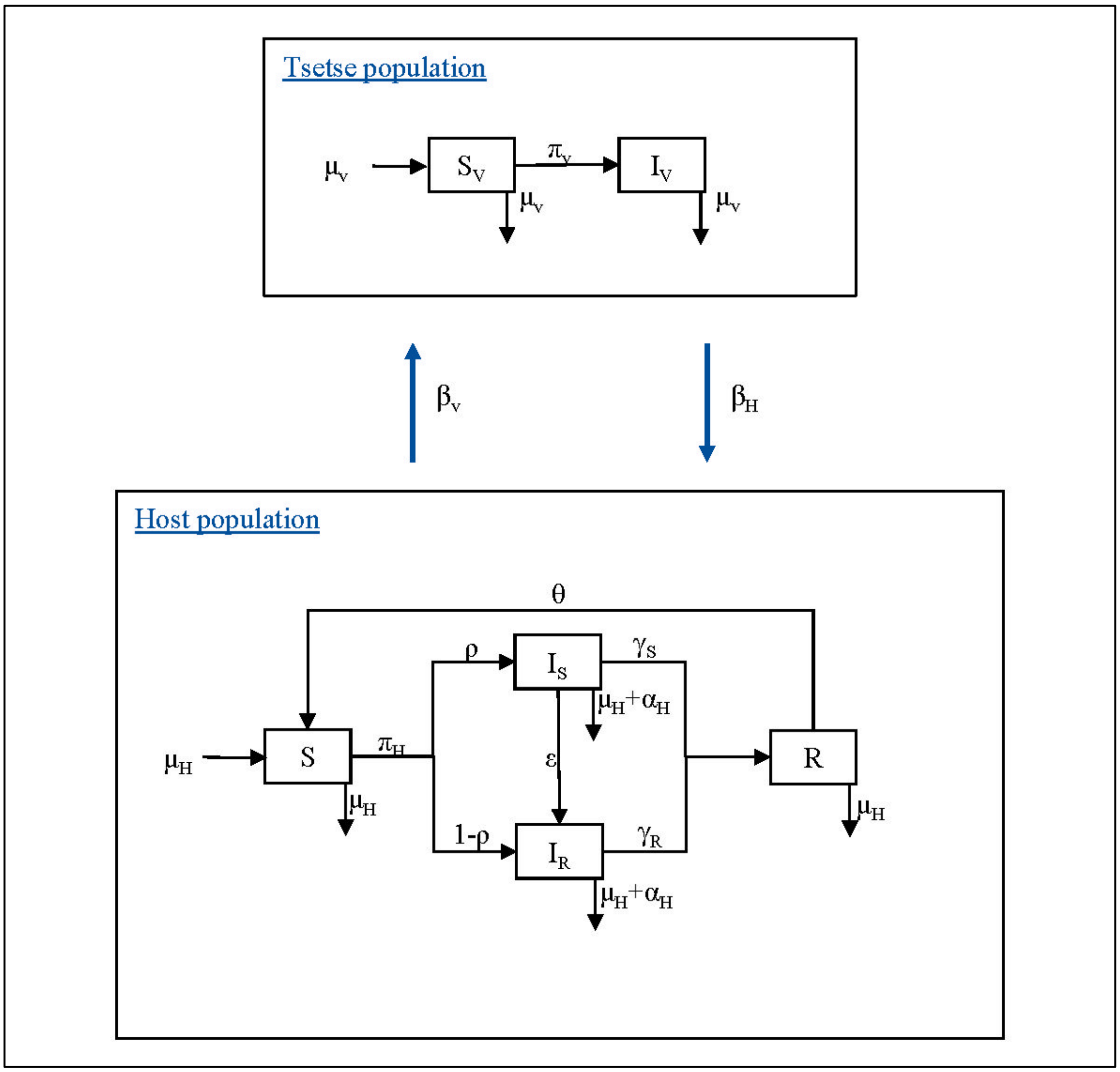

Figure 3.2 Schematic illustration of basic AAT model without treatment

Source: Own illustration

[1] For all variables with subscript $_H$ and $_V$, let subscript H = host and subscript V = vector.

To incorporate the possibility of drug resistance development into the model, we divide the infected host population (I) into animals infected with drug-sensitive AAT strains (I_S) and animals infected with drug-resistant AAT strains (I_R). We let a proportion ϕ of hosts be infected with drug-sensitive AAT strains and (1-ϕ) hosts be infected with drug-resistant AAT strains. In addition, we allow for drug resistance development due to a treatment failure at rate ε. We assume that an incorrect administration of the drug by a cattle farmer reduces the effectiveness of the drug and causes the AAT pathogen to become drug resistant. Because of drug misuse, hosts infected with drug-sensitive AAT strains, for which treatment should have been effective, progress to a resistant infection class (I_R), where treatment is no longer effective (Tumwiine, Hove-Musekwa, and Nyabadza 2014).

The transmission of AAT is caused by an interaction between vectors and hosts. Susceptible hosts (S) are infected by infected tsetse (I_V) at the force of infection in hosts (β_H):

(1) $$\beta_H = \delta \pi_H S I_V / N_H ,$$

where δ is the daily biting rate of tsetse, π_H indicates the probability that an infected bite infects susceptible host, and N_H is the total host population ($N_H=S+I_S+I_R+R$). Infected hosts either die from AAT at a death rate α_H or naturally lose parasitaemia at a constant rate γ. In the latter case, the host develops some temporary immunity against AAT, and infected hosts move to the removed class (R). As drug-resistant trypanosomes are likely to be less fit than their non-drug-resistant counterparts, we assume that drug-resistant infections are cleared at a faster rate than sensitive infections (Van den Bossche et al. 2006). However, as cattle infected with drug-resistant strains are unable to be treated, they are more likely to die than cattle infected with drug-sensitive strains. Finally, temporary immunity decreases by a rate θ, and immune hosts again become susceptible to AAT.

Susceptible tsetse flies (S_V) become infected by biting an infected host that is infected with either a sensitive or a resistant AAT strain (I_S+I_R). We specify the force of infection in tsetse (β_V) as follows:

(2) $\beta_V = \delta\pi_V S_V (I_S + I_R) / N_H$,

where π_V indicates the probability that a bite infects susceptible tsetse. We further assume that once flies are infected, they remain infected (Milligan and Baker 1988).

Having defined our basic model of AAT transmission, we incorporate curative and preventive drug treatment in a next step.

In general, we assume that curative treatment is administered only to AAT-infected animals and that only susceptible animals are treated with preventive drugs. In both cases, we allow resistance to evolve through inappropriate use of drugs. In particular, we make the following adjustments to our basic model.

First, we distinguish between the possibilities of resistance development to curative drugs and resistance development to preventive drugs. Therefore, we split the host population that is infected with drug-resistant AAT strains (I_R) into a population of animals that are infected with AAT strains that are resistant to curative drugs (I_{Ru}) and a population of animals that are infected with AAT strains that are resistant to preventive drugs (I_{Rq}). The parameter ϕ is adjusted accordingly, i.e., a fraction ϕ_1 of hosts are infected with drug-sensitive AAT strains, ϕ_2 hosts are infected with curative drug-resistant AAT strains, and (1-ϕ_1- ϕ_2) hosts are infected with preventive drug-resistant AAT strains.

In the case of curative drug treatment, we assume that the drug that is administered to infected animals clears the drug-sensitive AAT infection at rate u and that these animals return to the susceptible class (S). If the curative drug is incorrectly applied to infected cattle (at treatment failure rate ε_u), the treatment is ineffective, and animals progress to the curative drug-resistant infection class (I_{Ru}) (Tumwiine et al. 2014).

Second, to analyze the effect of preventive drug treatment, we incorporate an additional class into our host population model, i.e., the class of hosts under prophylaxis prevention

(P). Preventive drugs administered to susceptible animals at rate q prevent AAT infection in these animals, and these animals progress to the prevented class (P). However, prophylaxis treatment does not guarantee the prevention of AAT infection but offers a degree of protection indicated by the parameter ψ. The degree of protection varies between 0 and 1, where $\psi=0$ suggests no protection and treated animals return to the susceptible class and $\psi=1$ implies full protection. Additionally, the effect of protection diminishes over time at rate χ, and infection can no longer be prevented (Milligan and Baker 1988; Nyabadza 2008). We further assume that the misuse of prophylactic treatment reduces the degree of protection and causes infection in the host. Therefore, AAT pathogens develop resistance and mistreated animals move from the sensitive infection class (I_S) to the preventive drug-resistant infection class (I_{Rq}) at rate ε_q.

Based on the specifications of AAT transmission and treatments described above, we can derive the following coupled system of nonlinear differential equations for hosts:

(3) $$\frac{\partial S(t)}{\partial t} = \mu N + \theta R + \chi P + uI_S - \frac{\delta\pi_H S I_V}{N_H} - (q + \mu_H)S$$

(4) $$\frac{\partial P(t)}{\partial t} = qS - \frac{(1-\psi)\delta\pi_H P I_V}{N_H} - (\chi + \mu_H)P$$

(5) $$\frac{\partial I_S(t)}{\partial t} = \frac{\phi_1\delta\pi_H S I_V}{N_H} + \frac{\phi_1(1-\psi)\delta\pi_H P I_V}{N_H} - (u + \gamma_S + \mu_H + \alpha)I_S - \frac{\varepsilon_u\phi_1\delta\pi_H S I_V}{N_H} - \frac{\varepsilon_q\phi_1(1-\psi)\delta\pi_H P I_V}{N_H}$$

(6) $$\frac{\partial I_{Ru}(t)}{\partial t} = \frac{(1-\phi_1-\phi_3)\delta\pi_H S I_V}{N_H} - (\gamma_R + \mu_H + \alpha)I_{Ru} + \frac{\varepsilon_u\phi_1\delta\pi_H S I_V}{N_H}$$

(7) $$\frac{\partial I_{Rq}(t)}{\partial t} = \frac{(1-\phi_1-\phi_2)\delta\pi_H S I_V}{N_H} + \frac{(1-\phi_1-\phi_2)(1-\psi)\delta\pi_H P I_V}{N_H} - (\gamma_R + \mu_H + \alpha)I_{Rq} + \frac{\varepsilon_q\phi_1(1-\psi)\delta\pi_H P I_V}{N_H}$$

(8) $$\frac{\partial R(t)}{\partial t} = \gamma_S I_S + \gamma_R(I_{Ru} + I_{Rq}) - (\theta + \mu_H)R$$

and the following system of nonlinear differential equations for vectors:

(9) $$\frac{\partial S_V(t)}{\partial t} = \mu_V N_V - \frac{\delta\pi_V S_V (I_S + I_{Ru} + I_{Rq})}{N_H} - \mu_V S_V$$

(10) $$\frac{\partial I_V(t)}{\partial t} = \frac{\delta\pi_V S_V (I_S + I_{Ru} + I_{Rq})}{N_H} - \mu_V I_V \, .$$

Table 3.2 presents all the baseline values of the parameters specified in the biological component of our bio-economic model.

Table 3.2 Parameters and baseline values used in the biological component

Parameter	Description	Value	Reference
Host: Domestic cattle			
π_H	Probability that a bite infects susceptible hosts	0.025	McDermott and Coleman (2001)
ϕ_1	Fraction infected with sensitive strains	variable	Own survey (2011)
ϕ_2	Fraction infected with curative drug-resistant strains	variable	Own survey (2011)
γ_S	Rate at which hosts infected with sensitive strains acquire immunity	1/100	Rogers (1988)
γ_R	Rate at which hosts infected with resistant strains acquire immunity	$\gamma_S < \gamma_R$	Van den Bossche et al. (2006)
θ	Rate of loss of immunity	1/100	Rogers (1988)
μ_H	Natural death rate	0.0005	Milligan and Baker (1988)
α_H	Death rate due to AAT	0.002	Milligan and Baker (1988)
Vector: Tsetse (G. m. morsitans)			
π_V	Probability that a bite infects susceptible tsetse	0.46	McDermott and Coleman (2001)
δ	Feeding rate	1/3	Hargrove (2003)
μ_V	Natural death rate	0.03	Rogers (1988); Milligan and Baker (1988)
Treatment			
ε_u	Rate of evolution of drug resistance due to *curative* drug misuse	variable	Own survey (2011)
ε_q	Rate of evolution of drug resistance due to *preventive* drug misuse	variable	Own survey (2011)
ψ	Degree of protection	$0 \leq \psi \leq 1$	Nyabadza (2008)
χ	Rate of loss of prophylaxis	0.017	Milligan and Baker (1988)

To complete our bio-economic model, we include the economic component as described in the next section.

3.3.2 Economic component

The economic component (Figure 3.1b) identifies the economically optimal allocation of curative and preventive treatment of AAT. Gersovitz and Hammer (2005) provide an economic framework for the optimal implementation of therapeutic and prophylactic treatment of vector-borne diseases. We use their framework and adjust it to our case of AAT.

We aim to identify the optimal treatment allocation that minimizes the present discounted value of total losses from AAT. McInerney (1996) suggests that total losses from livestock diseases, such as AAT, include losses in the production system that arise from the direct effects of the disease (e.g., reduction in output production, death of animals) and expenditures for disease control and prevention.

In the case of AAT in cattle, we define losses in terms of forgone milk and meat production and consider expenditures for curative and preventive drug control against AAT. We obtain the following objective function:

$$\text{(11)} \quad \begin{aligned} &\underset{u,q}{Min} \quad v(L) = \int_0^T \left[v(A(I_S + I_{Ru} + I_{Rq}) + bu^2 + cq^2)e^{-rt} \right] dt, \\ &0 \le u(t) \le 0.9 \\ &0 \le q(t) \le 0.9. \end{aligned}$$

To achieve the private minimum of the present discounted value (*v)* of total losses (*L)* from AAT subject to the underlying disease dynamics specified in equations (3) – (10), we apply cumulative prospect theory to define a utility function for losses as follows:

$$\text{(12)} \quad v(L) = \omega(L)^{\sigma},$$

where the parameter ω reflects the degree of loss aversion and the parameter σ can be interpreted as a proxy for risk aversion (Tversky and Kahneman 1992). In addition, the parameter A reflects the current money costs of being infected with either type of infection (I_s, I_{Ru} or I_{Rq}), b and c are the respective prices of curative treatment rate u and preventive treatment rate q, and r is the rate of time preference. Both treatment rates are quadratic terms to reflect nonlinear treatment behavior and are bounded to a maximum of 90% animal coverage (Lenhart and Workman 2007; Brown and White 2011).

To minimize the present discounted value of total losses from AAT, we derive the current-value Hamiltonian, H_c, which consists of the current-value of losses and the change in losses that depend on changes in state variables over time valued at respective shadow prices λ. We can write the current-value Hamiltonian as follows:

$$
\begin{aligned}
H_c &= A(I_S + I_{Ru} + I_{Rq}) + bu^2 + cq^2 \\
&+ \lambda_1\left[\mu N + \theta R + \chi P + uI_S - \frac{\delta\pi_H SI_V}{N_H} - (q+\mu_H)S\right] \\
&+ \lambda_2\left[qS - \frac{(1-\psi)\delta\pi_H PI_V}{N_H} - \chi P - \mu_H P\right] \\
&+ \lambda_3\left[\frac{\phi_1\delta\pi_H SI_V}{N_H} + \frac{\phi_1(1-\psi)\delta\pi_H PI_V}{N_H} - (u+\gamma_S+\mu_H+\alpha)I_S - \frac{\varepsilon_u\phi_1\delta\pi_H SI_V}{N_H} - \frac{\varepsilon_q\phi_1(1-\psi)\delta\pi_H PI_V}{N_H}\right] \\
&+ \lambda_4\left[\frac{(1-\phi_1-\phi_3)\delta\pi_H SI_V}{N_H} - (\gamma_R+\mu_H+\alpha)I_{RU} + \frac{\varepsilon_u\phi_1\delta\pi_H SI_V}{N_H}\right] \\
&+ \lambda_5\left[\frac{(1-\phi_1-\phi_2)\delta\pi_H SI_V}{N_H} + \frac{(1-\phi_1-\phi_2)(1-\psi)\delta\pi_H PI_V}{N_H} - (\gamma_R+\mu_H+\alpha)I_{RQ} + \frac{\varepsilon_q\phi_1(1-\psi)\delta\pi_H PI_V}{N_H}\right] \\
&+ \lambda_6\left[\gamma_S I_S + \gamma_R(I_{Ru}+I_{Rq}) - (\theta+\mu_H)R\right] \\
&+ \lambda_7\left[\mu_V N_V - \frac{\delta\pi_V S_V(I_S+I_{Ru}+I_{Rq})}{N_H} - \mu_V S_V\right] \\
&+ \lambda_8\left[\frac{\delta\pi_V S_V(I_S+I_{Ru}+I_{Rq})}{N_H} - \mu_V I_V\right].
\end{aligned} \tag{13}
$$

From the Hamiltonian, we derive the following necessary conditions for an optimal control allocation that minimizes total losses from AAT:

(14) $\frac{\partial H_c}{\partial u} = 0 \to u^*(t) = \frac{I_S(\lambda_3-\lambda_1)}{v'2b}$ for curative drugs and

(15) $\frac{\partial H_c}{\partial q} = 0 \to q^*(t) = \frac{S(\lambda_1-\lambda_2)}{v'2c}$ for preventive drugs.

Finally, we derive the dynamic equations for the multipliers, which can be specified as follows:

(16) $$\dot{\lambda}_1 = (r + \frac{\delta\pi_H I_V}{N_H} + q + \mu_H)\lambda_1 - q\lambda_2 - (\frac{\phi_1\delta\pi_H I_V}{N_H} - \frac{\varepsilon_u\phi_1\delta\pi_H I_V}{N_H})\lambda_3 - (\frac{(1-\phi_1-\phi_3)\delta\pi_H I_V}{N_H} + \frac{\varepsilon_u\phi_1\delta\pi_H I_V}{N_H})\lambda_4 - (\frac{(1-\phi_1-\phi_2)\delta\pi_H I_V}{N_H})\lambda_5$$

(17) $$\dot{\lambda}_2 = -\chi\lambda_1 + (r + \frac{(1-\psi)\delta\pi_H I_V}{N_H} + \chi + \mu_H)\lambda_2 - (\frac{\phi_1(1-\psi)\delta\pi_H I_V}{N_H} - \frac{\varepsilon_q\phi_1(1-\psi)\delta\pi_H I_V}{N_H})\lambda_3 - (\frac{(1-\phi_1-\phi_2)(1-\psi)\delta\pi_H I_V}{N_H} + \frac{\varepsilon_q\phi_1(1-\psi)\delta\pi_H I_V}{N_H})\lambda_5$$

(18) $$\dot{\lambda}_3 = -v'A - u\lambda_1 + (r + u + \gamma_S + \mu_H + \alpha)\lambda_3 - \gamma_S\lambda_6 + (\lambda_7 - \lambda_8)(\frac{\delta\pi_V S_V}{N_H})$$

(19) $$\dot{\lambda}_4 = -v'A + (r + \gamma_R + \mu_H + \alpha)\lambda_4 - \gamma_R\lambda_6 + (\lambda_7 - \lambda_8)(\frac{\delta\pi_V S_V}{N_H})$$

(20) $$\dot{\lambda}_5 = -v'A + (r + \gamma_R + \mu_H + \alpha)\lambda_5 - \gamma_R\lambda_6 + (\lambda_7 - \lambda_8)(\frac{\delta\pi_V S_V}{N_H})$$

(21) $$\dot{\lambda}_6 = -\theta\lambda_1 + (r + \theta + \mu_H)\lambda_6$$

(22) $$\dot{\lambda}_7 = (r + \frac{\delta\pi_V(I_S + I_{Ru} + I_{Rq})}{N_H} + \mu_V)\lambda_7 - (\frac{\delta\pi_V(I_S + I_{Ru} + I_{Rq})}{N_H})\lambda_8$$

(23) $$\dot{\lambda}_8 = (\frac{\delta\pi_H S_H}{N_H})\lambda_1 + (\frac{(1-\psi)\delta\pi_H P}{N_H})\lambda_2 .$$

We solve the optimal control problem by using the *Forward-Backward Sweep Method*, as suggested by Lenhart and Workman (2007). The corresponding procedure is written in Matlab R2013b.

In the following, we calibrate the model for the baseline scenario. We then outline alternative scenarios and recalibrate the model in order to determine the costs of particular strategies and treatment decisions.

3.4 Model calibration

We first calibrate our bio-economic model by using the observed data from our specific study area and determine the optimal allocation of curative and preventive treatment against AAT. This specification serves as the baseline scenario. In addition, we explore optimal AAT control under different scenarios. In particular, we investigate the benefit of optimal control in terms of the avoidance of losses relative to the observed mix of treatment strategies, the improvement of disease management, and changes in risk and time preferences.

3.4.1 Baseline scenario

In the baseline scenario, we use the observed data from the 202 small-scale cattle farmers described in Table 3.1 and the parameter specifications provided in Table 3.2.

In particular, we use reported numbers of AAT-infected animals and subjective probabilities to estimate initial values in the respective states of health, i.e., S = 2884, P = 0, I_s = 638, I_{Ru} = 245, I_{Rq} = 245, R = 15. The ratio of animals that were infected with AAT and that did not respond to treatment to the number of animals that were infected with AAT provides an indication of the proportion of cattle that were infected with sensitive and resistant strains, i.e., $\phi_1 = 0.74$ and $\phi_2 = \phi_3 = 0.13$. In addition, we use the reported treatment failure rates as an indication of the rate of drug resistance development due to drug misuse, i.e., $\varepsilon_u = 0.184$ and $\varepsilon_q = 0.273$.

Furthermore, we assume that the initial number of susceptible tsetse flies is 5,000 and that 2% of susceptible flies are infected with AAT (Rogers 1988).

Following Kristjanson et al. (1999), we set the costs of infection *A* at US$34.1 in purchasing power parity ($PPP-2005) per head of infected cattle for forgone milk and meat production. Because preventive drug treatment must be applied on a regular basis, we assume higher costs for preventive control than for curative control. Therefore, we assume US$3.65 ($PPP) per head treated with preventive drugs and US$1.22 ($PPP) per head treated with curative drugs (Kristjanson et al. 1999).

Finally, we use the elicited behavioral parameters obtained by Liebenehm and Waibel (2014) to specify the utility function and the discount rate. We assume that the average risk-averse, patient farmer optimizes the allocation of curative and preventive control by minimizing the total losses from AAT over a finite horizon of 20 years.

We compare the baseline scenario to the hypothetical scenarios that we introduce in the following sections.

3.4.2 Optimal treatment strategy vs. observed treatment strategy

In the first scenario, we aim to assess the present discounted value of losses due to AAT for the optimal mix of treatment strategies compared with the observed mix of treatment strategies.

To obtain a valid estimate of the total observed losses, we assume that the number of AAT infections as reported in Table 3.1 remains constant over the total horizon of 20 years. We evaluate each infection with the costs of infection in terms of losses in milk and meat production (A = US$34.1).

We then calculate the losses avoided through optimal control relative to observed control. We expect that the observed mix of treatment strategies is non-optimal and that the potential to avoid losses through optimization is high.

3.4.3 Improved treatment practices vs. observed treatment practices

In a second scenario, we aim to identify the benefits of adequate disease management practices. Therefore, we create a hypothetical scenario in which farmers avoid every second treatment failure that was actually observed. In other words, we decrease the treatment failure rates by half, i.e., $\varepsilon_u = 0.092$ and $\varepsilon_q = 0.1365$, which decreases the number of animals that move to the two resistant infection classes I_{Ru} and I_{Rq}.

Finally, we compare the baseline scenario of observed treatment failures reported in Table 3.1 with the hypothetical scenario of reduced treatment failures to determine the losses avoided through improved disease management. We expect that the reduction of treatment failures increases the potential cost savings.

3.4.4 Changes in risk and time preferences

Liebenehm and Waibel (2014) report that cattle farmers in our study area are, on average, risk-averse and patient. In a third scenario, we aim to investigate the impact of changes in farmers' risk and time preferences. Therefore, we define two hypothetical scenarios.

In the first scenario, we change farmers' average time preference and increase the discount rate to 20%. By comparing this case with the baseline, we can analyze changes in optimal treatment rates under the assumption that farmers change from being risk-averse and patient to being risk-averse and impatient. We expect that a risk-averse farmer with a shorter time horizon is likely to have a greater preference for curative treatment over preventive treatment than a risk-averse farmer with a longer time horizon.

In the second scenario, we aim to investigate how the optimal treatment rates would change if farmers were less risk-averse. Hence, we increase the risk aversion parameter above 0.5 (σ = 0.6) and decrease the loss aversion parameter below one (ω = 0.8), and we assume that the average farmer is risk-taking and patient. Consequently, we expect risk-taking farmers with a long time horizon to exhibit a higher preventive treatment rate than risk-averse farmers with a long time horizon.

In the next section, we present the results.

3.5 Results

We first demonstrate the performance of our bio-economic model without treatment interventions given the observed values of our underlying sample in Table 3.1 and the parameter specifications in Table 3.2. In a next step, we include curative and preventive drug control and identify the optimal treatment mix. In addition, we investigate the change in optimal treatment rates given the scenarios described above.

3.5.1 Basic AAT model without control

Figure 3.3 illustrates the state variables' paths to the steady state for both hosts and vectors without intervention.

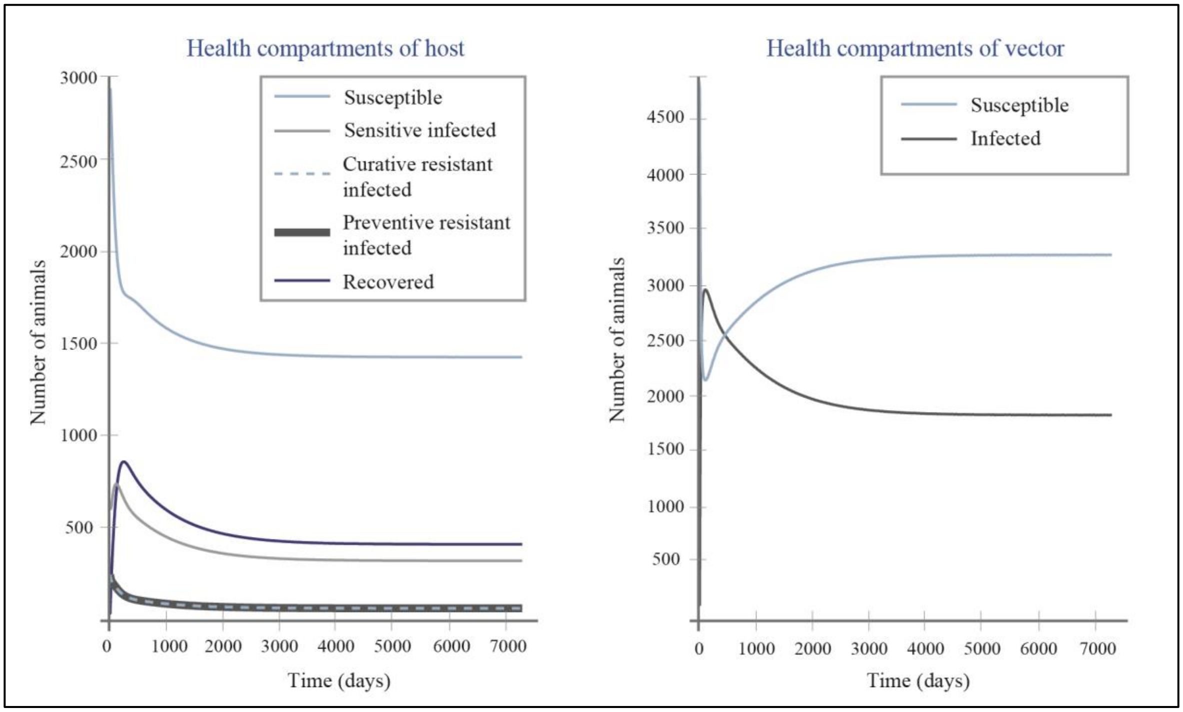

Figure 3.3 Steady states of hosts and vectors without control

Source: Own illustration

The movement of the state variables toward the steady state is straightforward. The number of cattle that are susceptible decreases monotonically, whereas the number of sensitive infected animals increases monotonically by approximately 20% to a maximum of 750 animals in the first year. The number of cattle in the recovered state follows the course of the sensitive infected state variable with a slight delay.

After the maximum infection rate is reached, the number of sensitive infected cattle decreases until the steady state is achieved in year five. The number of animals in the two resistant infection classes decreases monotonically because we exclude treatment interventions; hence, we have no incidence of treatment failure. The average overall prevalence of AAT in cattle is approximately 20%.

The course of vector state variables is consistent with the movements in the cattle population. While the number of susceptible tsetse flies is decreasing, the number of infected flies is increasing, reaching the steady state at an average prevalence of approximately 40%. In their model, Milligan and Baker (1988) report similar fluctuations in the prevalence rates of AAT in cattle and tsetse flies. In addition, our simulated prevalence in hosts is similar to the observed prevalence reported by farmers (Table 3.1). Therefore, we are confident that our model can simulate valid results.

3.5.2 Basic AAT model with optimal curative and preventive control

In a next step, we include curative and preventive drug treatment and identify the private optimal control allocation that minimizes the disutility of total losses from AAT (Figure 3.4).

We can describe the course of the optimal curative and preventive control allocation over the finite horizon of 20 years as follows:

In the initial period, it seems optimal to treat approximately 12.5% of AAT-infected animals with curative drugs and to apply prophylaxis to 28% of animals that are susceptible to AAT. Consequently, the number of animals that are infected with drug-sensitive strains is decreasing through therapeutic intervention, and preventive drug control moves susceptible animals to the protected class.

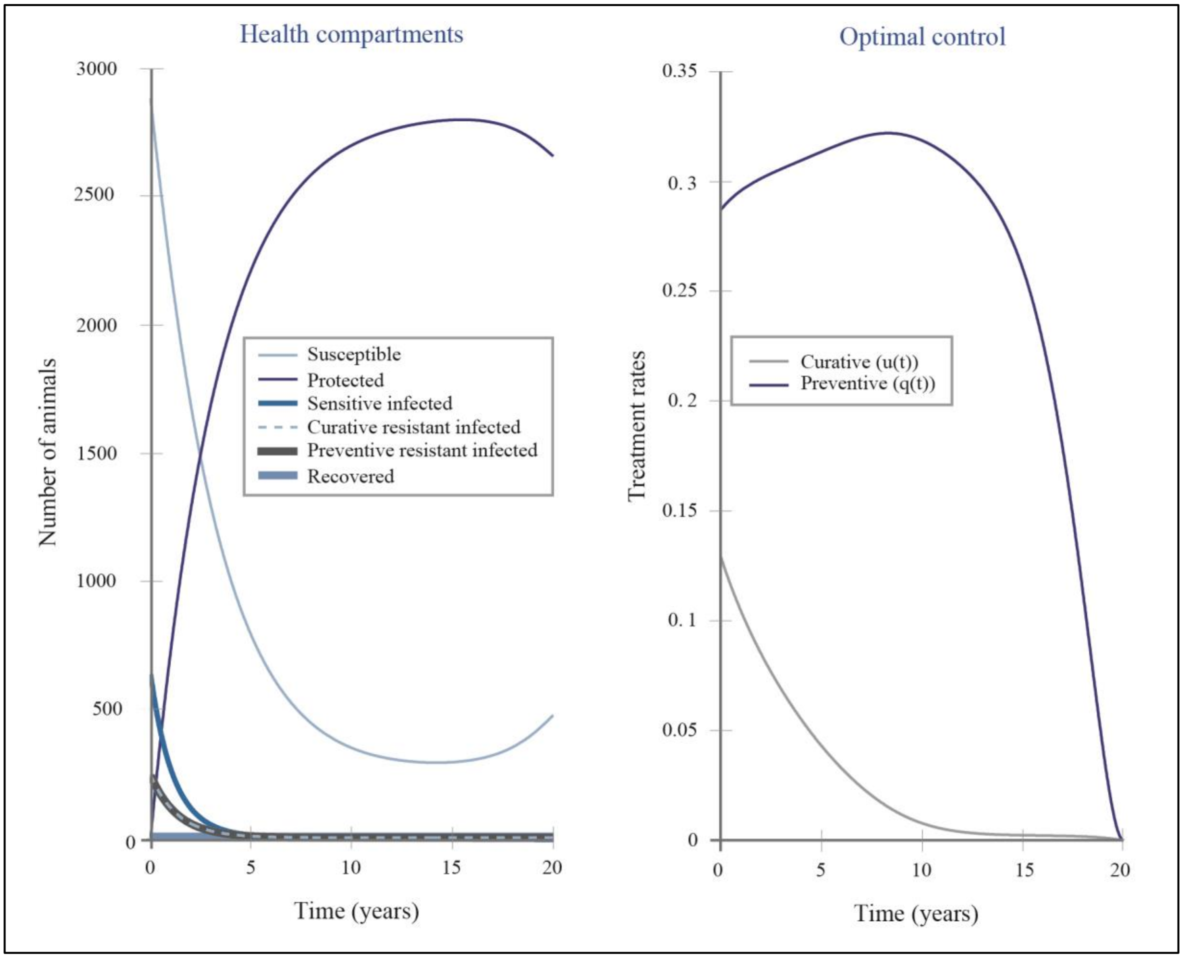

Figure 3.4 Number of animals in different states of health and optimal treatment rates

Source: Own illustration

After the initial period, the curative treatment rate monotonically decreases until year ten with the declining number of sensitive infected animals. Simultaneously, the preventative treatment rate is increasing leading to a monotonic increase in the number of animals that are protected from AAT infection.

The increase in the protected cattle population reaches a turning point when the preventive treatment rate is at its maximum of approximately 32%. After the maximum is reached, the preventive treatment rate decreases, slowing down the increase in the number of protected animals. While the preventive treatment rate decreases, the curative treatment rate remains constant at a relatively low level.

The slopes of the number of animals in the two resistant classes marginally decrease over time because the treatment is not effective and because mortality from AAT is high. However, the number of animals infected with AAT strains that are resistant to preventive drugs is slightly higher than the number of animals infected with AAT strains that are resistant to curative drugs because we observe a higher treatment failure rate for preventive AAT control.

However, for our risk-averse, patient cattle farmers, the privately optimal mix of treatment strategies involves applying a preventative treatment strategy until a maximum number of susceptible cattle are protected from the risk of AAT infection and supporting this preventive treatment with a small number of curative treatments for infected cattle.

3.5.3 Optimal treatment strategy vs. observed treatment strategy

To better assess the value of this result, we compare the losses due to AAT for optimal treatment allocation with the observed total losses. We plot the benefit of optimal control in terms of avoided losses in Figure 3.5.

In the first year, the costs of AAT are higher in the optimal control scenario than in the observed case. The higher costs of AAT with optimal control during the initial period result from the higher treatment rates, particularly higher preventive treatment, and the lagged treatment impact.

However, after the initial period, optimal AAT control can avoid losses in two ways. First, curative control clears sensitive AAT infections and reduces the number of infected animals, which saves meat and milk production losses. Simultaneously, preventive control protects animals from new infections and hence prevents potential losses. The maximum benefit is reached in year two when the majority of sensitive infections are treated successfully and when a large number of animals are protected.

Across the remaining horizon of 20 years, the total disease losses with optimal control remain below the total disease losses without optimal control. On average, the private benefit of optimal control in terms of avoided losses is US$125 per year, which corresponds to 5% of the annual income from cattle production.

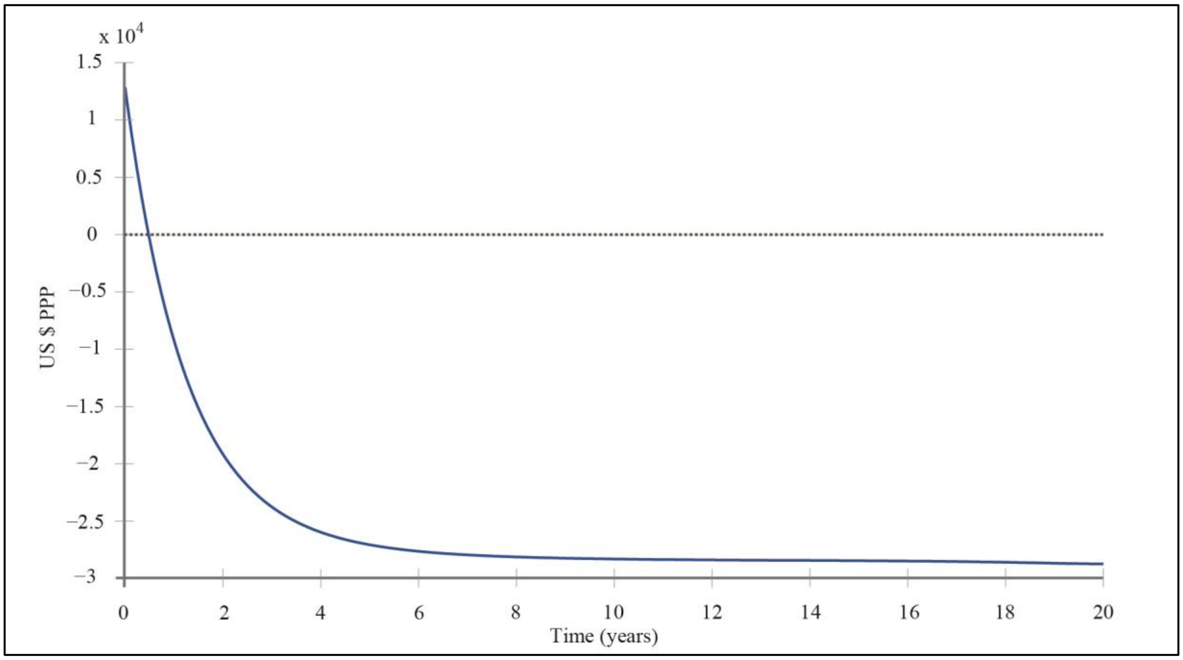

Figure 3.5 Avoided losses through optimal control

Source: Own illustration

In the next section, we investigate the optimal allocation of curative and preventive control from different behavioral perspectives.

3.5.4 Improved treatment practices vs. observed treatment practices

In the next scenario, we aim to assess treatment practices in terms of avoided treatment failures. Therefore, we compare optimal treatment rates between the baseline scenario and the hypothetical scenario, where the incidence of every second treatment failure is avoided (Figure 3.6).

Figure 3.6 indicates that less treatment failure is associated with lower treatment rates. In particular, a high treatment failure rate that leads to drug resistance requires more prophylaxis. In other words, good treatment practices contain the benefit of saving expenditures for preventive control. If an average West African cattle farmer avoided every second treatment failure, he would save approximately US$128 per year.

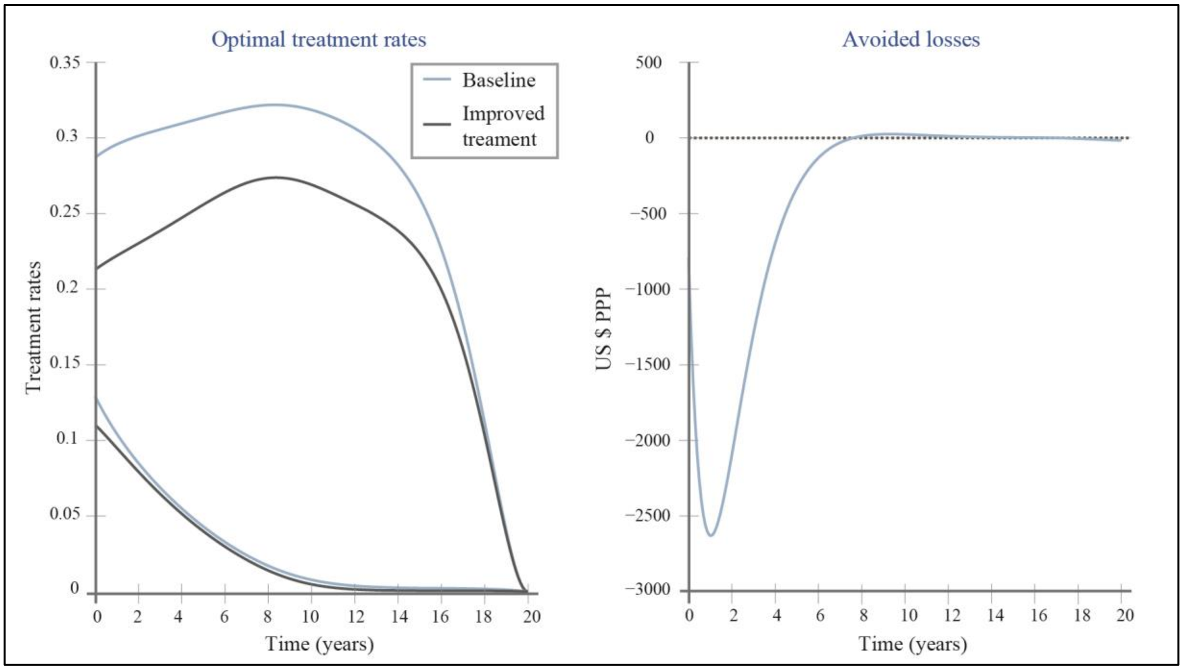

Figure 3.6 Avoided losses through improved treatment practice

Source: Own illustration

3.5.5 Changes in risk and time preferences

Having identified the impact of improved treatment practices, we investigate the role of behavioral attitudes such as risk and time preferences in a next step.

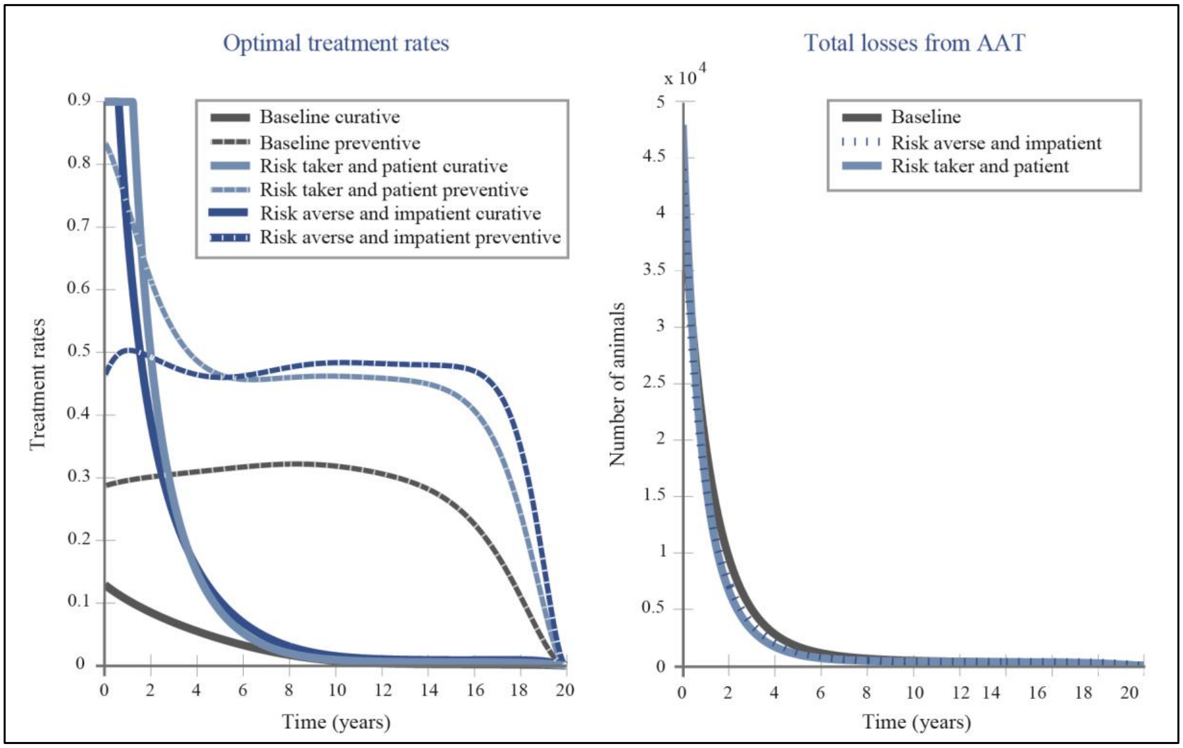

Figure 3.7 Treatment rates and total losses under different behavioral attitudes

Source: Own illustration

Figure 3.7 compares the optimal curative and preventive treatment rates between the baseline and hypothetical scenarios of higher discount rates and risk-taking behavior.

Under the assumption that farmers are as risk-averse as they were observed to be but more impatient, both the curative and the preventive treatment rates increase. Impatience is associated with a high curative treatment rate of infected animals for a short horizon in the beginning of the horizon and a preventive treatment rate of approximately 45% of susceptible animals across the total horizon.

In contrast, if we assume that farmers would be less risk-averse, the optimal preventive treatment rate is larger than 80% in the initial period but decreases over time below the optimal preventive treatment rate of risk-averse farmers. The optimal course of curative treatment is similar to that of risk-averse farmers. However, the initially high curative treatment rate of risk-taking farmers persists over a longer horizon, crosses the line of risk-averse farmers, and remains below this line. Therefore, risk-taking and patient behavior is linked to high initial investments, especially in preventive treatment, that will save treatment expenditures in the future.

Consequently, risk-taking and patient behavior that is associated with a higher preventive treatment rate during the first years requires more investments in treatment and hence higher costs. However, after the two years, risk-taking and patient behavior reduces total losses the most. Under the assumption that the average farmer is less risk-averse, he would annually save approximately US$130.

3.6 Summary and conclusions

This paper aimed to identify the privately optimal allocation of curative and preventive drug control that minimizes the present discounted value of total disease losses from AAT given the risk of resistance development through trypanocide misuse.

To achieve our objective, we developed a bio-economic model in which the biological component simulates the transmission of AAT from vector to host and the economic component identifies the economically optimal allocation of curative and preventive treatment against AAT.

We used the observed epidemiological and socio-economic characteristics of 202 cattle farmers living in remote areas of Mali and Burkina Faso. In particular, we were able to mimic farmers' behavioral characteristics with available experimental data on their risk and time preferences. We are confident that our model realistically simulates AAT transmission because we obtain prevalence rates that are similar to the observed prevalence in the study area.

We found that the optimal allocation of disease control resources for an average farmer who is risk-averse and patient involves applying a preventive treatment strategy until a maximum number of susceptible cattle are protected from the risk of AAT infection. In addition, this preventive treatment should be supported with a small number of curative treatments for infected cattle. Compared to observed practices, adopting the optimal strategy would save each farmer US$125 annually, which corresponds to 5% of the annual income from cattle production.

We also demonstrated that improvements in AAT treatment practices have the potential to save losses. If farmers could reduce treatment failure by 50%, the development of drug resistance would be delayed, and drugs would remain effective for a longer period. Reducing the number of resistant infections alone corresponds to approximately US$128 in avoided losses per average herd.

Finally, we found that risk-averse and patient behavior as observed in the study area is associated with high disease losses. If education programs could be developed that are effective in changing farmers' behavior, e.g., livestock farmer field schools (Braun et al. 2006), and reduce risk aversion, such programs would generate annual benefits of approximately US$130 per farmer.

Our results are useful for developing targeted policy interventions that can generate incentives to optimize current treatment against AAT. For example, livestock field schools could provide special training in drug management to reduce treatment failures and the risk of drug resistance development (Grace et al. 2008). Other interventions might include treatment subsidies to encourage farmers to make higher investments in prophylaxis in order to reduce the probability of infection.

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Chapter 4: Changes in Risk Attitudes and Vulnerability to Idiosyncratic and Covariate Shocks - Evidence from Panel Household Data in Thailand and Vietnam

This chapter is a modified version of

"Changes in Risk Attitudes and Vulnerability to Poverty – Evidence from Panel Household Data In Thailand and Vietnam." Paper presented at the PEGNet Conference 2014, September 18-19, Lusaka, Zambia and at Ausschuss für Entwicklungsländer (AEL) of Verein für Socialpolitik Conference, June 27-28, Passau, Germany.

Abstract

In this paper we aim to explain temporal variation in individual risk attitudes by an exogenous measure of idiosyncratic and covariate shocks. We estimate the impact of idiosyncratic and covariate shocks in terms of variation in consumption, at the individual and at the aggregate level, using multilevel modeling. The empirical basis for our analysis is a panel data set of 2812 respondents from rural Thailand and Vietnam that was collected in 2008 and 2010.

We find that on average, risk attitudes change over time in Thailand and Vietnam. In addition, we show that idiosyncratic shocks trigger changes in risk attitudes of respondents from Thailand, whereas covariate shocks affect risk attitudes of respondents from Vietnam. The impact is also different for poor and non-poor respondents. The results suggest the existence of a negative feedback loop, where shocks increase poor individuals' risk aversion and consequently their likelihood of remaining in poverty.

We conclude that respondents living in persistent poverty in Vietnam perform better in insuring idiosyncratic shocks through risk-sharing and safety nets. In Thailand, such mutual insurance mechanisms across individuals are not likely to perform well.

Keywords: Idiosyncratic and covariate shocks, multilevel modeling, risk attitude, Thailand, Vietnam, vulnerability

4.1 Introduction

Negative shocks can destroy assets and reduce income. Particularly in developing countries where people are constrained in liquidity and in assets, negative shocks can keep them below the poverty line or push them deeper into poverty – sometimes resulting in poverty traps (Barrett and Carter 2013). In this context, risk attitudes play an important role (Mosley and Verschoor 2005). If negative shocks increase risk aversion this would cause a doubly negative effect as poor and risk-averse people are likely to invest in low-risk, low return activities and stay poor (Morduch 1994; Rosenzweig and Binswanger 1993; Dercon 1996; Mosley and Verschoor 2005; Naschold 2012)

In this paper we examine if shocks affect human behavior in such a way as to change her willingness to take risk? And if so, to what extent?

We argue in this paper, that there are events that may change human's risk attitudes over time. Such events can appear at two different levels, i.e. (i) idiosyncratic shocks at the individual level such as sudden unemployment or illness, and (ii) covariate shocks at the aggregate level that affect an accumulation of individuals such as natural disasters or an economic crisis.

Long-term panel studies that investigated the impact of idiosyncratic and covariate shocks on individual risk attitudes have one common conclusion, namely: idiosyncratic shocks show no significant impact on risk attitudes, while covariate shocks show a significant impact on risk attitudes (Andersen et al. 2008; Brunnermeier and Nagel 2008; Doss, McPeak, and Barrett 2008; Malmendier and Nagel 2011; Cassar, Healy, and Kessler 2011; Voors et al. 2012; Sahm 2012; Guiso, Sapienza, and Zingales 2013; Willinger, Bchir, and Heitz 2013; Callen et al. 2014; Hanaoka, Shigeoka, and Watanabe 2014)

In this paper we aim to test if this pattern is true for rural Thailand and Vietnam. Gloede, Menkhoff and Waibel (2013) investigated the correlation between self-reported idiosyncratic and covariate shocks and risk attitudes using data from more than 4000 households from rural Thailand and Vietnam collected in 2010. In their cross-sectional study, they find that idiosyncratic shocks are correlated with larger risk aversion in Vietnam, whereas covariate shocks are associated with larger risk aversion in Thailand. However, we enhance Gloede et al.'s (2013) study in several ways.

First we use a panel data set of 2812 identical household heads from rural Thailand (1431) and Vietnam (1381) and analyze the impact of idiosyncratic and covariate shocks on changes in individual risk attitudes from 2008 to 2010. Second, we do not use self-reported shocks, because we argue that individual perceptions and emotions strongly influence the propensity to report a shock by the respondent. For example, a risk-averse respondent will perceive a shock in a different way than a risk-taking respondent and may report more shocks[1]. The explanation of risk attitudes by self-reported shocks would then be biased. We use a more objective measure of shock experienced. We assume that the impact of a shock is reflected in variation of consumption. Therefore, we estimate the variation in consumption using Günther and Harttgen's (2009) concept of vulnerability to idiosyncratic and covariate shocks. Third, we apply multilevel modeling in order to distinguish between the impact of idiosyncratic shocks and covariate shocks over time. In particular, we estimate the variation in consumption at the individual level and at the community level as proxies for idiosyncratic and covariate shocks. In the next step, we use the proxies to

[1] In our data set we find a correlation between risk aversion and number of shocks reported of 0.368.

explain changes in risk attitudes over time. Finally, we examine if the estimated impact of shocks on changes in risk attitudes is different between poor and non-poor individuals.

Our main findings are that, first, risk attitudes significantly change over time both in Thailand and Vietnam. Second, we find that idiosyncratic shocks affect risk attitudes of respondents in Thailand, whereas covariate shocks influence risk attitudes of respondents in Vietnam. Third, in both countries, risk attitudes of transient poor individuals are affected by both kinds of shocks. Hence, our results indicate the existence of a negative feedback loop, where shocks increase poor individuals' risk aversion and consequently their likelihood of remaining in poverty (Morduch 1994; Rosenzweig and Binswanger 1993; Dercon 1996; Mosley and Verschoor 2005; Naschold 2012). Fourth, mutual insurance mechanisms against idiosyncratic shocks such as risk-sharing or safety nets are likely to perform well across chronically poor individuals in Vietnam. However, these mechanisms seem to be less effective in Thailand.

Our finding that idiosyncratic shocks increase risk aversion in Thailand and covariate shocks increase risk aversion in Vietnam does not confirm the results of Gloede et al. (2013) that use cross-sectional data and self-reported shocks. However, we believe that our approach is more precise as we use panel data of identical decision-makers and measure shock impacts in terms of variation in consumption.

The country-specific difference in the kind of shocks that affect risk attitudes in Thailand and Vietnam can be possibly explained by political differences. Until 2011 public investments into social protection schemes by the Thai government leaves the majority of small-scale farmers in rural areas uncovered (Schmitt, Sakunphanit, and Prasitsiriphol 2013). Vietnam has seen extensive public investments in social protection in the last ten years targeting vulnerable groups, which might lead to the reduction of idiosyncratic risks, but is not effective to reduce covariate risks (Bonnet et al. 2012; Cuong, Tung, and Westbrook 2014).

Comparing our findings with those from the recent literature that apply longitudinal data from developing countries, we can identify similarities and differences. Our result that risk attitudes are time-variant in Thailand and Vietnam corresponds to other long-term panel studies in rural areas of Southeast Asia. Respondents from rural areas that experienced natural hazards like the tsunami in Thailand in 2004 (Cassar et al. 2011) or the volcano outbreak in central Java in 2010 (Willinger et al. 2013) showed significant changes in risk attitudes. Our result that covariate shocks affect risk attitudes in Vietnam is therefore consistent with these studies. However, our finding that idiosyncratic shocks alter risk attitudes in Thailand contradicts findings from East Africa, where the impact of shocks at the individual level on farmers' risk attitudes was found to be less important than the impact of covariate shocks (Doss et al. 2008).

In the next section, we review the literature and develop our conceptual framework, which is followed by a description of the data. The empirical strategy is introduced in section four. In section five we present the results and finally in section six we draw conclusions.

4.2 Conceptual framework

In the literature on time-variant risk attitudes we find two strands. On the one hand, there are studies that find that risk attitudes are a stable function of time. However, all these studies were conducted with respondents, mostly students interrogated in a laboratory experimental set up, from developed countries using small sample sizes and short time horizons (Love and Robison 1984; Schoemaker and Hershey 1992; Smidts 1997; Harrison et al. 2005; Vlaev, Chater, and Stewart 2009; Lönnqvist et al. 2014; Wölbert and Riedl 2013).

On the other hand, there are studies that investigate the causality between shocks and risk attitudes by means of long-term panel data. These studies have one common conclusion, i.e. idiosyncratic shocks at the individual level show no significant impact on risk attitudes, while covariate shocks at the aggregate level show a significant impact on risk attitudes.

Long-term panel studies that cover large samples of respondents from the US over ten years (Sahm 2012) and over 20 years (Brunnermeier and Nagel 2008) find that idiosyncratic shocks like unemployment, health shocks, or changes in income, assets or wealth do not affect the stability of risk attitudes over time. Empirical evidence from East Africa also suggests that the influence of idiosyncratic shocks is small (Doss et al. 2008).

In contrast, long-term panel studies which measure covariate shocks at an aggregated level such as economic shocks (Andersen et al. 2008; Malmendier and Nagel 2011; Sahm 2012; Guiso et al. 2013), social shocks (Voors et al. 2012; Callen et al. 2014), and natural disasters (Cassar et al. 2011; Willinger et al. 2013; Hanaoka et al. 2014) are found to alter risk attitudes over time. For example, Malmendier and Nagel (2011) and Sahm (2012) find a significant impact of macro-economic shocks on risk attitudes of US citizens over time. Guiso et al. (2013) investigates the change in risk attitudes of Italian investors following the 2008 financial crisis. The literature on social shocks showed that risk attitudes change over time if people are exposed to violent conflicts and war. This has been shown by Voors et al. (2012) in rural Burundi and by Callen et al. (2014) in Afghanistan. Panel studies that investigate the impact of natural disasters, like the 2004 tsunami in Thailand (Cassar et al. 2011), the eruption of a volcano in Java (Willinger et al. 2013) or the great East Japan earthquake (Hanaoka et al. 2014), also find a significant impact on individual risk attitudes over time.

One possible explanation for this commonly observed phenomenon that covariate shocks matter, but idiosyncratic shocks do not matter, may be that insurance of consumption against idiosyncratic shocks is better than against covariate shocks. Mutual insurance mechanisms within a community are more likely to decrease idiosyncratic shock impacts, because they are by definition not correlated across individual households (Ray 1998). Another explanation may be collective fear. Guiso et al. (2013) suggest that large-scale negative shocks may create a state of collective fear, where individuals are likely to adopt fear of the group and thereby lead to an increase in risk aversion.

In this paper we aim to investigate if this common pattern that covariate shocks alter risk attitudes over time, but idiosyncratic shocks show no influence, can also be observed in rural Thailand and Vietnam and if the impact of shocks is different between poor and non-poor respondents.

Our analysis aims to explain temporal variation in individual risk attitudes by an exogenous measure of idiosyncratic and covariate shocks. Therefore, we estimate the variation in consumption at the individual level and at the community level following Günther and Harttgen's (2009) approach in order to obtain exogenous measures of idiosyncratic and covariate shocks. We use these proxies of idiosyncratic and covariate shocks to explain changes in risk attitudes over time. Finally, we aim to investigate if the impact of the shock proxies on risk attitudes is different between poor and non-poor respondents. Figure 4.1 illustrates the steps that we will explain in more detail in the following.

Günther and Harttgen (2009) assume that the impact of a shock is reflected in variation of consumption. We follow their approach and apply a hierarchical model structure and estimate the impact of idiosyncratic and covariate shocks in terms of variation in consumption at the individual and at the aggregate level. In the first step, we estimate variation in consumption (*Cons*) at the individual level and the district level given exogenous variables. To model variation in consumption at the individual level we use common socio-economic variables often found in the literature such as age, education, employment, household size, dependency ratio and land size (Chaudhuri 2003; Günther and Harttgen 2009; Imai, Gaiha, and Kang 2011; Azam and Imai 2012). In addition, we include ethnicity and war veteran for Vietnam, because we expect that belonging to an ethnic minority or having participated in the Vietnam War, play a significant role in individual consumption. The variance in consumption at the individual level is then used as a proxy for the impact of idiosyncratic shocks on individual consumption. To model variance in consumption at the district level we use variables such as geographic location, the number of medium-to-large enterprises and district population (Günther and Harttgen 2009; Azam and Imai 2012). The variance in consumption at the district level is then used as a proxy for the impact of covariate shocks on individual consumption.

In the second step we analyze the impact of the estimated shock proxies, at the individual and district level, on changes in household head's willingness to take risk (ΔWTR) over time. Following the studies that use long-term panel data to investigate changes in risk attitudes over time in developing countries (for example Doss et al. 2008; Cassar et al. 2011 or Willinger et al. 2013), we expect a significant impact of the covariate shock proxy, but no significant impact of the idiosyncratic shock proxy on the change in willingness to take risk. We also control for other socio-economic, physical and psychological factors that are usually used to explain differences in risk attitudes between individuals. For example, Dohmen et al. (2011) suggest that gender and height are important characteristics that help to explain differences in individual risk attitudes. Women are usually found to be less willing to take risk than men, whereas height – used as a proxy for self-confidence – is found to be positively associated with risk-taking. Marital status (Sahm 2012) and physical fitness (Hanaoka et al. 2014) are also found to play an important role. As being married may improve individual's safety nets, we expect it to be positively related to risk-taking behavior. According to Hanaoka et al. (2014) we expect healthiness and general well-being to be positively correlated with risk-taking.

Finally, in the third step, we further expand our approach to examine the impact of shocks on the risk attitudes of poor and non-poor respondents. We expect that non-poor respondents may dispose of enough resources to buffer idiosyncratic shocks and their risk attitudes may hence be not affected. However, covariate shocks with deeper and longer impacts may alter risk attitudes of non-poor people. In contrast, we expect that poor people are more strongly affected by both idiosyncratic and covariate shocks, which in turn may alter their risk attitude.

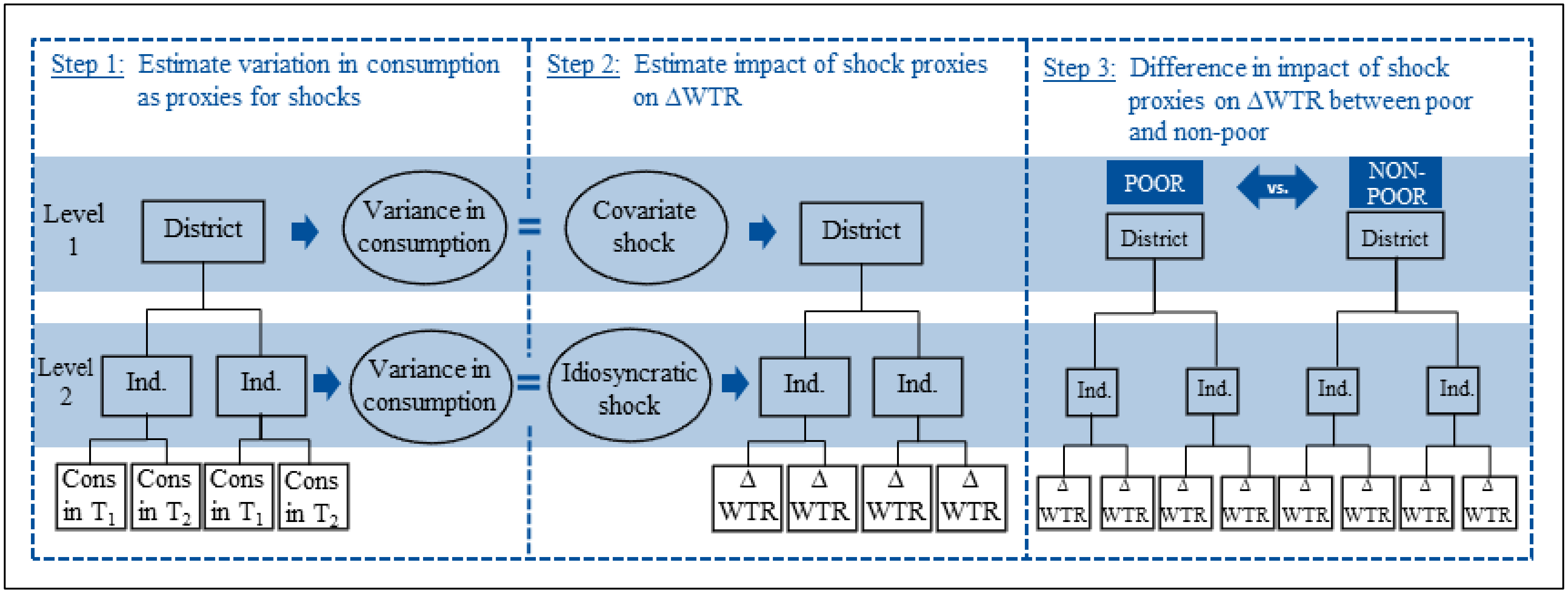

Figure 4.1 Conceptual framework

Source: Own illustration

4.3 Data and descriptive statistics

The data used in this paper come from the project “Impact of Shocks on the Vulnerability to Poverty: Consequences for Development of Emerging Southeast Asian Economies”, funded by the German Research Foundation (FOR 756). The survey covers 4212 households that are representative for rural areas in Thailand and Vietnam[2].

In this paper we investigate behavior of individuals that are the decision-makers of households. Therefore, we consider only respondents that were the head and the decision-maker inside the household, because we assume that they are responsible for risk management. This leads to a final sample of 2812 respondents from 76 districts.

Comprehensive information is available about the 2812 respondents. We have data on socio-economic characteristics of the household and its members, information about income generating activities and expenditures as well as information about perceived shocks in the past and expected risks in the future. We measure risk attitudes using Dohmen et al.’s (2011) survey-based measure, where respondents are asked to classify themselves on an eleven-point Likert scale. The survey question reads: “Are you generally a person who is fully prepared to take risk or do you try to avoid taking risk? Please choose a number on a scale from zero (unwilling to take risk) to ten (fully prepared to take risk)”. The survey-based measure is not a perfect measure of risk aversion in that it does not reflect risk aversion in concavity of the utility function (Pratt 1966; Arrow 1971). However, the survey-based measure has been validated in several countries and several contexts and is generally found to be less noisy than experimental measures (Lönnqvist et al. 2014; Guiso et al. 2013; Wölbert and Riedl 2013; Chuang and Schechter 2014). Furthermore, Hardeweg, Menkhoff and Waibel (2013) validated the survey-based measure by an incentive compatible experiment using a sub-sample of the current paper’s sample. In the following we define this variable as respondent’s willingness to take risk.

Table 4.1 presents an overview of individual- and district-specific descriptive statistics of the sample. Some of these will be used later as explanatory variables in the analysis. The descriptive statistics at the individual level show that the change in willingness to take risk

[2] For more information on sampling please see Hardeweg, Klasen and Waibel (2013).

over time was small (a half category), but significant in both countries. On average, respondents appeared to be more willing to take risk in 2010 than in 2008. However, Thai respondents were in general more willing to take risk than Vietnamese respondents.

The average respondent from Thailand was approximately 50 years old and had spent five years in formal school. The average respondent from Vietnam was approximately two years younger than Thai respondents and spent two more years in formal school. In Thailand, more than 60% of respondents were female, whereas 45% of respondents in Vietnam were female. In both countries, approximately 80% of respondents were married. The percentage of socio-political members decreased significantly in Thailand from approximately 10% to 5%. In contrast, the percentage of socio-politically active respondents in Vietnam remained high at 75%. Health and individual well-being in Thailand significantly improved over time. In Vietnam, individual well-being improved over time, too, but the percentage of respondents who reported that they were sick increased over time. Approximately 20% of respondents from Vietnam belonged to an ethnic minority and the same percentage experienced the Vietnam War.

There is a significant increase in income and consumption over time in Thailand, whereas income and consumption remained at the same, but lower level, in Vietnam. Consequently, the headcount ratio (US$2 consumption poverty line) decreased over time from 12% to 3% in Thailand, whereas in Vietnam the share of respondents below the poverty line remained at approximately 25%.

In both countries there was a significant increase in the number of self-reported idiosyncratic shocks over time, whereas the number of covariate shocks significantly decreased from 2008 to 2010.

District level characteristics are scaled up from information provided by the village head. The average district population for our sample was approximately 29,000 inhabitants in Thailand and 46,000 in Vietnam. In both countries, there were approximately eight enterprises with more than 9 employees. Approximately 85% of respondents from Thailand resided in plain country, 13% lived close to rivers, lakes or sea and 2% stayed in mountainous areas. In Vietnam, the majority of respondents lived close to water and in mountainous areas.

Table 4.1 Summary of mean socio-economic characteristics

	Thailand		Vietnam	
	2008	**2010**	**2008**	**2010**
Individual characteristics				
Willingness to take risk (WTR)	4.072	4.572***	3.58	4.13***
Age (years)	51.53	53.55***	48.17	50.16***
Female (%)	60.52	60.52	45.19	45.19
Height (m)	1.57	1.58	1.58	1.58
Education (years)	5.17	5.21	7.43	7.41
Married (%)	79.87	79.87	82.61	82.68
Member of socio-pol. organization (%)	10.06	5.66***	75.16	74.86
Health status				
Can manage (%)	29.35	32.5*	63.58	51.99***
Sick (%)	15.09	12.44**	21.51	26.74**
Present well-being				
Same as last year (%)	39.9	39.27	51.2	42.36***
Better than last year (%)	29.91	33.68**	25.27	34.18***
Much better than last year (%)	2.31	5.66***	0.29	0.22
Minority (%)	n.a.	n.a.	19.26	19.26
Vietnam war (%)	n.a.	n.a.	20.05	20.05
Household size	3.906	3.859	4.25	4.08**
Dependency ratio	0.671	0.631**	0.701	0.627***
Land size (ha)	1.027	1.027	0.239	0.283
Income per month ($PPP per capita)	113.65	139.21***	105.77	101.04
Consumption per month ($PPP per capita)	121.54	184.61***	91.41	91.25
Headcount ratio (2 $PPP poverty line)	0.119	0.036***	0.253	0.267
Number of self-reported idiosyncratic shocks	0.465	1.18***	0.218	1.513***
Number of self-reported covariate shocks	0.779	0.64***	1.214	0.749***
District characteristics				
Population	N.a.	28,741		46,356
Number of enterprises > 9 employees	N.a.	7.604		8.387
Location				
Mountain (%)	N.a.	2.446	N.a.	56.988
Close to water (%)	N.a.	13.206	N.a.	40.623
N	1431	1431	1381	1381

Note: Means are compared by Wilcoxon-Mann-Whitney test. N.a. means not available. Single, double, and triple asterisks (*,**,***) denote p < 0.10, 0.05, and 0.01, respectively. Source: DFG 756 Survey 2008 and 2010; own calculations

4.4 Empirical strategy

In order to appropriately explain changes in individual risk attitudes over time by idiosyncratic and covariate shocks we use variation in consumption as a proxy for shocks experienced and differentiate between the levels of shock impact. We apply multilevel modeling with two levels. Level 1 represents the individual respondent's level (*i*) and level 2 is the district level (*j*). The chosen levels provide sufficient variation in the dependent variable willingness to take risk[3].

We implement our empirical strategy in three steps. In the first step, we estimate the variance in consumption at the individual level and at the community level in order to obtain proxies for the impact of idiosyncratic and covariate shocks. In the second step, we aim to identify if the variation in consumption has an impact on the change in risk attitudes over time. Finally, in the third step, we investigate if the impact of shocks on changes in risk attitudes is different between poor and non-poor respondents. We describe the empirical procedure in more detail in the following.

In order to obtain an objective proxy for shocks in the first step we follow Günther and Harttgen's (2009) concept of vulnerability to idiosyncratic and covariate shocks. We estimate the expected idiosyncratic and covariate variance of consumption based on the following multilevel household's consumption equation:

$$(1) \qquad \ln Cons_{ij} = \beta_{oo} + \sum_{p}^{P} \beta_{p0} X_{pij} + \sum_{q}^{Q} \beta_{0q} Z_{qj} + \sum_{p}^{P} \sum_{q}^{Q} \beta_{pq} X_{pij} Z_{qj} + \sum_{p}^{P} u_{pj} X_{pij} + u_{0j} + e_{ij} .$$

In equation 1, we regress monthly log consumption per capita of respondent *i* in district *j* ($Cons_{ij}$) on a set of individual characteristics (X_{ij}), a set of district characteristics Z_j, and individual-district-characteristic interactions ($X_{ij}Z_j$). We assume that the individual-level error term e_{ij} captures the impact of idiosyncratic shocks and the community-level error

[3] Approximately 12% of the total variance in willingness to take risk is represented at the district level and 20% is represented at the individual level, both are above the minimum threshold of 10% (Hox 2010).

term u_{0j} captures the impact of covariate shocks. The squared residuals are then regressed against a set of individual and district level characteristics. Finally, we estimate the expected idiosyncratic variance ($\hat{\sigma}^2_{e_{ij}}$) and covariate variance ($\hat{\sigma}^2_{u_{0j}}$) of consumption and use them as proxies for idiosyncratic and covariate shocks (Günther & Harttgen 2009).

In the second step, we use these proxies of idiosyncratic and covariate shocks as explanatory variables and investigate their impact on the change in willingness to take risk over time:

$$(2) \qquad WTR_{ijt} = \beta_{oo} + \beta_{10}T_{ijt} + \beta_{20}\hat{\sigma}^2_{e_{ij}} + \sum_{p}^{P}\beta_{p0}X_{pij} + \beta_{01}\hat{\sigma}^2_{u_{0j}} + \sum_{q}^{Q}\beta_{0q}Z_{qj} + u_j + u_{ij} + e_{ijt},$$

where $\hat{\sigma}^2_{e_{ij}}$ reflects the impact of idiosyncratic shocks at the individual level and $\hat{\sigma}^2_{u_{0j}}$ represents the impact of covariate shocks at the district level. In addition we include other explanatory variables X_{ij} at the individual level and other explanatory variables Z_j at the district level that had been introduced in our conceptual framework.

In the third step, we investigate the impact of idiosyncratic and covariate shocks on risk attitudes for different poverty groups, i.e. structural poor, transient poor and non-poor. We define chronic poverty as permanent low consumption prospects and transient poverty as the contribution of high consumption volatility to expected poverty (Ravallion and Jalan 1998). In other words, if the estimated mean consumption ($\hat{c}$) and the estimated total standard deviation ($\hat{\sigma}_{e_{ij}} + \hat{\sigma}_{u_{0j}}$) in consumption lie below the poverty line (z), then the respondent is referred to as chronically poor, i.e.

$$(3) \qquad chronically \quad poor = 1 \quad if \quad \hat{c} + (\hat{\sigma}_{e_{ij}} + \hat{\sigma}_{u_{0j}}) < z \text{, 0 otherwise.}$$

If the estimated mean consumption is above the poverty line, but a high estimated total standard deviation in consumption leads to a drop in consumption below the poverty line or the estimated mean consumption is below the poverty line and the total standard deviation leads to a push above the poverty line, then the respondent is categorized as transient poor:

(4) $$transient \quad poor = 1 \;\; if \;\; \hat{c} - (\hat{\sigma}_{e_{ij}} + \hat{\sigma}_{u_{0j}}) < z \;\; or \;\; \hat{c} + (\hat{\sigma}_{e_{ij}} + \hat{\sigma}_{u_{0j}}) > z$$, 0 otherwise.

Finally, the respondent is classified as non-poor, if mean consumption and the total standard deviation in consumption lie above the poverty line (Azam and Imai 2012).

(5) $$non - poor = 1 \;\; if \;\; \hat{c} - (\hat{\sigma}_{e_{ij}} + \hat{\sigma}_{u_{0j}}) > z$$, 0 otherwise.

In the next section we present the results.

4.5 Results

We aim to assess the impact of idiosyncratic and covariate shocks on the change in willingness to take risk over time using variation in consumption as a proxy for shocks experienced.

In order to obtain an objective proxy for shocks experienced, we estimate the consumption equation (1) in a first step (Table 4.2). All significant variables contain the expected signs (Günther and Harttgen 2009), however are not the core focus of this article. The model fits the data relatively well, because the proportion of variance that is modeled by the explanatory variables at the individual level is 0.796 (R^2_i) and 0.656 at the district level (R^2_j) for Thailand. The goodness-of-fit for the Vietnam model is lower than in the Thai sample, however with an explained variance in consumption at the individual level of 0.492 (R^2_i) and of 0.109 at the district level (R^2_j) the values remain on par or higher than comparable studies (Günther and Harttgen 2009; Azam and Imai 2012).

Table 4.2 Multilevel mixed regression results of ln consumption per month

	Thailand	**Vietnam**
Individual level		
Age	0.029***	0.016**
Age²	-0.0002***	-0.0002**
Education		
Secondary education (5-6 years)	0.14***	0.068*
Tertiary education (>7 years)	0.36**	0.183***
Employment		
Agricultural employment	-0.003	-0.042
Non-agricultural employment	0.026	0.019
Self-employed	0.214***	0.202***
Civil servant	0.141	0.318**
Household size	-0.096***	-0.097***
Dependency ratio	-0.163***	-0.037
Land size	0.017**	0.37***
Minority		-0.35***
Vietnam war		0.117***
District level		
Population	-0.000002	0.0000002
Enterprises	0.0005	0.001
Location		
Mountain	-0.007	0.26***
Water	-0.143***	0.202**
Individual * district interaction		
Dependency ratio * Population	0.000002	-0.0000009**
Land size * mountain	0.001	-0.361***
Land size * water	0.075***	-0.356***
Intercept	4.498***	4.289***
σ_{eij} (individual level)	0.107	0.264
R^2_i	0.796	0.492
N_i	1254	1082
σ_{uj} (district level)	0.052	0.163
R^2_j	0.656	0.109
N_j	45	31

Notes: Dependent variable is ln consumption in $PPP per capita. Single, double, and triple asterisks (*,**,***) denote $p < 0.10$, 0.05, and 0.01, respectively.
Source: DFG 756 Survey 2008 and 2010; own calculations

Based on the estimation of consumption, we can identify the idiosyncratic variance ($\hat{\sigma}^2_{e_{ij}}$) and covariate variance ($\hat{\sigma}^2_{u_{0j}}$) of consumption (Table 4.3). We observe that the idiosyncratic and covariate variance is larger in Thailand than compared to Vietnam. In addition, the idiosyncratic variance is larger than the covariate variance in both countries, which is consistent with findings from Madagascar (Günther and Harttgen 2009) or Bangladesh (Azam and Imai 2012).

Table 4.3 Estimated mean and variance of ln consumption per month ($PPP per capita)

	Thailand		**Vietnam**	
	2008	**2010**	**2008**	**2010**
Mean ln consumption per month				
Observed	4.673	5.087	4.397	4.385
Estimated	4.913	4.937	4.455	4.488
Variance ln consumption per month (estimated)				
Idiosyncratic variance	0.193	0.191	0.148	0.15
Covariate variance	0.055	0.055	0.031	0.031
Total variance	0.246	0.248	0.178	0.178

Source: DFG 756 Survey 2008 and 2010; own calculations

In the second step, the estimated idiosyncratic variance in consumption serves as our proxy for idiosyncratic shocks, while the estimated covariate variance serves as our proxy for covariate shocks. These two proxies are used as explanatory variables to explain changes in willingness to take risk over time. We report standardized regression coefficients in Table 4.4 in order to compare the relative magnitude of coefficients.

In contrast to our expectations derived from the literature (Doss et al. 2008; Callen et al. 2014; Cassar et al. 2011), in Thailand we find that the impact of idiosyncratic shocks at the individual level is negative and significant. An increase in idiosyncratic variance by one standard deviation is associated with a decrease in willingness to take risk by approximately 0.05 standard deviation units. Consistent with our expectations derived from the literature (Hanaoka et al. 2014), health and present well-being significantly affect willingness to take risk. Healthy respondents are more willing to take risk than respondents, who report some health constraints but are generally not restricted in their daily activities. Improvements in present well-being are also associated with an increase in willingness to take risk. At the district level, however, the effect of covariate shocks on the willingness to take risk is not significant in Thailand.

In Vietnam we obtain the expected result, where covariate shocks are significant and idiosyncratic shocks are not significant. An increase in variation in consumption at the district level by one standard deviation decreases the district average willingness to take risk by 0.23 standard deviation units. That means the estimated covariate shock impact evaluated in terms of variation in district-level consumption is likely to alter risk attitudes over time.

However, we also find other factors at the individual level that show a significant impact on willingness to take risk in Vietnam. Factors that increase security, such as marriage, or self-confidence, such as height, are significantly positive and in line with expectations (Dohmen et al. 2011; Sahm 2012).

One possible explanation for the country-specific difference that idiosyncratic shocks trigger changes in risk attitudes of respondents from Thailand, whereas risk attitudes of Vietnamese respondents are affected by covariate shocks is the difference in the political orientation. In the last ten years, the Vietnamese government has made extensive investments into social protection schemes that may mitigate and/or prevent large impacts from idiosyncratic shocks. For example, under the "Social Insurance Law" a mandatory social insurance scheme for workers was created, a health insurance scheme was introduced and different "National Target Programs" were launched aimed to provide basic social services to specific vulnerable groups e.g. orphans, older people or ethnic minorities (Bonnet et al. 2012; Cuong et al. 2014). In addition, informal support networks tend to be stronger in socialist and former socialist countries, reducing the impact of idiosyncratic shocks. Correspondingly, covariate shocks are significant in Vietnam, because the informal network may be unable to cope (Cook, Kabeer, and Suwannarat 2003). Furthermore, at the time of the survey, the Vietnamese government just initiated public programs to manage covariate shocks (Trung 2015).

In Thailand, the two major social protection schemes, i.e. the “Universal Coverage Scheme” that provides health care and the “500Baht Scheme for Older People” leaves the majority of farmers from rural Thailand uncovered and hence vulnerable to idiosyncratic shocks (Schmitt et al. 2013). Empirical evidence from other studies also question the effectiveness of social protection in Thailand (Amare et al. 2012). Consistently, the impact of covariate shocks on risk attitudes are less likely in Thailand, because affected households receive compensation from the Thai government through specific relief programs (Poaponsakorn, Meethom, and Pantakua 2015).

Table 4.4 Impact of variation in consumption on the change in willingness to take risk over time

	Thailand	Vietnam
Individual level		
Estimated idiosyncratic variance	-0.048**	-0.028
Female	-0.013	0.009
Married	0.028	0.073***
Height	0.023	0.064**
Member of socio-pol. organization	-0.028	0.039*
Health status		
Can manage	-0.073***	0.033
Sick	-0.01	-0.033
Present well-being		
Same as last year	0.025	0.053**
Better than last year	0.056**	0.166***
Much better than last year	0.04*	0.037
Time	0.08***	0.133***
District level		
Estimated covariate variance	-0.04	-0.233**
Intercept	2.874***	1.648***
σ_{eij} (individual level)	0.711	0.844
R^2_i	0.249	0.353
N_i	1253	1081
σ_{uj} (district level)	0.275	0.677
R^2_j	0.99	0.652
N_j	45	31

Notes: Dependent variable is willingness to take risk. Coefficients are standardized. Single, double, and triple asterisks (*,**,***) denote $p < 0.10$, 0.05, and 0.01, respectively.
Source: DFG 756 Survey 2008 and 2010; own calculations

Comparing the magnitude of idiosyncratic shocks on changes in respondents' willingness to take risk in Thailand with the magnitude of the covariate shock in Vietnam, shows that the impact of covariate shocks is larger. This is consistent with the literature as idiosyncratic shocks are generally found to be insignificant, it is therefore reasonable for the magnitude of covariate shocks to be larger than idiosyncratic shocks (Doss et al. 2008; Cassar et al. 2011; Willinger et al. 2013).

Finally we further investigate if the impact of idiosyncratic and covariate shocks on the change in willingness to take risk is different between poor and non-poor respondents. In order to classify respondents as poor or non-poor, we use the respective national poverty lines in Thailand and Vietnam. Table 4.5 gives an overview of the poverty lines and the percentage of respondents that were classified as chronically poor, transient poor and non-poor.

The national consumption poverty line in Thailand is approximately US$115 (PPP$) per capita per month both in 2008 and in 2010. In Vietnam, the national poverty line is approximately US$73 (PPP$) per capita per month[4].

Separating the poverty status into the three groups shows that only a small percentage is permanently below the poverty line with only 1% below in Thailand and 5% below in Vietnam. The majority of respondents in both countries is transient poor and faced with a high variation in consumption that may pull them below the poverty line. However, we observe a decline in poverty in Thailand, as the percentage of non-poor respondents increases from approximately 22% to 47%.

Table 4.5 Distribution of structural poor, transient poor and non-poor respondents

	Thailand		**Vietnam**	
	2008	**2010**	**2008**	**2010**
National poverty line ($ PPP per month per capita)	115.12	115.865	72.48	72.48
Chronically poor	0.005	0.003	0.037	0.028
Transient poor	0.893	0.878	0.702	0.667
Non-poor	0.224	0.466	0.385	0.394

Source: (Thailand 2013; Vietnam 2012); DFG 756 Survey 2008 and 2010; own calculations

[4] We apply 4,800,000 VD in 2008 and 2010 as the national poverty line in Vietnam and 1,978 THB in 2,008 and 2099 in THB 2010 as the national poverty lines in Thailand (Vietnam 2012; Thailand 2013).

As the number of respondents classified as structurally poor is too small, we use only transient poor respondents and non-poor respondents as two sub-samples to investigate differences in the impact of shocks on respondents' willingness to take risk (Table 4.6).

In separating the respondents into transient poor and non-poor we find no major changes between the impacts of shocks on changes in willingness to take risks, neither in Thailand nor in Vietnam. For the transient poor and non-poor, idiosyncratic shocks have a significant negative impact on changes in willingness to take risk in Thailand whilst covariate shocks remain insignificant. In Vietnam, for both groups covariate shocks show a significant negative impact, whereas idiosyncratic shocks stay insignificant.

However, the consequences of covariate shocks on changes in willingness to take risks in Vietnam are different for the transient poor and non-poor. We see that the magnitude of the impact of covariate shocks on transient poor individuals is greater than on non-poor. Overall we see that the magnitude and impact of shocks on changes in willingness to take risks has a far more negative effect on the transient poor than the non-poor. This negative effect also carries further consequences for transient poor households, as through their increased risk aversion, they are more likely to make decisions that keep them further embedded in poverty (Mosley and Verschoor 2005).

Table 4.6 Impact of variation in consumption on the change in willingness to take risk over time for poor and non-poor respondents

	Thailand		**Vietnam**	
	Transient poor	**Non-poor**	**Transient poor**	**Non-poor**
Individual level				
Estimated idiosyncratic variance	-0.02**	-0.08**	-0.026	0.05
Female	-0.014	0.008	0.0002	0.006
Married	0.034	0.016	0.064**	0.041
Height	0.014	0.057	0.077***	0.028
Member of socio-pol. organization	-0.047	-0.009	0.032	0.057
Health status				
Can manage	-0.056***	-0.084**	0.024	-0.035
Sick	0.004	-0.068*	-0.009	-0.069
Present well-being				
Same as last year	0.034	0.03	0.013	0.046
Better than last year	0.06**	-0.007	0.134***	0.123***
Much better than last year	0.05*	0.034	0.036	0.003
Time	0.071***	-0.006	0.125**	0.171***
District level				
Estimated covariate variance	-0.032	-0.052	-0.235***	-0.153**
Intercept	2.893***	2.589	-2.061	0.068
σ_{eij} (individual level)	0.647	0.967	0.575	0.354
R^2_i	0.119	0.156	0.254	0.233
N_i	1166	578	835	512
σ_{uj} (district level)	9.97e^06	0.511	1.145	1.21
R^2_j	0.99	0.459	0.267	0.211
N_j	45	45	31	31

Notes: Dependent variable is willingness to take risk. Coefficients are standardized. Single, double, and triple asterisks (*,**,***) denote $p < 0.10$, 0.05, and 0.01, respectively.
Source: DFG 756 Survey 2008 and 2010; own calculations

This result is, however, sensitive to the chosen poverty line. Therefore, we run the same multilevel regression model for different consumption thresholds which we commonly apply to Thailand and Vietnam (Table 4.7). In both countries, idiosyncratic and covariate shocks affect the willingness to take risk of the transient poor as the threshold increases. In Vietnam we observe this pattern from the US$4 (PPP$) threshold and in Thailand from the US$5 (PPP$) threshold on ward. Possibly, transient poor that are pushed in and out of poverty are more likely to be affected by idiosyncratic and covariate shocks, because correlated variations in consumption reduce their ability to cope with shocks.

We also observe that transient poor are distinctively different from chronically poor in Vietnam. Across all poverty thresholds, the willingness to take risk of the chronically poor is only affected by covariate shocks. At the US$4 threshold, not only covariate shocks decrease the willingness to take risk of transient poor, but also idiosyncratic shocks. Probably respondents in permanent poverty have lower consumption variation than transient poor and find other coping strategies to buffer idiosyncratic shocks e.g. by means of individual risk-sharing arrangements or safety nets (Dercon 2002; De Weerdt 2005; De Weerdt and Dercon 2006). However, these mutual insurance mechanisms across individuals seem to perform worse for wealthier respondents in Vietnam.

The results for Thailand suggest that such mutual insurance may not be existent, because idiosyncratic shocks significantly affect transient poor respondents' willingness to take risk across all thresholds. In addition, the willingness to take risk of the transient poor at a higher threshold is also significantly altered by covariate shocks. This observation indicates that shocks that are correlated across individuals are likely to influence wealthier respondents in Thailand.

Table 4.7 Sensitivity analysis with different consumption thresholds (in US$ PPP per capita per day)

Consumption threshold	Thailand			Vietnam		
	Chronically poor	**Transient poor**	**Non-poor**	**Chronically poor**	**Transient poor**	**Non-poor**
US$2.5 PPP		N_i = 517	N_i = 914		N_i = 869	N_i = 300
Est. idio. variance	N.a.	-0.049	-0.04	N.a.	-0.032	0.069
Est. cov. variance		0.008	-0.065**		-0.244***	-0.202***
US$3 PPP		N_i = 905	N_i = 525	N_i = 145	N_i = 913	N_i = 105
Est. idio. variance	N.a.	-0.051**	-0.01	-0.036	-0.031	0.036
Est. cov. variance		-0.001	-0.093**	-0.126***	-0.269***	-0.138
US$4 PPP		N_i = 1179	N_i = 111	N_i = 468	N_i = 725	
Est. idio. variance	N.a.	-0.043**	-0.004	-0.043	-0.053**	N.a.
Est. cov. variance		-0.041	-0.088	-0.142*	-0.321***	
US$5 PPP		N_i = 1204		N_i = 818	N_i = 384	
Est. idio. variance	N.a.	-0.046**	N.a.	-0.015	-0.076*	
Est. cov. variance		-0.048*		-0.17**	-0.266***	N.a.
US$6 PPP		N_i = 1105		N_i = 964	N_i = 185	
Est. idio. variance	N.a.	-0.064***	N.a.	-0.008	-0.128**	N.a.
Est. cov. variance		-0.053**		-0.197**	-0.208**	

Notes: Dependent variable is willingness to take risk. Each model controls for the same covariates as in Tables 4.4 and 4.6. Coefficients are standardized. Single, double, and triple asterisks (*,**,***) denote $p < 0.10$, 0.05, and 0.01, respectively. N.a. means coefficients are not available because of small sample size.
Source: DFG 756 Survey 2008 and 2010; own calculations

4.6 Summary and conclusions

Large-scale shocks like a war (Callen et al. 2014), a tsunami (Cassar et al. 2011) or a volcano outbreak (Willinger et al. 2013) can trigger substantial changes in people's risk attitudes. In contrast, idiosyncratic shocks like unemployment or illness seem not be related to individual risk attitudes (Doss et al. 2008).

In this paper we aimed to examine the impact of large-scale and idiosyncratic shocks on changes in individual risk behavior over time using variation in consumption as an exogenous measure of the impact of shocks experienced. In addition, we investigated if the impact of shocks on changes in risk attitudes is different between poor and non-poor respondents.

We found that risk attitudes significantly change over time, i.e. on average respondents appeared to become more willing to take risk both in Thailand and Vietnam. Furthermore, we found that idiosyncratic shocks affect risk attitudes of respondents in Thailand, whereas covariate shocks altered risk attitudes of respondents in Vietnam. The result appears plausible considering the differences in social policies.

Investigating the impact of shocks for poor and non-poor respondents separately showed that the magnitude of covariate shocks is larger for the poor than for the non-poor in Vietnam. We also investigated the impact of shocks across different consumption thresholds. We found that only covariate shocks affect the willingness to take risk of chronically poor, whereas idiosyncratic and covariate shocks matter for transient poor at a higher consumption threshold in Vietnam. In Thailand, the willingness to take risk of transient poor is affected by idiosyncratic shocks across all thresholds. At a higher threshold also covariate shocks matter. One possible explanation is that transient poor respondents that move in and out of poverty have lower abilities for shock prevention and mitigation and perceive the shock impact larger which in turn leads to increasing risk aversion. Consequently, transient poor respondents whose risk attitudes are affected by both kinds of shocks may be more likely to remain poor (Mosley and Verschoor 2005).

The results may also indicate that the chronically poor in Vietnam perform better in insuring idiosyncratic shock impacts than wealthier respondents. Possible insurance mechanism may include individual risk-sharing or safety nets across poor individuals that support each other in case of idiosyncratic shocks (Dercon 2002; De Weerdt 2005; De Weerdt and Dercon 2006).

For Thailand, the results suggest that such mutual insurance mechanisms to cope with idiosyncratic shocks are not working well. The finding may point to a possible lack of social cohesion and may indicate a division of the Thai society.

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