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An urban-rural divide (or not?): Small firm location and the use of digital technologies

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Abstract:

Regarding the spatial impact of digitalization, the concern is often expressed that rural areas and the companies located there are disadvantaged by a digital divide compared to urban regions. Against this background, this paper explores the role of the urban/rural location of a small firm in the use of digital communication and information technologies (ICT). With the help of a cluster analysis approach, different modes of digitalization in the German small enterprise sector are identified. According to this, four groups of small firms can be distinguished in accordance to the maturity level concept of digital transformation: non-digital firms, digital beginners, platform-oriented firms and digital manufacturers. From a spatial perspective, it can be seen that the members of the platform-oriented group are relatively often located in urban regions, whereas the digital manufacturers are relatively often found in rural areas. These findings are interpreted as an indication that small firms at least partially consciously assign themselves to one of these digitalization modes, depending on which business model is most effective in the respective (urban or rural) business environment. By contrast, whether a small firm has not yet done anything in terms of digitalization or is only at the beginning of the digital transformation process does not significantly depend on the location of the company. The paper concludes with implications for policy and research.

JEL: D22; O33; R11; R12

Keywords: Digitalization; Rural regions; Digital divide; Urban-rural typology; SMEs

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1. Introduction

Addressing the particular challenges and exploiting the opportunities that exist in rural areas for people, firms and municipalities have a high priority on the policy agenda (Roberts et al., 2017; OECD, 2020). In this context, it is expected that digitalization is having and will continue to have a profound influence on rural business environments (Philip et al., 2015). However, at present it is not completely clear whether and to what extent rural companies – especially those with a smaller firm size – will be among the winners or losers of the digital transformation. The latter could be assumed if there is a digital divide between urban and rural regions, which especially confronts small rural firms with a number of barriers to take full advantage of the digital age, such as a lack of high-speed internet access or the unavailability of digitally savvy employees (Domenech et al., 2014; Franelli, 2021). Indeed, there is some empirical evidence that small rural firms are lagging behind in the context of digital transfor-mation due to an urban-rural divide, at least in certain aspects (e.g. in terms of broadband connectivity or the use of online marketing; see e.g., Richmond et al., 2017; Palmer-Abbs et al., 2021; Thonipara et al., 2022).

On the other hand, in line with the “death of distance” postulate (Cairncross, 2001), the use of digital technologies could be expected to reduce the "penalty" of larger distances from densely populated urban areas by making geographic location less relevant, especially for small, resource-constrained firms in rural areas, potentially allowing them to achieve relatively high returns from digital transformation (Galloway et al., 2011; Domenech et al., 2014; van der Loo et al., 2015). Moreover, the specificities of rural business environments also play a role in this context. Small rural firms can be expected to choose strategies adapted to the requirements of their local business environment when using new (digital) technologies. As a result, they are not automatically less innovative than their urban counterparts, but often simply different in terms of business model and technology use (Deakins and Bensemann, 2019; Fanelli, 2021). For example, small firms in rural areas are often strongly focused on local markets and locally oriented trade, which can be the actual reason for their lower use of business models for digital environments such as e-commerce or internet platforms (Galloway et al. 2011). Accordingly, not every difference between urban and rural firms in the adoption and use of digital technologies should be due to rural regions being disadvantaged by a divide with urban areas. One could assume that this may also be related to other factors, such as the industrial base of a region or the different nature of business-customer relationships in various spatial contexts, which can make the use of certain digital technologies either more or less meaningful from a small rural firm’s perspective.

Against this background, this paper examines the question of what role the urban/rural location of a small firm plays in its use of digital technologies. Theoretically, a company’s decision to adopt and use digital communication and information technologies (ICT) can be described as a result of a rational calculation that depends on internal resources and capabilities and the characteristics of the market, industrial and local contexts (Galliano and Roux, 2008). This is likely to hold particularly when a firm is small in size: it has long been known from the innovation literature that the use of new technologies in small firms – at least in theory – is strongly influenced by their resource and capability constraints and a high degree of dependence and responsiveness to the external business environment (Nooteboom, 1994; Hewitt-Dundas, 2006).

At the same time, a number of empirical studies point to the heterogeneity of the small enterprise sector in terms of innovation (e.g. Jong and Marsili, 2006; Thomä and Bizer, 2013). The results from Soluk and Kammerlander (2021) suggest that this also applies to the usage of digital technologies. According to their findings, the nature and level of digitalization in small and medium-sized enterprises (SMEs) strongly varies with different internal and external factors, which differ in terms of how strongly they relate to where a company is located. This heterogeneity of small firms in terms of digitalization is therefore the focus of the following empirical analysis on the relationship between the ur-ban/rural location of small firms and their use of digital ICT.

The contribution of this paper is twofold. First, it adds to the literature on the digital divide between rural and urban regions (for a literature review, see Haefner and Sternberg, 2020). We examine the spatial usage patterns of a broad set of digital ICT with varying degrees of complexity and different fields of application that can be used by small firms in their day-to-day operations. Related papers on the question of whether small rural firms face a digital divide compared to their urban counterparts often adopt a somewhat narrow focus on specific aspects such as broadband connectivity and the likelihood of website use or online marketing. As a result, other digital ICT in business functions such as production, logistics or administrative operations tend to be neglected (see e.g. Richmond et al., 2017; Palmer-Abbs et al., 2021; Thonipara et al., 2022). Second, this paper adds to studies examining the general validity of an urban-rural dichotomy in explaining differences in economic and innovation performance between SMEs from different spatial contexts (e.g. Deakins and Bensemann, 2019; Laurin et al., 2020). In our empirical analysis of the heterogeneous spatial patterns in small firm digitalization, we will therefore also examine the extent to which a basic urban-rural dichotomy is still meaningful.

The remainder of the paper is organized as follows. In Section 2, the conceptual basis for our exploratory empirical analysis is derived from the literature. A number of working propositions are formulated, which – although not testable in a strict sense – nevertheless underpin the empirical part from a theoretical perspective. Section 3 presents the data set and describes our methodical procedure, before the results are detailed in Sections 4 and 5. Finally, in Section 6 we summarize our findings and conclude with implications for policy and research.

2. Theory

2.1. Models of ICT adoption

When modeling the rationale for a small firm to adopt digital ICT, it is necessary to distinguish between "epidemic effects" and "rank effects" (Galliano and Roux, 2008; Reino et al., 2011). The empirical results of Galliano and Roux (2008) imply that ICT use by rural firms is primarily determined by rank effects (with the exception of sector-related epidemic effects), whereas according to their results an urban firm's intensity of ICT usage is strongly driven by epidemic effects. The latter relates to the role of knowledge spillovers and network effects for the diffusion of new technologies. From this perspective, the more information about a new digital technology that is available to potential users on the customer side and the faster the rate of diffusion, the larger the number of ICT adopters at the company level. Such epidemic effects should thus mainly come to bear in densely populated urban areas where higher levels of knowledge spillover from ICT users to non-ICT users take place, not least because the digitalization activities of firms (especially smaller ones) also depend on the ICT use by private households, given that they are their main customers (Billon et al., 2016).

Hence, a business model based on digital marketing and internet-based customer contact should be an effective strategy, especially for small urban firms. On the other hand, their counterparts from rural areas with lower population densities are likely to be less strongly influenced by "epidemic effects" in their decision to use digital ICT. This is consistent with empirical evidence that the rural business environment is characterized by a persistent focus on local markets and locally oriented trade, which could imply that small firms in rural areas are fundamentally less inclined to adopt business models for digital environments (Galloway et al., 2011).

By contrast, from the perspective of rank effects, the decision to adopt and use digital ICTs results from a rational calculation made by the company. Here, various company-related characteristics such as size, financial resources, internal capabilities, industry context, local market conditions or the costs and complexity of a new digital technology are important determinants of corresponding decisions at the company level (Galliano and Roux, 2008; Reino et al., 2011). As mentioned above, weighing up such factors is likely to be relatively important in small firms in general due to their resource and capability constraints and their strong dependence and responsiveness to the external business environment. However, such rank effects are likely to be particularly important for small firms in rural areas, as it can be particularly challenging to conduct business in rural environments due to a lack of locally available resources and skills, or because they are relatively distant from key urban markets (Laurin et al., 2020). Hence, depending on rank effects, some small rural firms may be able to derive higher net benefits from adopting digital ICTs than others. From this view, the rural location of a small firm may be indicative of an urban-rural digital divide (see Subsection 2.2). However, at the same time, some rank effects such as the nature of the industrial base in a rural region may be rather helpful features in explaining the particular spatial environment in which small firms are successfully operating (and digitalizing). Manufacturing SMEs in rural areas are an illustrative example of this. As mature firms, in many cases they are quite innovative and competitive (for the case of the UK, see e.g. North and Smallbone, 1996, 2000; Smallbone et al., 1999; for the case of the German "Mittelstand", see e.g. Lehrer and Schmid, 2015; Pahnke and Welter, 2019; Rietmann, 2022). Business models based on digital enabling technologies of Industry 4.0 (e.g. in terms of digitally controlled means of production or data collection and digital transmission between facilities, manufacturing processes and products) should therefore offer small rural manufacturing firms many opportunities and potential for innovation and improvement (Somohano-Rodríguez et al., 2022). This leads to two working propositions.

WP1: The adoption of digital ICTs by small firms from urban areas is strongly influenced by epidemic effects.

WP2: The adoption of digital ICTs by small firms from rural areas is mainly influenced by rank effects.

2.2. Urban-rural digital divide

Epidemic effects can also be related to the degree of accessibility to new sources of digitalization, and thus a potential divide between urban and rural areas. This is the case because the location of a small firm may be associated with fundamental barriers to the adoption of digital ICTs, such as a general lack of knowledge about new digital ICT among customers in rural areas or limited infrastructural conditions for rural firms to participate in the economic opportunities of digital technology diffusion (Reino et al., 2011; Fanelli, 2021). There are a number of studies on the question of whether there is such a digital divide between firms in rural and urban regions (for an overview, see Salemink et al., 2017; Haefner and Sternberg, 2020). Two levels of a possible digital divide between urban and rural areas are distinguished. The first one refers to internet availability, which can mean both basic access and the performance of the existing connection (i.e. whether or not high-speed internet access is available). Both are often seen as a locational disadvantage of rural areas, potentially limiting the ability of rural SMEs to seize the benefits of digital ICT (van der Loo et al., 2015; Palmer-Abbs et al., 2021; Thonipara et al., 2022). A second-level digital divide between rural and urban areas may exist in terms of ICT usage and the availability of relevant skills and capabilities. In these cases, driving factors such as the qualification and age of the workforce may be weaker in rural companies than in urban areas, which could leave small firms in rural regions at a long-term disadvantage in the digital transformation process (Richmond et al., 2017; Fanelli, 2021; Thonipara et al., 2022). Hence, there are two further working propositions.

WP3: Small rural firms face a lack of digital connectivity in comparison with their counterparts from urban areas, especially in terms of high-speed internet access.

WP4: Sociodemographic factors such as the skills and age of the workforce explain a digital divide between small firms from rural and urban areas.

3. Data and methods

The empirical analysis is based on data from the IAB Panel 2017 (Bellmann et al., 2019). The data was accessed via remote data processing to the Research Data Centre (FDZ) of the Federal Employ-ment Agency (BA) at the Institute for Employment Research (IAB). The IAB Panel is an annual labor market survey of establishments in Germany. The survey sample is representative of all German firms with at least one employee subject to social security contributions and for all economic sectors (Ellguth et al., 2014; Fischer et al., 2009). We reduced the 2017 data in two ways: first, only firms with a maximum of 49 employees are taken into account so that our investigation refers to small firms according to the European Commission's SME definition; and second, establishments that are part of larger or diversified enterprises are excluded. This allows a focus on economically independent companies (i.e. a qualitative characteristic of small firms, see Curran and Blackburn, 2001), which are truly free from external control in their decision whether and how to use digital ICT.

In the 2017 panel wave, the small firms in our sample were asked to assess their use and perceived importance of nine different types of digital ICT on a six-point Likert scale, of which 8,331 fully responded to this question set (Table 1). The order in which these digital technologies are listed in Table 1 – which also corresponds to the order of the respective items in the IAB Panel questionnaire – is based on the concept of digital maturity (Cristobal-Fransi et al., 2020; Mittal et al., 2018; Brodny and Tutak, 2021; Jones et al., 2021; Rodríguez-Espíndola et al., 2022). According to this, digital transformation at the company level is understood as a step-by-step development process that follows a certain pattern from the first basic steps into digitalization to more complex digitalization aspects. This is reflected in the descriptive statistics in Table 1, whereby – as expected – a relatively large proportion of small firms in our sample already uses IT-supported work equipment or mobile devices within the firm, while only relatively few companies are already so far advanced in the digital transformation that they attach stronger importance to digital sales channels or the use of digital enabling technologies of Industry 4.0.

In the first part of the empirical analysis (Section 4), we will condense the information on these nine digital ICTs into three factors (i.e. main types of digital ICT) using factor analysis. The resulting factor scores are then used as cluster variables to ascertain how the use of digital ICT is related to a company's spatial context. This is based on the theoretical assumption that a company's urban/rural location influences or shapes its decision to use digital technologies in one way or another (see Section 2). For this purpose, we also consider a variable in the statistical cluster analysis that measures whether a small firm is located in a rural area or not.

To generate this binary cluster variable, we use two pieces of information from the IAB Panel: first, information on whether the county ("Landkreis") in which a company is located is classified as rural in official statistics; and second, we also take into account the fact that "rural" does not always necessarily mean the same thing, in the sense that certain rural municipalities are located closer to (or even integrated into) functional metropolitan areas than other, more remote rural municipalities (OECD, 2020). For this purpose, we use the German BIK classification (Table A1 in the Appendix), which measures urban-rural relations at the municipality level and can therefore be taken as an indication of whether the rural municipality of a small firm is intertwined with a functional metropolitan area (see e.g. Hoffmeyer-Zlotnik, 2003; Hank and Huinink, 2015). The BIK indicator groups those municipalities into "BIK regions" that have a relevant functional interaction, i.e. a certain number of commuters. These regions are differentiated according to their number of inhabitants, and the larger ones are internally divided into core and non-core areas (see Table A1). On this basis, we define a small firm as rural if its county is classified as rural and – at the same time – the company's municipality is not located in the core of a functional metropolitan area, so that it does not have the opportunity to benefit directly from urban advantages in terms of digitalization (see Table 1). According to this definition, 39% of the small firms in our sample have a rural location.

Table 1. Descriptive statistics of the clustering variables (N = 8,331)

Variable	Description	Mean
Variables on the use and importance of digital ICT		
• IT-supported work equipment (e.g. stationary computers, electronic cash registers, CAD systems)	Assessment for each digital technology using the scale from '0 = non-usage' to '5 = usage and very important'	4.47
• Use of mobile devices within the firm (e.g. laptops, notebooks, smartphones, tablets, data glasses)		3.90
• Software, algorithms or web interfaces for IT-based optimization of business processes (e.g. big data analyses, cloud computing systems)		2.00
• Social media I: for staff recruitment		0.60
• Social media II: for internal and external communication		1.19
• Digital procurement (e.g. internet platforms, crowd working)		0.80
• Digital sales channels for product distribution (e.g. internet platforms or online shops)		0.90
• Program-controlled means of production (e.g. industrial robots or CNC machines)		0.44
• Networking and data exchange between facilities, processes or products (e.g. Smart Factory, drones, cyber-physical, systems Internet of Things, self-propelled machinery)		0.33
Rural location	1 if a small firm's municipality is located in a rural county and not in the core of a functional metropolitan area (i.e. none of the BIK codes 10, 8 and 6), 0 otherwise	0.39

Based on this statistical cluster analysis, we identify four groups of small firms in terms of the relationship between digital ICT use and urban/rural location. In the second part of the empirical analysis (Section 5), we then use multinomial probit regression to examine the determinants of membership in these groups. The explanatory variables are selected not least against the background of the theoretical statements in Section 2. This serves to profile the identified clusters and provides further information on the conditions under which a small firm might choose a particular digitalization strategy depending on its location.

4. Results I: Exploratory analysis

As a first step, the nine digital ICT variables were condensed into composite measures using factor analysis to obtain robust cluster variables (Hair et al., 1998). To ensure that the original variables are sufficiently correlated to justify the use of factor analysis, two standard measures are used, with Bartlett's test for sphericity (7255.48, $p < 0.000$) and the Kaiser-Meyer-Olkin measure of sampling adequacy (KMO = 0.688) both showing satisfactory results. The latent root criterion (eigenvalues > 1) was used to decide on the number of factors to extract.

According to the results of the factor analysis, three main types of digital ICT can be distinguished (see Table A2 in the Appendix): The factor of "basic digital technologies" is characterized by higher loadings on IT-supported work equipment, the use of mobile devices within the firm and IT-supported optimization of business processes. The use of social media for recruitment or communication purposes, digital procurement and the use of digital sales channels for product distribution load on the second factor of "digital platform technologies". The factor of "digital manufacturing technologies" shows high loadings on digital technologies of Industry 4.0 (program-controlled means of production; digital-based networking and data exchange between facilities, processes or products).

The factor scores for these three factors serve as metric cluster variables standardized to a mean of zero and a standard deviation of one. A fourth cluster variable – as mentioned above – measures whether a company is located in a rural or urban region. On this basis, a hierarchical clustering procedure is carried out using Ward's method with squared Euclidean distances. The result shows a clear four-cluster solution (Table 2).[1] All cluster variables significantly differ across the identified groups of small firms, confirming that they are distinctive in view of the cluster variables. In accordance with the concept of digital maturity, small firms can thus be divided into four different groups regarding the use of digital ICT and the urban/rural location of the company. The first group is labeled as "non-digital firms", comprising 17.4% of the small firms surveyed. Corresponding companies are below average in all three types of digital ICT: especially in the terms of basic digital technologies, they perform significantly worse than the other groups. Members of the first group are thus likely to be companies that have not yet even taken basic steps in the digital transformation. In spatial terms, it is noticeable that the proportion of rural small firms in this group is only slightly above, but overall close to the sample average. The question of whether a small firm is "non-digital" thus hardly seems to depend on whether the company's location is in an urban or rural region.

Table 2. Cluster solution: mean values of the clustering variables (N = 8,331)

	Total	Cluster of small firms				Chi-square
		(1)	(2)	(3)	(4)	
Use and importance of digital ICT (factor scores)						
Basic digital technologies	0.00	-1.66	0.44	0.27	0.14	3587.72*
Digital platform technologies	0.00	-0.08	-0.48	1.35	0.04	3338.32*
Digital manufacturing technologies	0.00	-0.14	-0.37	-0.51	2.24	4195.05*
Rural location	38.91	41.46	39.76	27.04	48.64	142.48*
Share of sample in percent	100.0	17.43	50.29	18.56	13.72	
Label		Non-digital firms	Digital beginners	Platform-oriented firms	Digital manufacturers	

* report a significance level of 1 percent (Kruskal-Wallis test, Pearson's chi-square test)

[1] This was shown by the associated dendrogram of hierarchical clustering and confirmed by the results of two cluster stopping rules implemented in our statistical software (Calinski/Harabasz pseudo-F index; Duda-Hart index).

The second cluster of small firms is the “digital beginners” group (Table 2), accounting for the largest part of the sample with 50.3 %. The companies in this group have already acquired basic competences in the field of digitalization through the use of basic digital technologies (above-average importance of this factor), while digital platform or digital manufacturing technologies (still) play a below-average role. Regarding the question of whether a company is located in a rural or urban area, no spatial concentration tendency can be detected in case of this group of digital beginners.

Small firms participating in the platform economy are to be found in the third group. In addition to basic digital technologies, the companies in this group strongly rely on the use of digital platform technologies (“platform-oriented firms”; Table 2). They are relatively often found in urban regions, which is reflected in the below-average share of rural small firms in this group (27.04 % compared to the overall average of 38.91 %). Hence, as expected (see Section 2), it appears that for small rural firms in comparison to urban ones it is less likely to have a business model based on digital marketing and internet-based customer contact using platform technologies.

The label of "digital manufacturers" was chosen for the fourth cluster of small firms. According to the maturity concept of digital transformation, the companies in this group have reached a relatively advanced level of digitalization, as they have implemented or are in the process of implementing digital manufacturing technologies according to the principle of Industry 4.0 in addition to basic digital technologies and digital platforms (Table 2). Interestingly, the members of the fourth group are relatively likely to be located in rural areas (a 48.6% share of rural companies compared to the total share of 38.9%), which confirms that rural small firms can indeed be innovative in terms of digitalization, depending on certain "rank effects" such as the industrial base of their region.

The results displayed in Table 3 show that the derived cluster solution holds predictive validity. Four variables that were not used for clustering but can theoretically be assumed to be related to a company’s digitalization activities are used for validation. The number of employees indicates the firm size and thus the company’s resource base. Here, it can be seen that the small firms in the "digital manufacturers" group are the largest with an average of 19.3 employees per company. This is consistent with the above finding that relatively complex, resource-intensive digitalization projects are carried out in this group. Something similar applies to the platform-oriented firms (Group 3), where firm size is also relatively high with an average of around fourteen employees. On the other hand, in the "digital beginners" and "non-digital" groups, the average firm sizes are lower – as expected – with the latter group having the fewest employees on average (8.2 per firm).

The percentage of employees under 30 years old is used as an indicator of the within-firm presence of so-called “digital natives” who by nature are more predisposed to drive digitalization activities at the company level (Table 3). In this case, the small firms in the platform-oriented group are particularly well positioned, followed by the digital manufacturers. Among both the non-digital firms and digital beginners, the share of digital natives among the workforce is below average and similar in the two groups. Regarding the proportion of highly qualified employees – as an indicator of the necessary skill base within the company to cope with the process of digital transformation – the picture is similar to that of the findings on digital natives, with the group of non-digital firms lagging relatively far behind in this case.

Table 3. Validating the cluster solution: mean values for four variables not used for clustering

	Total	Cluster of small firms				Chi-
		Non-digital firms	Digital beginners	Platform-oriented firms	Digital manufacturers	
Number of employees (total)	12.13	8.21	10.86	13.98	19.26	635.45*
Percentage share of employ-	14.99	13.17	13.28	20.38	16.31	233.54*
Percentage share of highly	0.06	0.03	0.06	0.08	0.07	271.21*
High-speed internet access [a]	76.57	63.88	77.22	84.65	79.31	190.40*

Note: Within-cluster results are provided. For example, the average firm size in the “digital beginners” group amounts to 8.21 employees, while the overall sample mean is 12.13 employees.

* report a significance level of 1 percent (Kruskal-Wallis test, Pearson's chi-square test)

[a] 1 if a firm has high-speed internet access, e.g. broadband connections such as DSL, UMTS or LTE

Finally, the availability of high-speed internet access is used as a spatially related validation variable, which often lies in the focus of related studies (see Section 2). Here, it can be seen that in the group of non-digital firms, the proportion of those with a broadband connection is actually the lowest (63.9 % compared to the total sample average

of 76.6%; Table 3), while among platform-oriented firms – which are often found in urban areas – the proportion of small firms with high-speed internet access is relatively high, as expected (85%). In the group of digital beginners, the corresponding share is in line with the overall average of the sample, while it is slightly higher among digital manufacturers.

5. Results II: Multinominal probit regression

Multinomial probit regression is used to derive a more in-depth profile of the four small firm groups based on a set of variables that can be assumed to be related to a company's digitalization activities (and thus contribute to the prediction of cluster membership). Table A3 in the Appendix provides an overview of the independent variables and their descriptive statistics. A multinomial probit model is appropriate because our dependent variable is categorical in nature. The base category here is the "digital beginners" group (Cluster 2). The regression coefficients are listed in Table A4 in the Appendix. They must always be interpreted in relation to the base category, i.e. they form relative probabilities. By contrast, the average marginal effects of the multinomial probit coefficients are presented in Table 4, which show the effects of an independent variable on the absolute likelihood of falling into one of the four groups.

Table 4. Average marginal effects after multinomial probit (dep. variable: cluster membership)

	Cluster of small firms			
	Non-digital firms	Digital beginners	Platform-oriented firms	Digital manufacturers
Log (number of employees)	-0.034***	-0.030***	0.021***	0.043***
Start-up firm	0.046***	-0.105***	0.058***	0.001
Digital natives	0.000	-0.002***	0.002***	0.000
Highly qualified workforce	-0.234***	0.131***	0.035	0.068***
Family-led business	0.016	0.004	-0.033**	0.013
High-speed internet access	-0.090***	0.020	0.054***	0.015*
Operational investments	-0.050***	-0.013	0.022**	0.040***
Technological innovation	-0.044***	-0.058***	0.061***	0.040***
Export activity	-0.072***	-0.007	0.034***	0.045***
Strong competitive pressure	-0.019**	-0.008	0.038***	-0.011
Positive business performance	-0.019*	-0.044***	0.031***	0.032***
Growth of employment	-0.030**	-0.020	0.026**	0.023**
Craft enterprise	0.004	0.020	-0.027**	0.003
Industry sector (reference: manu-				
Construction	-0.043***	0.207***	0.056***	-0.220***
Trade	-0.029**	0.121***	0.096***	-0.188***
Services	0.011	0.107***	0.103***	-0.221***
East Germany	0.002	-0.011	-0.029***	0.038***

Notes: N = 7,433, results of the baseline regression can be found in Table A4 (appendix).
*p < 0.10, ** p < 0.05, *** p < 0.01

Regarding core company characteristics, the marginal effects in Table 4 confirm that a larger firm size is associated with a more advanced level of digitalization maturity, with the strongest effects being observed – as expected – for membership of the digital manufacturers group. A somewhat different picture emerges regarding company age: while for a young start-up firm the digital manufacturers group does not play a significant role, younger small firms are more likely to belong to the non-digital or platform-oriented groups and less likely to be digital beginners. This could indicate that the companies in the latter group tend to be older and have already passed the start-up phase. On the other hand,

start-ups are likely to have either not yet started the digital transformation (non-digital group) or the adoption of a digital-based business model forms the core of their newly launched business activity (platform-oriented group). This interpretation is supported by the fact that companies with a high proportion of "digital natives" among their employees are more likely to belong to the platform-oriented group, while in this case there is a negative correlation in terms of belonging to the digital beginners group. By contrast, the skill base of a company seems to be particularly important in the early stages of digital transformation, i.e. for the transition from the non-digital group to the digital beginners group: while a higher proportion of highly qualified employees strongly reduces the likelihood of belonging to the non-digital group, it primarily increases the probability of being a digital beginner (see Tables 4 and A4). Furthermore, there is a positive but somewhat weaker correlation between a highly qualified workforce and membership of the digital manufacturers group.

Interestingly, the question of whether a small firm is family-controlled or not only plays a role in belonging to the platform-oriented group, where a negative correlation is observed (Table 4). One possible explanation for this fact is that family firms are often particularly active in incremental innovation but tend to be more reluctant to engage in more radical types of innovation – such as in the area of radical business model innovation regarding digitalization – due to certain company characteristics (e.g. lower risk preference, preference for self-financing, certain human-related factors; see Soluk and Kammerlander, 2021).

Having a broadband connection – as expected – reduces the probability of being a non-digital firm, while it increases the likelihood of belonging to a more advanced digitalization group. The latter is especially true for being a platform-oriented firm, where a relatively strong effect of high-speed internet access is observed (Table 4). From the perspective of the maturity concept of digitalization, the relative probabilities of the multinomial probit base coefficients also hold interest in this context (see Table A4). A comparison of effect sizes in this regard indicates that high-speed internet access is more decisive for the further development of a non-digital firm into a digital beginner than for the transition from the digital beginners group to the platform-oriented group. As shown above, only the latter group shows a pronounced urban/rural difference. Hence, in line with Section 2, this suggests that other factors besides a possible digital divide (such as the business environment in urban regions, which make digital business models particularly effective) may also contribute to a small firm's preference for the platform-oriented group or its decision to choose a different strategy.

The remaining regression results confirm the previous findings and round off the profiling of the four small firm groups. A number of competition and innovation indicators are negatively correlated with belonging to the group of non-digital firms (Table 4). These are thus characterized by low investment and innovation activity and weak economic performance combined with low employment growth. However, at the same time, they obviously operate in market environments that demands less of those aspects (e.g. due to lower competitive pressure or regional sales focus). From an innovation and competition perspective, the level of operational investments and the internationality of the market environment primarily determine the transition from the group of non-digital firms to the digital beginners (see the relative probabilities in Table A4).

On the other hand, the introduction of technological innovation and an economically positive business development reduce the absolute likelihood of being in the digital beginners group and not a group with a higher level of digitalization maturity (Table 4). This suggests that in the digital beginners group, "innovation" and "digitalization" are still separate phenomena, while in the other two groups they merge. For example, a higher level of operational investment and innovation activities increases the absolute likelihood of belonging to the platform-oriented or digital manufacturer groups. The correlation with the level of operational investment is particularly strong in case of the latter group, which can be explained by the strong complexity and high resource requirements of Industry 4.0 projects, especially for manufacturing SMEs (see Horváth and Szabó, 2019; Somohano-Rodríguez et al., 2022). At the same time, innovation activity is associated with a particularly high probability of belonging to the platform-oriented group. This confirms the above findings that these small firms – which tend to be located in urban business environments – pursue innovative, digital-based business models that are often radical in nature. This goes hand in hand with a higher probability of being exposed to strong competitive pressure (Table 4). On the other hand, export activity, a positive business performance and employment growth are factors that make affiliation more likely in absolute terms for both the platform-oriented and digital manufacturers groups.

Finally, the results on the industry variables show that digitalization is an important issue in the manufacturing sector. For obvious reasons, belonging to manufacturing industries strongly increases the probability of belonging to the fourth group (Table 4). However, at the same time, manufacturing small firms are also more likely to be found in the non-digital group. By contrast, companies from construction, trade and service industries tend to belong to the digital beginners or platform-oriented groups. In the latter case, it is also noticeable that small firm from the crafts

sector are less likely be found in it. This confirms the findings of Proeger and Runst (2020), according to which craft SMEs are often weak in implementing digital, platform-supported business models.

6. Discussion and conclusions

The spatial effects of digitalization are a topic of continuing interest from both a research and policy perspective. In this context, the concern is often expressed in corresponding discussions that rural areas and the companies located there are disadvantaged in the use of new digital ICTs and therefore lag behind urban regions due to a digital divide. In order to contribute to this debate, this paper has identified different modes of digitalization using the small enterprise sector as an illustrative example and examined how these are distributed between urban and rural regions. According to the results and in line with the maturity level concept of digital transformation, four groups of small firms can be distinguished: 1) non-digital firms, 2) digital beginners, 3) platform-oriented firms and 4) digital manufacturers. Table 5 provides an overview of the derived typology.

While small firms in the first two groups use digital ICT either hardly at all (non-digital firms) or only at a basic level (digital beginners), the third group of platform-oriented firms focuses on the use of social media for personnel recruitment or communication purposes as well as the use of digital sales channels (e.g. via internet platforms or online shops). The fourth group of digital manufacturers strongly relies on program-controlled production facilities (e.g. industrial robots or CNC machines) as well as data collection and digital transmission between facilities, manufacturing processes and products (e.g. smart factories, drones, cyberphysical systems, Internet of Things). In spatial terms, it has been shown that members of the platform-oriented group often are located in urban regions. By contrast, the digital manufacturers are relatively often found in rural areas. Hence, based on our empirical results, a double "digital divide" can thus be identified, albeit in opposite directions: on the one hand, small firms pursuing new digital business models of the platform economy tend to operate in urban areas, while on the other hand, innovative small firms from manufacturing industries – which are at the forefront of Industry 4.0 digitalization processes – are often located in rural areas (at least in the case of the German ”Mittelstand”; see Pahnke and Welter, 2019).

Interestingly, there are no clear differences between urban and rural areas, neither for non-digital firms nor for digital beginners. Put differently, whether a small firm has not yet done anything in terms of digitalization or is only at the beginning of the digital transformation process does not significantly depend on where the company is located. Only in advanced stages of digital transformation does it matter whether the company is located in an urban or rural area. In general, it has been shown that the digitalization strategy of small firms is strongly determined by certain core company characteristics and the respective market and industry environment, and thus reflects the current economic and technological development status of a company (see Table 5). We interpret this is an indication that small firms at least partially consciously assign themselves to one of the identified digitalization groups, depending on which business model is most effective in the respective (urban or rural) business environment.

This leads to the policy implications of our findings. Even if the present study is not suited to disprove the existence of a digital divide to the disadvantage of rural regions, its findings nevertheless indicate that concerns about a digital divide between urban and rural areas should not be exaggerated. At the same time, this study emphasizes how important it is from a policy perspective to strengthen the framework conditions of business environments in rural and urban areas in such a way that the innovative potential of the advanced digitalization groups of platform-oriented firms and digital manufacturers can develop as optimally as possible in their respective urban or rural locations.

At the same time, the fact that a number of companies in the small enterprise sector are not yet “digital” or only at an early stage of digital transformation is an important starting point for support measures, even if there is no fundamental urban-rural divide to bridge here. Showing those small firms the potentials of such a development and supporting them in their digital transformation is therefore certainly a relevant starting point for policy, not only to turn non-digital firms into digital beginners but also to support promising companies in the group of digital beginners in the transition to a more advanced level of digitalization. Of course, the limitations of the present study must also be considered in this context. For example, it has been shown that a lack of high-speed internet access is a typical feature, especially for non-digital firms. It could play a role here that the urban-rural dichotomy – as it underlies the present study – may be suitable for capturing the broad patterns of the location-digitalization relationship, but less so for measuring the finer differentiations between various types of rural areas and the corresponding conditions of digitalization in small firms (see on this Laurin et al., 2020; Palmer-Abbs et al., 2022). Companies from certain, very remote rural regions may therefore well have a particularly strong need for support in taking their first steps towards digital transformation.

To further deepen the scientific basis necessary for this, future research could capture "rurality" in a more differentiated way when it comes to the link between the digitalization activities of small firms and their location. Another promising avenue for future research would be to transfer our study design to other countries. In Germany in particular, rural regions are characterized by a relatively high concentration of highly innovative SMEs (so-called “Mittelstand” firms). The present paper shows that this is also reflected in the area of digitalization. Future studies could therefore investigate whether the present results only apply to Germany or hold a more general relevance. Finally, it could also make sense to supplement our results with a qualitative analysis based on interview data to review the typology of small firms developed regarding their location and use of digital ICT and – if necessary – expand it to include other content-related aspects.

Table 5. Typology of small firms according to their location and use of digital ICT

	Non-digital firms	Digital beginners	Platform-oriented firms	Digital manufacturers
Digital ICT	Below-average use across all digital ICTs	Only basic digital technologies	Basic digital technologies *plus* Digital platform technologies	Basic digital technologies *plus* Digital manufacturing technologies
Urban-rural divide?	No	No	Yes, relatively often in urban regions	Yes, relatively often in rural regions
Core company characteristics	- Fewer employees - Start-up firms - Relatively few highly qualified employees - Low likelihood of high-speed internet access	- Fewer employees - Mature firms - Older employees - Highly qualified workforce - Type of internet access does not play a role	- Tendency towards more employees - Start-up firms - Younger employees - Highly qualified workforce - Lower probability that the firm is family-led - Highest likelihood of high-speed internet access	- Relatively large firm size - Relatively high likelihood of high-speed internet access
Innovation and competition	- Low level of operational investments - Low propensity to innovate - Rare activity in foreign markets - Weak competitive pressure - Unchanged or declining business volume - No employment growth	- Low propensity to innovate - Unchanged or declining business volume	- Higher degree of operational investments - Highest propensity to innovate - Strong competitive pressure - Engagement in foreign markets - Positive business performance - Employment growth	- Highest level of operational investments - Relatively high propensity to innovate - Engagement in foreign markets - Positive business performance - Employment growth
Sector	- Tendency towards manufacturing	- Construction, to some extent also trade and service firms	- Trade and services, to some extent also construction, relatively rarely firms from the skilled crafts sector	- Prominent role of manufacturing industries

Appendix A

Table A1. Spatial classification of German municipalities by using the BIK indicator (BIK region 1 to 10)

BIK indicator	Description of BIK region
1	Fewer than 2,000 residents
2	Between 2,000 and 5,000 residents
3	Between 5,000 and 20,000 residents
4	Between 20,000 and 50,000 residents
5	Between 50,000 and 100,000 residents (non-core)
6	Between 50,000 and 100,000 residents (core)
7	Between 100,000 and 500,000 residents (non-core)
8	Between 100,000 and 500,000 residents (core)
9	500,000 and more residents (non-core)
10	500,000 and more residents (core)

Source: Destatis (2021)

Table A2. Factor analysis on the use of digital ICT (principal component factoring, varimax rotated factor loadings, N = 8,331)

	Factor 1	Factor 2	Factor 3
IT-supported work equipment	-0.067	0.025	0.700
Use of mobile devices within the firm	0.151	-0.079	0.626
Software, algorithms or web interfaces for IT-based optimization of business processes	0.176	0.226	0.647
Social media I: staff recruitment	0.763	0.032	0.015
Social media II: internal and external communication	0.797	-0.052	0.058
Digital procurement	0.444	0.304	0.271
Digital sales channels for product distribution	0.512	0.215	0.191
Program-controlled means of production	-0.045	0.809	-0.008
Networking and data exchange between facilities, processes or products	0.086	0.775	0.102
Interpretation:	Digital platform technologies	Digital manufacturing technologies	Basic digital technologies

Table A3. Descriptive statistics (N = 7,433)

Metric variables	Description	Mean	S.D.
Number of employees (total)	Number of employees in 2017	11.91	11.71
Digital natives	Percentage share of employees younger than 30	15.21	18.61
Highly qualified workforce	Percentage share of highly qualified employees	0.05	0.14
Categorical variables	**Description**	**Percentage**	
Start-up firm	1 if a firm was founded 2013 or later, 0 otherwise	14.69	
Family-led business	1 if a firm is managed exclusively or partially by the owners or family members of the owners, 0 otherwise	92.90	
High-speed internet access	1 if a firm has high-speed internet access, e.g. broadband connections such as DSL, UMTS or LTE, 0 otherwise	76.63	
Operational investments	1 if a firm invested in areas such as software, information and communication technology or production facilities, plant and equipment, furniture and fixtures etc., 0 otherwise	54.43	
Technological innovation	1 if a firm introduced new or significantly improved products or processes in the previous year, 0 otherwise	37.82	
Export activity	1 if a firm had any exports in the previous year, 0 otherwise	16.70	
Strong competitive pressure	1 if a firm faces medium or substantial pressure from competitors, 0 otherwise	30.84	
Positive business performance	1 if a firms expects an increase in business volume in the current year, 0 otherwise	25.66	
Growth of employment	1 if a firms expects an increase of its total number of employees for the next year, 0 otherwise	16.94	
Craft enterprise	1 if a firm belongs to the skilled crafts sector, 0 otherwise	30.74	
Industry sector			
Manufacturing	1 if a firm belongs to manufacturing industries, 0 otherwise	22.92	
Construction	1 if a firm belongs to construction industries, 0 otherwise	11.68	
Trade	1 if a firm belongs to trade industries, 0 otherwise	18.32	
Services	1 if a firm belongs to service industries, 0 otherwise	47.07	
East Germany	1 if firm is located in East Germany, 0 otherwise	41.80	

Table A4. Multinomial probit coefficients (dependent variable: cluster membership; baseline group: Digital Beginners)

	Cluster		
	Non-digital firms	Platform-oriented firms	Digital manufacturers
Log (number of employees)	-0.101 (0.029)***	0.149 (0.028)***	0.315 (0.032)***
Start-up firm	0.387 (0.071)***	0.428 (0.067)***	0.199 (0.085)**
Digital natives	0.003 (0.001)**	0.010 (0.001)***	0.004 (0.002)**
Highly qualified workforce	-1.274 (0.283)***	-0.060 (0.168)	0.207 (0.186)
Family-led business	0.062 (0.111)	-0.143 (0.093)	0.063 (0.103)
High-speed internet access	-0.430 (0.056)***	0.200 (0.062)***	0.075 (0.067)
Operational investments	-0.202 (0.052)***	0.127 (0.051)**	0.277 (0.059)***
Technological innovation	-0.099 (0.056)	0.369 (0.052)***	0.360 (0.057)***
Export activity	-0.312 (0.084)***	0.170 (0.071)**	0.294 (0.072)***
Strong competitive pressure	-0.071 (0.056)	0.175 (0.053)***	-0.040 (0.060)
Positive business performance	-0.012 (0.062)	0.216 (0.058)***	0.280 (0.062)***
Growth of employment	-0.100 (0.076)	0.152 (0.066)**	0.180 (0.073)**
Craft enterprise	-0.014 (0.065)	-0.150 (0.065)**	-0.025 (0.069)
Industry sector (reference: manufacturing)			
Construction	-0.541 (0.095)***	-0.125 (0.102)	-1.342 (0.106)***
Trade	-0.336 (0.084)***	0.187 (0.085)**	-0.964 (0.086)***
Services	-0.133 (0.076)*	0.226 (0.079)***	-1.180 (0.077)***
East Germany	0.027 (0.052)	-0.096 (0.052)*	0.244 (0.057)***
Constant	-0.089 (0.154)	-1.803 (0.149)***	-1.672 (0.162)***

Notes: N = 7,433, robust standard errors in parentheses

*p < 0.10, ** p < 0.05, *** p < 0.01

References

Bellmann, L., Ellguth, P., Grunau, P., Hohendanner, C., Kohaut, S., Leber, U., Möller, I., Schwengler, B., Stegmaier, J., Umkehrer, M., Nußbeck, V., Oberg, S., 2019. IAB Establishment Panel (IAB BP) – Version 9317 v1". Research Data Centre of the Federal Employment Agency (BA) at the Institute for Employment Research (IAB). DOI: 10.5164/IAB.IABBP9317.de.en.v1.

Billon, M., Lera-Lopez, F., Marco, R., 2016. ICT use by households and firms in the EU: links and determinants from a multivariate perspective. Rev World Econ 152, 629–654. https://doi.org/10.1007/s10290-016-0259-8.

Brodny, J., Tutak, M., 2021. Assessing the level of digital maturity of enterprises in the Central and Eastern European countries using the MCDM and Shannon's entropy methods. PloS one 16, e0253965. https://doi.org/10.1371/journal.pone.0253965.

Cairncross, F., 2001. The death of distance: How the communications revolution is changing our lives. Harvard Business School, Boston, Mass.

Cristobal-Fransi, E., Montegut-Salla, Y., Ferrer-Rosell, B., Daries, N., 2020. Rural cooperatives in the digital age: An analysis of the Internet presence and degree of maturity of agri-food cooperatives' e-commerce. Journal of Rural Studies 74, 55–66. https://doi.org/10.1016/j.jrurstud.2019.11.011.

Curran, J., Blackburn, R.A., 2001. Researching the small enterprise. SAGE Publications, Thousand Oaks, Calif, London.

Deakins, D., Bensemann, J., 2019. Does a rural location matter for innovative small firms? How rural and urban environmental contexts shape strategies of agri-business innovative small firms. Ma-nagement Decision 57, 1567–1588. https://doi.org/10.1108/MD-07-2017-0658.

Destatis, 2021. GV-ISys Verzeichnis der Regional- und Gebietseinheiten Definitionen und Beschrei-bungen: Statistisches Bundesamt (Destatis), https://www.destatis.de/DE/Themen/Laender-Regionen/Regionales/Gemeindeverzeichnis/Administrativ/beschreibung-gebietseinheiten.pdf?__blob=publicationFile (last accessed on 29 August 2022).

Domenech, J., Martinez-Gomez, V., Mas-Verdú, F., 2014. Location and adoption of ICT innovations in the agri-food industry. Applied Economics Letters 21, 421–424. https://doi.org/10.1080/13504851.2013.864032.

Ellguth, P., Kohaut, S., Möller, I., 2014. The IAB Establishment Panel—methodological essentials and data quality. J Labour Market Res 47, 27–41. https://doi.org/10.1007/s12651-013-0151-0.

Fanelli, R.M., 2021. Barriers to Adopting New Technologies within Rural Small and Medium Enter-prises (SMEs). Social Sciences 10, 430. https://doi.org/10.3390/socsci10110430.

Fischer, G., Janik, F., Müller, D., Schmucker, A., 2009. The IAB Establishment Panel – Things Users Should Know. Schmollers Jahrbuch 129, 133–148. https://doi.org/10.3790/schm.129.1.133.

Galliano, D., Roux, P., 2008. Organisational motives and spatial effects in Internet adoption and inten-sity of use: evidence from French industrial firms. Ann Reg Sci 42, 425–448. https://doi.org/10.1007/s00168-007-0157-z.

Galloway, L., Sanders, J., Deakins, D., 2011. Rural small firms' use of the internet: From global to local. Journal of Rural Studies 27, 254–262. https://doi.org/10.1016/j.jrurstud.2011.05.005.

Haefner, L., Sternberg, R., 2020. Spatial implications of digitization: State of the field and research agenda. Geography Compass 14, 23. https://doi.org/10.1111/gec3.12544.

Hair, J.F., Anderson, R.E., Tatham, R.L., Black, W.C., 1998. Multivariate data analysis, 5th ed. Pren-tice-Hall, Upper Saddle River, NJ.

Hank, K., Huinink, J., 2015. Regional Contexts and Family Formation: Evidence from the German Family Panel 67, 41–58. https://doi.org/10.1007/s11577-015-0322-9.

Hewitt-Dundas, N., 2006. Resource and Capability Constraints to Innovation in Small and Large Plants. Small Bus Econ 26, 257–277. https://doi.org/10.1007/s11187-005-2140-3.

Hoffmeyer-Zlotnik, J.H.P., 2003. Regional Influences on Attitudes Toward Foreigners. In: Alba, R., Schmidt, P., Wasmer, M. (Eds.) Germans or Foreigners? Palgrave Macmillan US, New York, pp. 255–268.

Horváth, D., Szabó, R.Z., 2019. Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? Technological Forecasting and So-cial Change 146, 119–132. https://doi.org/10.1016/j.techfore.2019.05.021.

Jones, M.D., Hutcheson, S., Camba, J.D., 2021. Past, present, and future barriers to digital transfor-mation in manufacturing: A review. Journal of Manufacturing Systems 60, 936–948. https://doi.org/10.1016/j.jmsy.2021.03.006.

Jong, J.P.J. de, Marsili, O., 2006. The fruit flies of innovations: A taxonomy of innovative small firms. Research Policy 35, 213–229. https://doi.org/10.1016/j.respol.2005.09.007.

Laurin, F., Pronovost, S., Carrier, M., 2020. The end of the urban-rural dichotomy? Towards a new regional typology for SME performance. Journal of Rural Studies 80, 53–75. https://doi.org/10.1016/j.jrurstud.2020.07.009.

Lehrer, M., Schmid, S., 2015. Germany's industrial family firms: Prospering islands of social capital in a financialized world? Competition & Change 19, 301–316. https://doi.org/10.1177/1024529415581970.

Mittal, S., Khan, M.A., Romero, D., Wuest, T., 2018. A critical review of smart manufacturing & In-dustry 4.0 maturity models: Implications for small and medium-sized enterprises (SMEs). Journal of Manufacturing Systems 49, 194–214. https://doi.org/10.1016/j.jmsy.2018.10.005.

Nooteboom, B., 1994. Innovation and diffusion in small firms: Theory and evidence. Small Bus Econ 6, 327–347. https://doi.org/10.1007/BF01065137.

North, D., Smallbone, D., 1996. Small business development in remote rural areas: The example of mature manufacturing firms in Northern England. Journal of Rural Studies 12, 151–167. https://doi.org/10.1016/0743-0167(96)00009-5.

North, D., Smallbone, D., 2000. Innovative Activity in SMEs and Rural Economic Development: Some Evidence from England. European Planning Studies 8, 87–106. https://doi.org/10.1080/096543100110947.

OECD, 2020. Rural Well-being: Geography of Opportunities: OECD Rural Studies, OECD Publishing, Paris, https://doi.org/10.1787/d25cef80-en.

Pahnke, A., Welter, F., 2019. The German Mittelstand: antithesis to Silicon Valley entrepreneurship? Small Bus Econ 52, 345–358. https://doi.org/10.1007/s11187-018-0095-4.

Palmer-Abbs, M., Cottrill, C., Farrington, J., 2021. The digital lottery: The impact of next generation broadband on rural small and micro businesses in the North East of Scotland. Journal of Rural Studies 81, 99–115. https://doi.org/10.1016/j.jrurstud.2020.08.049.

Philip, L.J., Townsend, L., Roberts, E., Beel, D., 2015. The Rural Digital Economy. Scottish Geograph-ical Journal 131, 143–147. https://doi.org/10.1080/14702541.2015.1083732.

Proeger, T., Runst, P., 2020. Digitization and Knowledge Spillover Effectiveness—Evidence from the "German Mittelstand". J Knowl Econ 11, 1509–1528. https://doi.org/10.1007/s13132-019-00622-3.

Reino, S., Frew, A.J., Albacete‐Sáez, C., 2011. ICT adoption and development: issues in rural accom-modation. JHTT 2, 66–80. https://doi.org/10.1108/17579881111112421.

Richmond, W., Rader, S., Lanier, C., 2017. The "digital divide" for rural small businesses. JRME 19, 94–104. https://doi.org/10.1108/JRME-02-2017-0006.

Rietmann, C., 2022. Hidden Champions and their integration in rural regional innovation systems: In-sights from Germany. ZFW – Advances in Economic Geography 0. https://doi.org/10.1515/zfw-2021-0024.

Roberts, E., Anderson, B.A., Skerratt, S., Farrington, J., 2017. A review of the rural-digital policy agenda from a community resilience perspective. Journal of Rural Studies 54, 372–385. https://doi.org/10.1016/j.jrurstud.2016.03.001.

Rodríguez-Espíndola, O., Chowdhury, S., Dey, P.K., Albores, P., Emrouznejad, A., 2022. Analysis of the adoption of emergent technologies for risk management in the era of digital manufacturing. Technological Forecasting and Social Change 178, 121562. https://doi.org/10.1016/j.techfore.2022.121562.

Salemink, K., Strijker, D., Bosworth, G., 2017. Rural development in the digital age: A systematic lit-erature review on unequal ICT availability, adoption, and use in rural areas. Journal of Rural Stud-ies 54, 360–371. https://doi.org/10.1016/j.jrurstud.2015.09.001.

Smallbone, D., North, D., Kalantaridis, C., 1999. Adapting to peripherality: a study of small rural manufacturing firms in northern England. Entrepreneurship & Regional Development 11, 109–127. https://doi.org/10.1080/089856299283227.

Soluk, J., Kammerlander, N., 2021. Digital transformation in family-owned Mittelstand firms: A dy-namic capabilities perspective. European Journal of Information Systems 30, 676–711. https://doi.org/10.1080/0960085X.2020.1857666.

Somohano-Rodríguez, F.M., Madrid-Guijarro, A., López-Fernández, J.M., 2022. Does Industry 4.0 really matter for SME innovation? Journal of Small Business Management 60, 1001–1028. https://doi.org/10.1080/00472778.2020.1780728.

Thonipara, A., Sternberg, R., Proeger, T., Haefner, L., 2022. Digital divide, craft firms' websites and urban-rural disparities—empirical evidence from a web-scraping approach. Rev Reg Res 130, 1781. https://doi.org/10.1007/s10037-022-00170-5.

Thomä, J., Bizer, K., 2013. To protect or not to protect? Modes of appropriability in the small enter-prise sector. Research Policy 42, 35–49. https://doi.org/10.1016/j.respol.2012.04.019.

van der Loo, S., Chen, L., Edwards, P., Holden, J.A., Karamperidis, S., Kollingbaum, M.J., Marqui, A.C., Nelson, J.D., Norman, T.J., Piecyk, M., Pignotti, E., 2015. Development of a Digital Tool to Overcome the Challenges of Rural Food SMEs. Scottish Geographical Journal 131, 212–219. https://doi.org/10.1080/14702541.2014.994673.