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Spatial implications of digitization: State of the field and research agenda

Lukas Haefner | **Rolf Sternberg**

Leibniz University Hannover, Institute of Economic and Cultural Geography, Hannover, Germany

Correspondence
Lukas Haefner, Leibniz University Hannover, Institute of Economic and Cultural Geography, Hannover, Germany.
Email: haefner@wigeo.uni-hannover.de

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Abstract

Digitization is an influential megatrend that is quickly and comprehensively transforming economic spaces worldwide. Its disruptive power has not yet been fully developed but, despite a lack of topical empirical or theoretical research, it nevertheless seems clear that it will significantly affect the economic order within and between economic spaces and places. Currently, digitization is high on the policy agenda in many countries. Several related programs and initiatives combine expansion and improvement of digital infrastructure with efforts to reduce spatial economic inequality and to facilitate a general catch-up process for lagging (often rural) regions. However, the idea that digitization can reduce spatial inequality remains highly controversial. This study aims to focus on the economic geography implications of digitization and to enrich the existing literature in two ways. First, the study overviews the state of research on the spatial consequences of digitization. Deploying a comprehensive literature review, this section discusses the primary theoretical and empirical results from two contradictory narratives on the ability of digitization to reinforce the death of distance and thus reduce spatial inequality. Second, we develop a research agenda concerning select fields of research that could appropriately be addressed in the future by economic geographers. These fields include spatial economic digitization effects, digital

competencies, entrepreneurial activities, and innovation activities in both urban and rural regions. Closing the research gaps would contribute to the development of much-needed policy measures.

KEYWORDS
digitization, digital competencies, digital entrepreneurship, digital innovation, digital transformation, lagging regions, spatial inequality

1 | DIGITIZATION AND INTERREGIONAL INEQUALITY

Inter-regional economic inequality in Europe has increased over the last decades (Iammarino, Rodríguez-Pose, & Storper, 2019). While most large cities are growing, many rural areas and smaller cities are facing economic stagnation or decline. Because of a lack of opportunities, people in these regions often feel left behind. Increasingly, these lagging, predominantly rural regions have risen up in protest against the established political system and shown their discontent by electing populist parties (Dijkstra, Poelman, & Rodríguez-Pose, 2020). Because this "revenge" is endangering social cohesion (Rodríguez-Pose, 2018), the growing discontent has attracted the attention of public, scientific, and political debates. Market-based processes and policy measures did not stop the growth of these disparities. Many politicians now encourage Internet expansion and digitization, believing that this will compensate for the missing agglomeration advantages in rural regions by diminishing the importance of spatial proximity, thus decreasing inter-regional inequality. Emphasizing the power of the Internet is not new; the "death of distance" was proclaimed over 20 years ago (Cairncross, 1997). However, inter-regional disparities have since increased. The thesis of Internet-led decentralization is thus doubted by many (Camagni & Capello, 2005), including some former enthusiasts (Cairncross, 2018). According to them, the Internet's potential to reduce the importance of distance is exaggerated (Morgan, 2004). Moreover, the effects of the Internet are inseparably connected to digitization—and digitization may even exacerbate disparities. Digitization creates many opportunities for innovation that are primarily seized in urban regions with higher innovation capacities, resulting from the large variety of specialized companies and supporting stakeholders. Therefore, the Internet and digitization do not simply compensate for disadvantages in rural regions; they simultaneously complement agglomeration advantages. The simultaneousness of centrifugal (i.e., decreasing disparity) and centripetal (i.e., increasing disparity) forces through digitization has been labeled "The Paradoxical Geographies of the Digital Economy" (Moriset & Malecki, 2009).

Within the last decade, digitization has entered a new phase. The first phase enabled production, consumption, and communication through digital means. The second phase of digitization has additionally enabled the widespread digitization of physical objects with embedded software. Connecting myriad physical objects like production machines, cars, or radiators to one another and to data networks and application systems, has extended the Internet's application areas and maintained its major importance in digitization (Hirsch-Kreinsen, 2016). For example, by facilitating innovative business models (Parida, Sjödin, & Reim, 2019), digitization yields unknown, disruptive consequences for the economy and society as a whole (Hirsch-Kreinsen, 2016; Loebbecke & Picot, 2015; Servoz, 2019).

For this article, we define digitization as the adoption of digital applications and technologies, including emerging technologies, in all sectors of the economy. Due to the pervasiveness of digitization, defining it in greater detail seems pointless for economic geographers. Nevertheless, it is important to note that digitization and its spatial effects go far beyond changes in single branches, professions, or forms of working. Technologies for storing and processing big data, artificial intelligence, cyber-physical systems, advanced use of software, or production technologies like 3D printing, are diffusing and placing pressure on many established industries, companies, professions, products, and processes. On the one hand, digitization has created "digital industries" like consumer electronics and continues to create digital

industries, such as the industrial data generating and processing industry (Clark & Sudharsan, 2020). On the other hand, due to their widespread use, information and communication technologies (ICT)—especially the Internet—are often regarded as "General Purpose Technologies", which drive follow-up innovations in all industries (Bresnahan & Trajtenberg, 1995). Consequently, established industries like car manufacturing have also changed and are still changing, with potentially novel spatial impacts. This is due to new digital production and processing technologies and increasing digitization of products themselves. Production technologies such as 3D printing have the potential to significantly alter the location patterns of the manufacturing sector (Gress & Kalafsky, 2015; Rehnberg & Ponte, 2018). Knowledge-intensive service sectors are also being affected more than ever (Servoz, 2019). Consequently, digitization is increasingly challenging established business models (Loebbecke & Picot, 2015; Nambisan, Wright, & Feldman, 2019; Parida et al., 2019) and reconfiguring value chains (Rehnberg & Ponte, 2018; Strange & Zucchella, 2017).

This article concentrates on spatial economic effects of digitization. To date, there is surprisingly little scientifically sound and empirically valid evidence concerning the spatial implications of current digitization. Moreover, the recent studies that have been conducted have come to diverging conclusions regarding whether digitization strengthens urban or rural regions relative to each other. Considering the tremendous economic, political, and social significance of digitization, this knowledge gap poses a problem. This has been reinforced by the COVID-19 pandemic. This crisis has put additional pressure on firms and business models and is likely to accelerate the adoption of digital technologies due to their potential for remote working. The pandemic may strengthen digital business models and decrease the importance of geographical proximity. There will certainly be abundant research on the effects of the pandemic. Although these effects are not our research object and we do not discuss them further, the pandemic is likely to impact future research in the areas discussed in various ways.

Supply gaps for broadband Internet, mostly for very fast and to a minor degree also for average connections (Briglauer, Dürr, & Gugler, 2019; Lobo, Alam, & Whitacre, 2020), still hinder digitization, especially in rural regions. This undersupply has been identified and is already being tackled (Briglauer, Dürr, Falck, & Hüschelrath, 2019). Although the undersupply in rural regions should not be overlooked, we believe that research on "the second-level digital divide" would be more productive (Büchi, Just, & Latzer, 2016; Evangelista, Guerrieri, & Meliciani, 2014; Philip & Williams, 2019). In most industrialized countries, insufficient Internet access (the first-level digital divide) is just one of many factors explaining the divide in the usage of digital technologies. Factors like skills, age, or other sociodemographic variables are also hampering digitization, probably with a greater significance than broadband access in the long term. Our article focuses on digitization specifically in companies, rather than digitization in private domains (which also has spatial economic consequences).

Our study has two primary goals. First, we present the current state of theoretical and empirical research on the spatial economic implications of digitization. Based on personal experience and a systematic review, we have created a selection from the relevant literature on economic geography, our area of expertise. The systematic part consists of a Scopus databank analysis (15 years, economic geography and regional economics) with relevant search strings covering the topics we address in Sections 2 and 3. To assess the potential impact of digitization on inter-regional economic inequality, we distinguish between the impacts on rural versus urban regions. Second, building on the current state of research, we outline a research agenda that identifies four areas in which economic geography and related disciplines can contribute to a better understanding of the spatial implications of digitization. New findings could support the development of policy measures that, for example, aim at fostering catch-up processes in lagging regions.

2 | SPATIAL ECONOMIC IMPLICATIONS OF DIGITIZATION: THE CURRENT STATE OF RESEARCH

At the level of companies and economic sectors, empirical studies mostly show that the use of digital technologies increases productivity (Bertschek, Briglauer, Hüschelrath, Kauf, & Niebel, 2015; Vu, Hanafizadeh, & Bohlin, 2020). However, research on the spatially relevant economic effects of digitization remains limited. While digitization

mitigates some of the disadvantages faced by rural regions, it also enhances the agglomeration advantages that have created economic prosperity in many cities. Of course, regions are multifaceted and interwoven in various ways and cities are not necessarily more affluent than rural regions. However, by contrasting centrifugal and centripetal effects, we illustrate that digitization promotes contrary forces regarding its spatial implications; the results for regional development and inter-regional inequality are not yet clear. Our overview of digitization's impacts on inter-regional inequality is divided into theoretical and empirical research. We devote special attention to digital entrepreneurship, regional human capital, and digital competencies as important factors that influence the intensity and direction of digitization.

2.1 | Theory

According to the initial narrative on the spatial economic effects of digitization, opportunities from mass Internet use exist mostly for companies in rural, often economically weak, regions. New development prospects for these regions were expected, even to the point that they would catchup with economically stronger urban regions. This idea is based on the assumption that the Internet has made large parts of the economy "weightless," with spatial distances losing their importance (Quah, 2000). Because information, ideas, digital (intermediate) products, and tacit knowledge (Malecki, 2017) can be exchanged digitally, geographically isolated companies can be better integrated into networks and value chains. Moreover, these companies can use previously inaccessible external resources and participate in larger market areas (Grimes, 2005). This generally diminishes agglomeration advantages, particularly the importance of frequent face-to-face contacts, thus reducing the "rural penalty" that rural companies historically faced (Galloway, Sanders, & Deakins, 2011; Malecki, 2003). Cairncross (1997) describes the decreasing importance of geographical proximity as the "death of distance" but has also postulated a more recent perspective (Cairncross, 2018). Again, these arguments are topical since novel and powerful digital technologies have very recently changed fundamental economic processes, leading to a new digitally driven openness. Current digital transformation is increasing opportunities not only in terms of who can participate in innovation or entrepreneurship, but also in terms of what and how they can contribute (digital transformation, see Nambisan et al., 2019). Knowledge, for instance, is increasingly cocreated in virtual spaces (Malecki, 2017), not only in the service sector but also in manufacturing companies using modern digital production technologies (Rayna, Striukuva, & Darlington, 2015). Advanced digital technologies allow for more flexible arrangements by disconnecting work processes from specific locations (Loebbecke & Picot, 2015). This could potentially lead to a more balanced distribution of added value in value chains (e.g., between places, Rehnberg & Ponte, 2018). Evolving digital technologies increase novel distribution or remote work opportunities; companies in rural regions, in particular, could benefit from the decreasing importance of locations. Of course, this would depend on the existence of adequate Internet infrastructure (Grimes, 2003; Townsend, Wallace, Fairhurst, & Anderson, 2017).

Nevertheless, a second, contrasting narrative denies that the Internet and digitization counterbalance the urban advantages associated with spatial proximity. This narrative rejects the notion that rural regions will catchup through increased digitization. Although ICT facilitates transporting codified, person-independent knowledge over long distances, transmitting person-related and context-dependent tacit knowledge still requires face-to-face interaction (Morgan, 2004). Therefore, corporate learning continues to occur primarily through trust-based personal encounters in places with a critical mass of human interaction: that is, in cities. As digitization offers new opportunities for interactive learning, it may potentially complement rather than substitute for agglomerations, especially as ICT is used primarily in cities (Craig, Hoang, & Kohlhase, 2017). In addition, digitization generates new business practices, causing "strategic reorientation," which exacerbates disparities (Camagni & Capello, 2005). This can be explained by the complementary nature of ICT to (predominantly urban) human capital (Akerman, Gaarder, & Mogstad, 2015), as well as the increasing importance (in times of uncertainty) of spatial proximity between the

sender and receiver for the transmission of codified knowledge (Leamer & Storper, 2001). Given the potential consequence of the possibly increasing importance of face-to-face contacts and regional innovation capacities, digitization could actually increase urban–rural disparities (Moriset, 2017).

In principle, digitization affects all companies, but it is plausible to assume that effects differ depending on company age and/or size. This assumption has spatial economic consequences because the spatial distribution of companies also differs according to age and size. For most of today's start-ups, product sales and marketing and even development are based on Internet-driven digitization. Increasing digitization accompanies the process of "creative destruction" sensu Schumpeter. In this recreation, young companies can often seize digital opportunities more effectively than larger companies (Malecki, 2003), which is why political leaders have explicitly promoted digital start-ups for quite some time (McQuaid, 2002). Through the intensive use of digital technologies, company founders in many sectors could theoretically settle anywhere (Brydges & Hracs, 2019). Due to the growing Internet affinity of most start-ups and their founders, along with the consequently increasing distance-independence, rural regions could benefit more from such start-ups than before—provided that broadband infrastructure is sufficient (Cumming & Johan, 2010; Müller & Korsgaard, 2018; Zhang & Li, 2018). This has been demonstrated in small home-based businesses (Philip & Williams, 2019) or firms in creative industries (Townsend et al., 2017). In rural regions, start-ups could thus avoid the disadvantages of agglomeration (e.g., wages and living costs), which harm small, low-capital start-ups more than established companies. This could negate the concept of "entrepreneurship as an urban event" (Bosma & Sternberg, 2014; Pereyra, 2019). Digitization could render space less relevant for entrepreneurship, although digital entrepreneurship should not be interpreted as being space-neutral or even footloose. Regional factors, such as the depth of companies' and employees' digital competencies, make it very unlikely that digitization and the Internet will lead to a death of distance in entrepreneurship.

2.2 | Empirical research

Case studies have shown that the use of digital technologies provides opportunities for companies in rural regions (Townsend et al., 2017). Other empirical findings, however, have revealed disproportionate digitization-related innovation activities in economic centers. Projects related to industry 4.0 have so far been implemented primarily in economically strong areas (Ciffolilli & Muscio, 2018; Rehnberg & Ponte, 2018). Thus, the "Paradoxical Geographies of the Digital Economy" (Moriset & Malecki, 2009) remain evident even in empirical research.

Econometric studies have demonstrated the positive economic effects of ICT at the national level (Bertschek et al., 2015; Gómez-Barroso & Marbán-Flores, 2020), even though many effects of emerging digital technologies are not yet evident (Brynjolfsson, Rock, & Syverson, 2019). Such studies often measure the impact of the availability or use of Internet infrastructure on variables such as gross domestic product (GDP) growth, productivity growth, average income, or employment rates. To some extent, this can be understood as an approximation of digitization's effects, since the Internet's "General Purpose Technology" nature makes it a central technology in digitization. In his assessment of the effects of ICT investments on economic growth, Niebel (2018) confirms the consistent effects of digitization even among developing, emerging, and developed countries.

At the subnational level, studies on the macroeconomic effects of Internet infrastructure show much less uniform results. What they clearly show is that the expansion of digital infrastructure does not necessarily lead to a catching-up process in rural regions. A study on rural regions in the United States in an earlier phase of digitization shows that rural regions located near urban agglomerations seem to benefit most from ICT investment, in terms of employment or annual payroll (Kandilov & Renkow, 2010). A more recent study found that public broadband investment in rural communities can help prevent emigration, but such support does not create jobs (Briglauer et al., 2019). For city regions, it appears that digital infrastructure is a necessary but not sufficient condition for regional economic growth (Tranos, 2012). Some studies that integrate both urban and rural regions have found that improving digital infrastructure has no effect on household income or the number of jobs (Whitacre, Gallardo, &

Strover, 2014) or unemployment rates (Czernich, 2014). Kolko (2012) reports the strongest positive effects on employment growth in regions with low population densities, but no effects on average wage. While some studies confirm stronger positive effects in rural than in urban regions for various dependent variables (Bertschek et al., 2015; Fabritz, 2013; Ivus & Boland, 2015), meta-studies come to the opposite conclusion, indicating a potential overall increase in inter-regional inequality (Tranos, 2016; WWG, 2015). Regarding fast Internet connections, Briglauer et al. (2019) have recently shown that the positive effects of broadband Internet (at least 50 Mb/sec) on GDP growth are higher in cities than in rural regions. In emerging economies, digitization seems to contribute to inter-regional convergence (Celbis & de Crombrugghe, 2018; Jung & López-Bazo, 2020).

While it remains unclear whether centripetal or centrifugal forces prevail, and thus how rural or urban regions are affected by digitization, empirical studies show that regional characteristics can influence digitization effects. Advantageous conditions can exist in every kind of region, but it is unlikely that they are evenly distributed among regions. It seems that the sheer availability of ICT is less determinative in driving the scope and direction of spatial digitization effects than the way in which ICT is deployed by users (Mack & Faggian, 2013; Salemink, Strijker, & Bosworth, 2017). Whitacre, Gallardo, and Strover (2014) report that increased use of the Internet in rural areas can contribute to income growth and lower unemployment. However, they found no effects from increased Internet availability (Whitacre et al., 2014). For companies, the qualification level of their employees is an important factor for how digital technologies are used. The lack of expertise and qualifications among employees are still obstacles to seizing digitization opportunities (Rachinger, Rauter, Müller, Vorraber, & Schirgi, 2019). In contrast, highly skilled employees and knowledge-intensive companies and industries particularly benefit from digitization (Akerman et al., 2015; Berger & Frey, 2016). This can apply to regions as well—regions with a highly skilled labor force benefit strongly from digitization (Forman, Goldfarb, & Greenstein, 2012; Hasbi, 2020; Mack & Faggian, 2013). Thus, human capital is a crucial factor that affects not only regional digitization effects but also inter-regional inequality.

Human capital plays a central role not only for existing companies; new companies seem to settle especially in regions with not only sufficient Internet infrastructure but also high human capital levels (Hasbi, 2020; McCoy, Lyons, Morgenroth, Palcic, & Allen, 2018). This result contradicts the assumption that start-ups become more footloose even though Internet infrastructure has become an important prerequisite in the start-up process (Audretsch, Heger, & Veith, 2015). The regional differences in the use of digital technologies that favor urban regions stem only partially from ICT availability (Salemink et al., 2017; Townsend, Sathiaseelan, Fairhurst, & Wallace, 2013). The lack of relevant skills in digital technologies has long been considered a reason that companies in rural regions have difficulties in seizing digitization opportunities (Grimes, 2005). Arguably, this indicates a digital divide between rural and urban regions in usage skills and the actual usage of digital technologies (Prieger, 2013; Salemink et al., 2017). The main cause of this digital divide favoring urban regions is their relatively high number of young, well-educated inhabitants and employees (Blank, Graham, & Calvino, 2018; Schleife, 2010). However, econometric results have previously shown that this potentially harmful divide is not (yet?) leading to a digitization-driven increase in inter-regional inequality.

3 | RESEARCH AGENDA: TOWARD A BETTER UNDERSTANDING OF DIGITIZATION'S EFFECTS ON INTER-REGIONAL INEQUALITY

We propose four topics for future research in economic geography and related disciplines. For each area, we outline three research opportunities. In these areas, significant research gaps exist and new research would profitably inform policy measures regarding social cohesion, regional development, innovation, and entrepreneurship. Reducing these research gaps would provide a much-needed basis for analyzing, forecasting, and politically managing future spatial digital transformations, which may be more extensive than the digital transformations to date.

3.1 | Econometric studies on the macroeconomic effects of digitization on the regional level

The first research opportunity in this area comprises econometric studies on macroeconomic variables such as growth in GDP, productivity, and income to assess the impact of digitization on regional economic development and inter-regional inequality. In contrast to the national level (Vu et al., 2020), evidence at the regional level is sparse (see the overview in Gómez-Barroso & Marbán-Flores, 2020). Such studies should address modern digital technologies, because their effects may differ from those of less advanced technologies. This could be the case for fast Internet connections (Ahlfeldt, Koutroumpis, & Valletti, 2017; Hasbi, 2020; Lobo et al., 2020). However, this has not remained empirically unchallenged (Bai, 2017; Ford, 2018; Whitacre, Alam, & Lobo, 2018). Additionally, it is important to analyze the spatial economic impact of previously less widespread but potentially disruptive digital technologies other than the Internet. For example, technologies for harnessing artificial intelligence or Industry 4.0 could affect the spatial implications of digitization in the future (Brynjolffson et al., 2019; Rehnberg & Ponte, 2018), potentially leading to increased inter-regional disparities (Ciffolilli & Muscio, 2018). Vu et al. (2020) has proposed conducting natural experiments to assess the effects of such emerging technologies. Gómez-Barroso and Marbán-Flores (2020) highlight the improvement in data quality in recent years and the need for sharing data in the future to facilitate new research at the regional level. Improved data could also allow for more appropriate econometric methods like Growth Accounting Analyses (Vu et al., 2020). Moreover, these studies should include data on regional characteristics, such as sociodemographic factors, in order to assess the impact of regional determinants on digitization's effects and to account for the complexity of spatial configurations.

A second research opportunity goes beyond ICT availability, which constitutes only a necessary condition for ICT usage; usage actually generates the economic effects. In order to obtain more precise data on spatial digitization effects, econometric studies must examine other factors affecting the regional degree of digitization, such as the usage of different digital technologies, the share of IT specialists, or digital public services. However, regional data on the usage of digital technologies in firms are scarce, particularly in Europe (Billon, Lera-Lopez, & Marco, 2016; Ruiz-Rodríguez, Lucendo-Monedero, & González-Relaño, 2017). Therefore, as a first step, meaningful indicators for ICT usage are needed. Harnessing social media and other public sources of big data (see von Bloh, Broekel, Özgun, & Sternberg, 2020) could generate useful data and introduce such indicators. Web-scraping is a central instrument here, and online surveys could also yield data at a tolerable expense. Many digitalized physical objects automatically generate and store data when used. Obtaining this data is difficult for researchers, but it would offer numerous options for researching where, how, and when digital technologies are being used (see Clark & Sudharsan, 2020).

The third research gap in this area surrounds digitization-driven job substitution for not only low-skilled but also high-skilled workers, which is an enormous threat for many regions (Frey & Osborne, 2013; Servoz, 2019). Thus far, it is unclear whether or not a highly qualified labor force will continue to benefit disproportionately from digitization (Akerman et al., 2015; Autor, 2015; Frey & Osborne, 2017); alternatively, it may be more at risk due to technological developments (Brynjolfsson & McAfee, 2011; Loebbecke & Picot, 2015; Servoz, 2019). Various technologies may have different employment effects (Balsmeier & Woerter, 2019) or these effects may be generally overestimated (Wajcman, 2017). However, "good" new jobs seem to emerge primarily in professions and sectors with a large stock of human capital (Berger & Frey, 2016/Berger & Frey, 2016; Balsmeier & Woerter, 2019). In addition to using data from labor statistics, text-mining job ads or activities reports may constitute a promising method for compiling and analyzing novel data regarding regional employment effects.

3.2 | Regional digital competencies

Only in regions with skills sufficient to efficiently utilize digital technologies will employees and the general population be able to master the challenges of digitization and take advantage of its concurrent opportunities. Yet

there are significant research gaps regarding the operationalization and attainment of digital skills for a company's employees and decision-makers, as well as the spatial distribution of these skills. In some countries such as Germany, there have been initial attempts to empirically and comprehensively record digital competencies (InitiativeD21, 2019), but these data only concern competencies in private domains. Indicators for firms must capture not only digital adoption (usage and experience) but also digital orientation (perception and assessment; Alam, Erdiaw-Kwasie, Shahduzzaman, & Ryan, 2018). We propose the following definition: digital competencies are an individual or company's ability to use digital technologies in entrepreneurial, professional, and private contexts, while assessing the economic, social, and ecological effects of these technologies and responding accordingly. Digital competencies and abilities are principally acquired through both formal and informal learning. The focus is on competencies related to digital technologies, which are relevant for business formation, leadership, and business innovation. Data on these skills must be gathered separately for management and employees. Technical skills are the primary focus of digital competencies. Nonetheless, practical skills and specific skills in digitization management should both be included in these studies.

Gathering such data in surveys is demanding. However, given the widespread anxiety regarding digital skill gaps, the first research opportunity in this area lies in gathering quantitative longitudinal data on the spatial distribution of digital competencies in companies and the general public. Such data would shed light on the idea that there is an increasing digital divide between rural and urban regions, along with its reasons and effects (Park, 2012; Philip & Williams, 2019; Salemink et al., 2017). Missing access to broadband Internet in some regions may be one reason among many others.

Digitization is transforming human capital (Castellacci, Consoli, & Santoalha, 2020). Given its importance for regional development, a changing spatial pattern of human capital endowment through digitization would have far-reaching consequences. As a second research opportunity, it is therefore important to consider whether digital competencies mimic or differ from the spatial patterns of conventional human capital indicators like formal education. This comparison is feasible when data for regional digital competencies are available. Moreover, studies have indicated that informal education is more decisive than formal education for the usage of digital technologies (Billon et al., 2016; Evangelista et al., 2014), and thus potentially for acquiring digital competencies. Research should analyze whether this constitutes an opportunity for poorly endowed regions to develop human capital through seminars and training programs that increase digital participation and competencies (Billon et al., 2016).

The third research opportunity calls for qualitative place-sensitive studies to complement quantitative work. Because digital competencies are not uniformly implemented, activated, or restricted among regions, they may therefore have differing consequences and benefits (Richardson & Bissell, 2019). For instance, digital competencies trigger technological diversification particularly in less wealthy regions (Castellacci et al., 2020). Group discussions with employees, as well as qualitative ethnographic research (see Philip & Williams, 2019) in comparative regional analyses, could reveal the impact of diverse spatial arrangements on utilizing digital competencies. This information could be useful for effective implementation of strategies regarding a region's digital future (Alam et al., 2018). An inter-regional comparison of the effects of government programs aimed at fostering digital competencies would offer valuable insights into the mediating role played by regional characteristics.

3.3 | Digitization and the geography of innovation

By fostering interactive learning with suppliers or customers, open innovation enables companies to apply external knowledge to their own innovation activities. Because cities offer more external knowledge, they are regarded as centers of innovation (Glaeser, 2011; Pike, Rodríguez-Pose, & Tomaney, 2006). However, this view has been contested recently (Fitjar & Rodríguez-Pose, 2020) and innovation activities in the periphery have received increasing attention (Eder, 2019; Rodríguez-Pose & Wilkie, 2019; Shearmur, 2015; Shearmur & Doloreux, 2016). Some economic geographers have conceptualized rural (open) innovation as “slow innovation,” which is

characterized by strategic information-seeking and the low importance of time-sensitive, market-based information and regular face-to-face contacts. By contrast, urban "fast innovation" requires time-sensitive market-based information and frequent face-to-face interaction (Shearmur, 2015; Shearmur & Doloreux, 2016). Despite its transforming character, the question of how digitization influences innovation activities has not yet been systematically integrated into the innovation literature (Nambisan et al., 2019). Despite initial attempts at illuminating this question (Morgan, 2004; Schmidt, Müller, Ibert, & Brinks, 2018), the first research opportunity regarding innovation calls for the comprehensive integration of digitization in future conceptual work on regional innovation (systems). Because innovation processes and preconditions differ between (rural and urban) regions (see Tödtling & Trippl, 2005), digitization should be expected to affect their innovation activities differently.

Additionally, the role of geographical proximity in open innovation must be reassessed. Digitization increases openness in innovation (Nambisan et al., 2019), enabling virtual networks and knowledge co-creation in virtual spaces (Grabher & Ibert, 2014; Malecki, 2017), even in creative and complex innovation processes (Lyytinen, Yoo, & Boland, 2016; Verstegen, Houkes, & Reymen, 2019). From a technological perspective, the digitization of physical objects, along with emerging technologies like 3D-visualization tools, cloud computing, and digital platforms, creates new forms of cooperation (Nambisan et al., 2019). New (spatial) innovation arrangements can be established, even in sectors with very tangible inputs (Lyytinen et al., 2016; Rayna et al., 2015). From a social capital perspective, however, while digital technologies have thus far helped to extend firms' networks, face-to-face interaction remains crucial for building trust (Bathelt & Turi, 2011; Townsend, Wallace, Smart, & Norman, 2016). As remote working and online events become ordinary, the psychological barrier against building trust via ICT could decrease. Consequently, advancing technological opportunities could induce more distance-independent innovation arrangements (Bathelt & Turi, 2011), possibly to the advantage of rural regions. However, the role of potential supply gaps of broadband Internet must be considered here. Processual, dynamic analyses could elucidate the interaction of physical and virtual spaces in collaborative innovation activities (see Aslesen, Martin, & Sardo, 2019), applying concepts from social psychology could enrich research in this domain (Bathelt & Turi, 2011). Moreover, a mixed-methods approach seems warranted. Expert interviews at firms regarding their innovation activities (Rachinger et al., 2019), accompanied by quantitative analyses using survey data or big data from firm websites or social media, could provide information on the innovation behavior and collaborations of firms.

Firms often need to reorganize to realize the full benefits of digital technologies (Parida et al., 2019). Hence, digitization boosts process and organizational innovation opportunities and necessities (Nylén, 2015). Regional characteristics like institutional and sociodemographic factors can influence how such innovations are implemented, as well as their outcomes. Older decision-makers or less-skilled employees may be less willing or able to implement innovations (Evangelista et al., 2014; Rachinger et al., 2019). Cultural factors must also be considered (Martinéz-Caro, Cegarra-Navarro, & Alfonso-Ruiz, 2020). In-depth case studies as a third research opportunity can reveal the role of spatial aspects in firms' organizational change, for example, regional social and economic characteristics, institutions, and actors. Such studies should integrate and contrast the views of different groups inside the firm (employees, management, and IT department) and outside the firm (consultants, users and customers, and public authorities). It may be particularly worthwhile to study the introduction of emerging technologies like artificial intelligence and compare digital reorganization in successful versus less successful firms and regions.

3.4 | Digitization and the geography of entrepreneurship

The first research opportunity concerns digital entrepreneurship. Hitherto, there has been a consensus among economic geographers engaged in regional entrepreneurship that the decision to found a company and the entrepreneurial success that potentially follows are, in addition to certain characteristics of the entrepreneur, primarily influenced by regional context factors (Feldman, 2001; Sternberg, 2009). Before digitization, entrepreneurship was strongly embedded regionally; thus, a concept of entrepreneurship as a region-specific process has

been plausible and economically rational (Dahl & Sorenson, 2012). This has led to urban regions having a location advantage over rural regions (Bosma & Sternberg, 2014).

The far-reaching importance of digitization in entrepreneurship has led to the establishment of the term "digital entrepreneurship," which may warrant its own research agenda (Nambisan et al., 2019). Thus far, spatial aspects have enjoyed only minimal consideration. Digitization creates countless opportunities to start a business, as traditional products and business models can be replaced. Because of the growing importance of ICT and digital intermediate and final goods, these new companies could theoretically be founded anywhere, including rural regions. Broadband Internet is an important facilitating factor in entrepreneurial decisions at the regional level (Hasbi, 2020; McCoy et al., 2018). However, there is currently a significant lack of large-scale, statistically representative empirical studies on digital entrepreneurship in rural areas. The rare exceptions (e.g., Townsend et al., 2017) show that digitization indeed offers new opportunities for creative entrepreneurs, but access to broadband that is fast (or at least not slower than in cities) may be relevant for those working in rural areas. Internet access and speed seem to be only necessary but not sufficient conditions to make rural areas an absolute (or even relative) winner in digitization, compared to urban areas. In fact, empirical research on remote British areas has shown the importance of "fit-for-purpose broadband in promoting digital inclusion for individuals, households, and small, home-based businesses" when seeking to avoid increasing interregional disparities due to (and not despite of) digitization at the expense of remote rural regions (see Philip & Williams, 2019). More empirical studies are needed on digital entrepreneurship outside of the well-known urban hotspots, and a research design that is comparable (across time and subnational regions in different countries) would be helpful in creating evidence for more (and better) spatially sensitive policy attempts.

In addition to infrastructure availability, the spatial patterns of digital competencies might also be relevant for entrepreneurial activities. What matters is the way in which digital technologies are used. Only entrepreneurs with sufficient digital competencies can perceive and seize digitization opportunities; only regions that provide potential entrepreneurs with sufficient digital competencies can benefit from digital start-ups. By acting as digital pioneers, such start-ups could be "agents of change" that transform rural economies (Feldman, 2014). Digital pioneers may be especially important for peripheral regions, where individual agency is of particular relevance (Döringer, 2020). In-depth research concerning, the spatial distribution of competencies in digital entrepreneurship remains lacking. This gives rise to the second research opportunity. Future studies should provide empirical evidence on the relationship between a population's digital competence (and openness) and the location decisions of digital entrepreneurs (even they are located somewhere). Potentially, digitization provides the opportunity for entrepreneurs to (re)locate to rural areas and profit from low-cost (labor, land, and infrastructure) if they know (or at least perceive) that the local population has the requisite digital competences. In other words, the digital competencies of the local population may become a location factor in a rural entrepreneur's location decision. To the best of our knowledge, no empirical work has yet been done on this topic.

The concept of Entrepreneurial Eco-Systems (EES) considers not only the potential entrepreneur but also surrounding actors; it is intensively discussed in regional entrepreneurship research (e.g., Feldman, Siegel, & Wright, 2019; Malecki, 2018; Sternberg, von Bloh, & Coduras, 2019). Internet-based start-ups also play an important role for local start-ups and growth processes (Autio, Nambisan, Thomas, & Wright, 2018). When applied to EES, with an implicit reference to the "Paradoxical Geographies of the Digital Economy" (Moriset & Malecki, 2009), affordance (*sensu* Nambisan et al., 2019) describes a central effect of digitization on business formation. Affordance has both an implicitly spatial component ("digital affordances") and an explicitly spatial component ("spatial affordances"; Autio et al., 2018). In some places, digitization can increase the territoriality of EES but simultaneously contribute to the creation of "virtual ecosystems," in which EES actors do not share any physical space (Nambisan et al., 2019). To date, it remains unclear whether physical space is gaining or losing importance for start-ups. Therefore, new research on the importance of space in EES is required. Future literature on EES should explicitly consider how digitization affects the territoriality of specific EESs. Again, empirical evidence is currently quite rare regarding this topic This is surprising given the high and still-increasing popularity of the EES idea among scholars and local policymakers (Brown & Mawson, 2019). This third research gap is a perfect arena for empirically skilled economic geographers.

4 | CONCLUSION

Digitization is currently very high on the policy agenda in many countries, also in terms of regional policies. Economic geographers should exploit the (place-related) research opportunities that emerge out of this hype and should not leave the field to other disciplines, as happened 2 decades ago with previous regional economic policy blockbusters like clusters (see Martin & Sunley, 2001). Politicians in many countries have recognized that missing digital infrastructure can be one cause for economic marginalization in many rural regions. Digitization clearly offers the opportunities for companies and rural populations that politicians have long desired. Upgrading infrastructure alone is not enough to seize these opportunities. Rather, endogenous regional factors (e.g., digital competencies, sociodemographic and economic factors, the composition of branches, and regional institutions) and mechanisms (e.g., knowledge co-creation, use of external knowledge, start-up opportunities, market access, and telecommuting) must be understood and therefore explicitly addressed in empirical studies, both cross sectional and longitudinal.

This article has summarized existing research on the effects of digitization on inter-regional inequality and has proposed a research agenda to address the many knowledge gaps concerning the spatial economic implications of digitization. Specifically, we have identified four relevant research areas for economic geography. First, quantitative studies on the regional economic effects of digitization, including income and employment effects, should aim to better comprehend the extent to which digitization has affected (and will potentially continue to affect) inter-regional inequality. The second research area calls for comprehensive data and a deeper understanding of the role played by regional digital competencies in generating digitization effects. The third and fourth research areas call for further conceptual and empirical research on how digitization shapes innovation and entrepreneurship, respectively.

In order to help lagging regions benefit from digitization and decrease inter-regional inequality, the knowledge gained from these research areas must be applied to developing efficient policy measures that respect regional characteristics such as actor constellations (companies, administration, and politics) and the importance of individual agency (Döringer, 2020). Policy measures must be both developed and assessed; future research could potentially help with both steps. So far, political programs are either very recent or have not yet been implemented. It is too early for empirically valid and generalizable *ex-post* analyses. In the future, however, such analyses should constitute an important pillar of economic geography and spatial economic research on digitization. Economic geographers should always raise their voices whenever policymakers or scholars act—consciously or unconsciously—in a spatially blind manner.

Obviously, our research agenda only provides a list of relevant questions. Nevertheless, addressing these research gaps constitutes a pivotal contribution to answering open questions and establishing a scientific foundation for much-needed policy measures. There is no doubt that digitization will continue to gain influence. It is important to consider that digitization does not happen haphazardly. Digitization and its outcomes can—at least partially—be shaped, if there is sufficient knowledge about how to effectively shape it. Promising areas for policy measures include developing digital competencies that align with regional characteristics and fostering digital entrepreneurship in weak EES. However, there are currently too many unknowns—hence our call for new research in support of desired goals, such as reducing inequalities between rural and urban regions.

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ORCID

Lukas Haefner https://orcid.org/0000-0001-6333-7071

Rolf Sternberg https://orcid.org/0000-0002-7649-0419

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AUTHOR BIOGRAPHIES

Lukas Häfner is a PhD student at the Institute of Economic and Cultural Geography at the Leibniz University Hannover. At the Institute of Economic and Cultural Geography, he works as academic associate within a third-party-funded project. His research interests lie in digitization, spatial economic change, and innovation and entrepreneurship in rural regions.

Rolf Sternberg is a full Professor of Economic Geography, Institute of Economic and Cultural Geography at the Leibniz University Hannover. His main research interests include the spatial causes and effects of entrepreneurship, of innovation networks, and of clusters. For his research projects and publications see www.wigeo.uni-hannover.de and http://scholar.google.de/citations?hl = de&user = 0wOZa1MAAAAJ. Since 1998 he is the leader of the German team of the Global Entrepreneurship Monitor (GEM). He is also a member of the GEM Research and Innovation Advisory Committee (RIAC) and belongs to the Associate Editors of several journals.

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