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Digital transformation as a segmented process

Empirical findings from a large German employer survey

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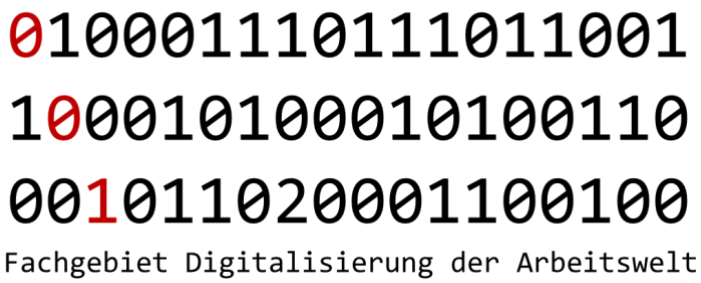

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Abstract

The view of a technologically determined, seamless and comprehensive digitalization has provoked sociological counter-arguments, claiming that digitalization processes are shaped by the interaction of technical and social conditions within systems of work and production. This paper engages with this controversy by analysing the most recent data from the German IAB Establishment Panel, which contains information on firms' usage of a variety of digital technologies. From a sociological perspective, we argue that digitalization unfolds in a highly segmented process. We show that establishments' usage of digital technologies differs substantially by industry, firm size, firm age, the extent of competitive pressure and the employee structure in the firm. Different new digital technologies are dependent on similar drivers and limitations at the firm level. Hence, our results support the idea that social embeddedness differentiates digitalization processes, resulting in a particular segmentation of firms' work and production systems.

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1. Introduction

The debate on the digital transformation in Germany has been ignited and dominated by the initial prognosis of potentially devastating employment losses (Frey/Osborne 2013) and broad concepts of digital transformation, such as "Industrie 4.0" (Spath et al. 2013). Initially, the digital economy was often expected to unfold in a seamless process thriving on radical change of technologies, polarizing employment and transforming industry structure.

This view of a seamless digitalization has provoked sociological counter-arguments (Hirsch-Kreinsen 2015; Pfeiffer 2017), claiming that digitalization processes are inadequately portrayed as being solely determined by technological or economic opportunities (e.g., increased productivity). Instead, critical views emphasize that the proliferation of new technologies is shaped by complex, mutual relations between technical and social conditions within systems of work and production (Liker et al. 1999; Howcroft/Taylor 2014). These relations lead to heterogeneous and partly paradoxical results of digitalization according to structurally and functionally different segments of work and production (Hirsch-Kreinsen 2015). Recent case study evidence supports this view, indicating that transformation takes a much more incremental path than is often expected and falls short of a radical break (Hirsch-Kreinsen 2019b; Kirchner/Matiaske 2019). However, until now, the sociological view has provided neither an integrated theoretical approach nor solid quantitative empirical evidence on the actual state and contours of the digital economy, leaving the controversy between the two opposing views unresolved.

This paper engages with this controversy by analysing the most recent data from the German IAB Establishment Panel. Building on the sociological view and complementary theoretical approaches, we argue that digitalization unfolds in a highly segmented process. Hence, we differentiate work organizations by structural characteristics, such as economic sector, firm size, competitive pressure and employment structure, and argue that the respective drivers and limitations regarding the introduction of digital technologies vary distinctly across these lines. We employ regression analysis to investigate potential segments and reveal their properties. We examine the following two research questions: 1) Which segments of German establishments have introduced digital technology? 2) Do these segments differ across different types of technologies?

Our results show that the diffusion of digital technologies is more likely for specific industries, establishment sizes and particular employment structures. This indicates that digitalization does not currently unfold in a seamless, all-encompassing process. Rather, digitalization affects establishments with specific characteristics, while other establishments do not utilize digital technologies. Overall, our results support the idea of a social embeddedness of digitalization processes that will likely subdivide the economy into specific segments and initiate distinct paths regarding changes in work and employment.

2. State of the Art and Theory

2.1 General debate: Digitalization in Germany

In Germany, debates on the most recent phase of digitalization were ignited by several widely received publications. In particular, the bleak prognosis by Frey and Osborne (2013) startled officials and civil society in Germany. The prognosis warned that the most recent wave of digitalization threatens 47 percent of jobs in the American labour market. This would not only affect low-skilled jobs that have continuously been replaced by automation for some time but also threaten routine-based medium-skilled jobs. Almost simultaneously, the "Industrie 4.0" concept (Spath et al. 2013) was proposed and initiated a discourse on the digital future of German manufacturing (Pfeiffer 2017). The core of this concept is the introduction of so-called cyber-physical systems where machines and products communicate directly and enable a new era of digitalized industry production. Among other aspects, these forecasted threats of substantial job losses and visions of a new industrial era shaped the current phase of digitalization in Germany.

The vision that digitalization would swiftly revolutionize work, employment and whole industries quickly provoked counter-prognosis and critique. For example, it was argued that for Germany, the prognosis by Frey and Osborne would not hold because qualifications and sectoral structures differ substantially from those in the U.S. and hence the actual potential for automation is overestimated. Bonin et al. (2015) argued that the prognosis underestimates societal, legal and ethical hurdles that frame and shape the introduction and usage of digital technologies. In a similar vein, sociologists highlighted that digitalization will not unfold in a seamless process. Rather, as Hirsch-Kreinsen (2015) argued, the introduction of digital technology likely progresses in various ways and contradictory steps. Instead of assuming one general pattern for all industries and employees, he proposed modelling possible future developments in several scenarios. All those scenarios are still possible, yet societal processes will determine the scenarios that actually come true.

Similarly, the Industrie 4.0 concept increasingly drew critique. While the debate on automation and potential job losses pertained to the whole economy, Industrie 4.0 narrowed digitalization to industrial sectors and associated service industries. As the concept became acknowledged by key actors in the German economy, questions arose as to how much of the Industrie 4.0 concept was practically introduced. Hirsch-Kreinsen (2019a, b) and Pfeiffer (2017) highlighted that the Industrie 4.0 concept turned out to be a discursive pattern instead of an actual introduction of practical applications in the manufacturing sector. The early claims of a swift technological revolution and the widespread introduction of Industrie 4.0 were for the moment debunked by limited adoption rates and an incremental pattern of industrial change. Here, the visions of a seamless digital transformation hit the realities of technological change and its practical implementation.

Overall, the growing difference between discourse hype and actual implementation casts serious doubt on the penetration of digital technologies in German industry as well as in the German economy as a whole. Here, however, the debate appears to be trapped by the bold claims of the most recent

phase of digitalization. In a broader view, it is easy to see that digitalization preceded the most recent stages of automation and Industrie 4.0. The introduction of computer technology in the German economy describes a long-term process that predates the current stage (e.g. Kern/Schumann 1984; Ortmann et al. 1990; Baukrowitz 2006). While the focus on particular aspects of the digitalization process has increased general awareness, the actual diffusion of digital technologies in Germany remains largely unknown. The few quantitative studies on selected digital technologies only shed some light on the practical relevance of digitalization for the German economy, or more specifically, in German establishments. Currently, it remains unclear which German establishments have introduced digital technology and whether there are particular segments of German establishments that have embarked on the digitalization trend while other establishments have not.

2.2 Segments of digitalization

To uncover the outlines of digitalization in different segments of the economy, we consider several characteristics of establishments that potentially relate to the diffusion of digital technology. For example, Hirsch-Kreinsen (2015, 2018) noted that certain establishment characteristics are likely to coincide with the adoption of new digital technologies. In the following, we elaborate on possible segmentation lines, including establishment size, industry, establishment age, industrial relations, employment structure and competitive pressure.

2.2.1 Establishment size

Several theoretical arguments suggest that larger companies are more likely to use digital technologies than small firms (Hirsch-Kreinsen 2015, p. 23). The main reason is that larger establishments command more resources that facilitate the implementation of digital technology, whereas smaller firms are likely to face several obstacles. Small and medium-sized firms may not have the budget or the possibility to fund costly investments in digital technologies. Apart from the costs of acquiring new technologies, additional costs may arise from service and maintenance or from training employees who apply the technologies. Small firms may also lack (high-skilled) IT employees and may have more severe problems recruiting these employees, which are necessary to introduce and run new technologies (Schröder 2016, p.4; Icks et al. 2017, p.2; Schöpper et al. 2018, p.41). As a consequence, otherwise reasonable investments in technology and thus feasible efficient ways of production are likely to be deferred, particularly in small firms. Further, process structures in large firms are more likely to allow an efficient application of digital technologies due to more standardized functions and subdomains and due to the larger scale of production (Hirsch-Kreinsen 2015, p. 23). Small and medium-sized companies may, however, hardly expect any productivity advantages and cost reductions and may also see little potential in offering new products and services (Arntz et al. 2016b). Furthermore, many small companies produce individual items according to special customer requirements and operate in niche markets, where historically grown employee knowledge is necessary. In combination with the often low degree of automation in small companies, modern concepts of Industrie 4.0 and digital technology are hardly adaptable (Ludwig et al. 2016, p.73). Additionally, pressure to adopt digital technologies might be substantially higher for larger establishments, as they are more involved

in discourses on innovation and depend to a larger extent on the legitimacy granted by their current activities (DiMaggio/Powell 1983).

Previous empirical research supports the general hypothesis that the diffusion of advanced digital technology is more common in larger firms (e.g. Wischmann et al. 2015; ZEW 2015; Saam et al. 2016; Schröder 2016; Icks et al. 2017; BMWi 2018). The use of digital technology thus increases gradually with the size of the company. This relationship holds across different types of digital technology. While basic information and communication technologies (ICTs) such as laptops, email and internet are used irrespective of company size, the differences between large and small companies become more evident with the increasing complexity of technologies. Big data and cloud computing technologies, human resource management tools, computer-aided facility management software and enterprise resource planning (ERP) systems exhibit the largest differences, where usage increases greatly if a company has more than 200 employees (Helmrich et al. 2016; see also Ahlers 2018).

Furthermore, it is reported that the environments (e.g., customers and suppliers) of small and medium-sized enterprises are often not adequately digitalized and that legal issues often serve as a barrier to digitalization (Lichtblau et al. 2018, p.57). A European study including five different countries also highlights insufficient digital infrastructure as well as cyber security concerns (KfW 2019). Öz (2019) reports, based on a limited number of case studies, that small companies implement new technologies much slower and take more time to restructure their organizational design to accommodate new technology. He argues that corporate digital strategies are missing, erratic solutions dominate and the potential for improvement of work processes is hardly or not at all reflected. In summary, theory and existing empirical findings suggest that the use of digital technology is more widespread among larger establishments than among small firms.

2.2.2 Industry

Although digital transformation has embraced all sectors of the economy by now, specific differences between industries can be expected. Even an extensive and disruptive transformation through digital technology will not affect all sectors in the same way (Hirsch-Kreinsen 2018). Industries are defined not only by the goods and services they provide but also by the application of core technologies and processes. According to the particular process structure, there are different fields of application and uses of digital technologies, as well as limits and problems regarding their realization (Hirsch-Kreinsen 2015, p. 23). For instance, the “Industrie 4.0” debate emphasized the importance of digital technologies for the manufacturing sector (Pfeiffer 2017), in particular to achieve the aim of (partly) self-organized production systems (smart firm). This might have increased pressures and opportunities for manufacturers to adopt digital technology, as these processes seem to be unavoidable to sustain competitiveness.

In the manufacturing sector, cyber-physical production systems and the automation of manual work are considered core technologies and processes (Spath et al. 2013; Lerch et al. 2017). In contrast, knowledge-intensive sectors (e.g., business consulting and market research institutes) focus on technology that complements highly skilled knowledge work, such as algorithmic software, big data

analytic tools, cloud computing, online platforms and shop systems (Arntz et al. 2016b). In service sectors (e.g., sales and restaurants), technologies adequate to complement the performance of low- and mid-skilled services, which comprise a large extent of interactive and social tasks, are more relevant (e.g., mobile devices). In healthcare, by contrast, many tasks are regarded as difficult to substitute by technology due to the importance of social interactions; however, working conditions are nonetheless comprehensively affected by the implementation of digital technologies, such as health monitoring systems (Apt et al. 2018). Special attention has to be paid to the ICT sector, where a particularly high level of ICT diffusion can be expected. Most digital technologies emerge in this sector, and establishments in ICT are often among the early adopters of these technologies because they have the knowledge and fondness to do so (Will-Zocholl/Kämpf 2016). Therefore, ICT companies are the main drivers of digital innovation processes (BMWi et al. 2010; Dolata 2015).

Existing empirical studies confirm that the application of digital technologies varies substantially across sectors. As expected, the ICT sector is the most digitalized sector, followed by knowledge-intensive service providers (management consultancy, market research and the media industry) and the finance and insurance sector. The automotive industry and the healthcare sector are the least digitalized (BMWi 2018). The “DGB Index-Gute-Arbeit” reports similar results: the sectors "information and communication" and "professional, scientific and technical services" lead in most of the examined fields (e.g., electronic communication, joint project work via the internet and software-supported work processes), while the social services and construction industries are far behind (DGB 2017, p.15).

A large representative analysis by Arntz et al. (2016b) also reports a heterogeneous diffusion of modern digital technologies across different sectors. The report considers the specific characteristics of production companies (especially cyber-physical systems, smart factories, and the Internet of Things) and service companies (especially analytic tools with big data, cloud computing and online platforms) with regard to digital technologies. They find that the service segment identifies and uses digital technologies more often as a central component of its business model and that the use of these technologies is generally slightly more common than in the production segment. However, approximately 47 percent of the production companies have not even considered the use of such advanced digital technologies, while this share amounts to approximately 30 percent of the service providers. Not surprisingly, it is also reported that companies in the field of ICT use ICT particularly intensively. It can also be seen that companies that operate in knowledge-intensive branches prefer to use digital technologies because they rely on research, development and highly qualified personnel — regardless of whether they belong to the production or service sector (ibid. p.3 ff.).

We therefore presume that the introduction and kind of digital technology in a firm depend on the respective industry. Application is expected to be particularly widespread in ICT, manufacturing and knowledge-intensive service sectors.

2.2.3 Establishment age

The age of establishments could also have an impact on the adoption of digital technologies, as the opportunities for radical structural change in organizations decrease with age. This is due to a growing

inertia of organizations, which tends to increase with age and is favoured, for example, by the investments already made. This inertia often leads to the disappearance of organizations (Hannan/Freeman 1984). In this understanding, new forms of organizations can emerge, for example, through technological change, but older organizations often do not offer the necessary flexibility to develop and expand on these new technologies (Woywode/Beck 2014, p. 261). Mintzberg's (1979) structural archetypes and their innovative potential carry similar implications. In his understanding, successful organizations design their structures to match their situation. Therefore, he develops five archetypes that include basic structural configurations of companies that operate in different environments (ibid. p.300). Hence, technology start-ups follow the type of adhocracy and are very flexible, open to adopting radical innovation and able to survive in volatile environments (Lam 2006, p.119). This leads to the conclusion that novel technology is probably easier to adopt in younger establishments. In general, newly founded firms (start-ups) often operate on the forefront of digitalization, developing and introducing digital technology or adopting it very early on. The current focus of the debate supports this idea since many of today's most successful companies in the world are comparably young. These internet firms influence many economic segments through new forms of organization and especially by using ICT, data and internet-based business models (Dolata 2015; Kirchner/Beyer 2016; Srnicek 2017). Empirical research reports that approximately one-third of all start-ups in Germany are active in the ICT sector (Kollmann et al. 2019) and that the comparatively young ICT sector in particular is highly digitalized (BMWi 2018). We therefore expect that establishments that were founded more recently are more likely to use digital technology.

2.2.4 Industrial relations

Collective bargaining agreements and worker co-determination in the firm could influence how firms deal with digital transformation. Works councils are common in large companies in Germany (Ellguth/Kohaut 2019), and they need to be consulted in the case of major technological changes. Works councils can play a decisive role in successfully implementing new technology, as the consultation procedures enable a joint decision process between employees and management (Sorge/Streeck 1988; Streeck 1991). Hence, unions in Germany recently initiated ambitious projects with the aim of promoting an offensive approach regarding digitalization processes by activating the works councils (IG Metall 2017; Haipeter 2018). However, works councils also have the right to block or slow down the implementation of new technologies in certain cases. Due to § 87 Abs. 1 Nr. 6 of the "Betriebsverfassungsgesetz" (BetrVG), works councils can veto implementation whenever technology is implemented that is designed to monitor the performance and behaviour of employees (Kuhlmann et al. 2019). Since the consequences of the same technology can be different for workers, depending on the pursued personnel strategy, works councils could intervene to ensure that new technologies are implemented in a worker-friendly way, particularly avoiding job losses, intensification of workloads, or extensive monitoring.

Additionally, there could be interdependencies between collective bargaining agreements and the introduction of digital technologies. Unions might try to advance the usage of new technologies and shape their application in a way that is beneficial to members and to employees in general. In the

public sector, for example, the union “verdi” calls for collective bargaining agreements to address digitalization together with employees (verdi 2018). Additionally, the large manufacturing union IG Metall engaged in the Industrie 4.0 discourse quite early and embraced digital transformation as a chance to connect to its own political goals, such as training programmes, better wages, and working-time flexibility (Ittermann et al. 2015; IG Metall 2017). However, unions could also try to slow down the introduction of new digital technologies to prevent potential job losses due to substitution effects.

Empirical evidence shows that works councils have surprisingly rarely shaped technology usage in rationalization processes in the past but that co-determination regarding new work arrangements ("Mitbestimmung und Arbeit 4.0") is now on the agenda of unions and works councils. As a result of globalization and the emerging trend towards rationalization and outsourcing, since the mid-1990s, the task of works councils has primarily been to protect locations and jobs (Dörre 2002). Constitutive approaches were aimed at the general organization of work, but the technological circumstances were rarely questioned at all (Haipeter 2018, p.308). Recent findings show that unions and works councils are now aware of the importance of shaping digitalization through co-determination and that they try to exercise influence by innovative, proactive practices (Georg et al. 2017; IG Metall 2017; Ahlers 2018; Haipeter 2018; Oerder et al. 2018; Haipeter et al. 2019; Klebe 2019). Co-determination regarding new work arrangements ("Mitbestimmung und Arbeit 4.0") could thus become more influential. In this process, works councils could regain legitimacy through a participation orientation that incorporates the expert knowledge of employees and their participation, for example, in divisional meetings (BMAS 2016, p.158; Ahlers 2018, p.17; Haipeter et al. 2019, p.146). Georg et al. (2017, p.262 f.), however, note that although many works councils have an interest in processes of digital transformation, they have few specific ideas about upcoming changes or the consequences of digitalization processes. Kuhlmann et al. (2019) point out that diverse and sometimes difficult arrangements are emerging between works councils and management in the course of digitalization processes.

In summary, existing studies on the relationship between industrial relations and digital technology provide contradictory suggestions and evidence. There are reasons for both positive and negative associations between industrial relations and digitalization.

2.2.5 Employment structure - qualifications, flexibility, gender and age

The literature on the digital transformation of work has identified changes in the structure of qualifications and tasks, increasing flexibility of work (Hirsch-Kreinsen 2015) and the generation of digital inequalities (Robinson et al. 2015) as major trends associated with digitalization. Hence, the mutual relations between technical opportunities and social arrangements in systems of work and production can be expected to differ systematically according to the presence of different groups of workers. Therefore, employment structure at the firm level can indicate segments of the labour market that differ regarding the application of digital technologies. In particular, we expect a positive relationship between employee skills and the application of digital technologies in a firm, a positive relationship between flexible forms of employment and digital technologies and a reduced likelihood of digital technology usage in establishments with a high share of women or older workers.

Regarding the application of new technology, the focus often rests on highly skilled employees because it is assumed that high skills are required to make use of the opportunities of digital technology (Arntz et al. 2016a; Hammermann/Stettes 2016). Existing theories predict either a general upgrading of the skill structure or a polarization of the skill and wage structure. Work could become more demanding due to an enrichment of work through the aspects of information and complementary application of digital technologies. Accordingly, the theory of skill-biased technological change stresses an increasing demand for (highly) skilled workers (Autor et al. 1998). Based on the "task approach", a polarization of the skill and employment structure is predicted because jobs with intermediate skill levels entail a relatively large extent of routine tasks, which are particularly likely to be substituted by technology (Acemoglu/Autor 2011). Based on expert assessments of occupational task contents, it has been shown that low- and medium-skilled employees are more likely to be replaced in the digitalization process than high-skilled employees because their tasks can potentially be automated by technology (Frey/Osborne 2013; Dengler/Matthes 2015; Dengler/Matthes 2018). However, for establishments with a well-functioning traditional (Tayloristic) organization of work that builds on a large extent of low-qualified labour, this potential is unlikely to be realized in the short term (Hirsch-Kreinsen 2015). It is therefore expected that establishments with a high share of low- or medium-skilled employees are less likely to apply digital technologies than establishments with a high share of high-skilled employees.

Digital transformation is further believed to initiate a flexibilization of work in terms of working time, place of work and possibly also employment stability and hence a progressing dissolution of the boundaries of the firm. Traditional bonds among companies, places, workforces and products are gradually being loosened (Cholotta/Kirchner 2017). Crowdwork is a particularly flexible arrangement (Boes et al. 2015) that refers to work that is performed almost completely digitally, usually via platforms, and therefore requires an adequate level of digital technology (Pongratz/Bormann 2017). Digital technologies are also associated with new forms of organization within firms, such as scrum and agile working, which include the formation of temporary teams (Schröder et al. 2019). Proponents of these concepts argue that flexibility and adaptability are not only consequences of digital technologies but also prerequisites for maxing out their potential. Further, it was suggested that advances in digital technology facilitate increased flexibility of labour (e.g. Benner 2002). Accordingly, the rising extent of atypical forms of employment could be associated with processes of digitalization (Keller/Seifert 2018; see also Eichhorst et al. 2016, p.4). Hence, we test whether new digital technologies are positively related to the extent of firms' usage of flexible staffing practices such as fixed-term or part-time contracts, marginal employment, temporary work and freelancers. Studies have so far not ascertained a significant relationship between digitalization and flexible forms of labour (Stettes 2016).

Digital inequalities across different groups in the labour market manifest in unequal access to digital technologies at work and in unequal acquisition of digital competences and are highly likely to cause disadvantages in pay and other working conditions (Robinson et al. 2015). In particular, there is literature on digital gender gaps and digital generation gaps that refer to the disadvantages of women and older workers, respectively. For women, these inequalities are to a large extent associated with

segregation processes connected to gender stereotypes regarding technology (Wajcman 2010); in contrast, older workers may have difficulties accessing and commanding digital technologies because they have not acquired the necessary skills from an early age (digital natives/digital immigrants). Digital natives, born after 1980, are described as having a high affinity for technology, while digital immigrants are those adults who were not surrounded by technology from birth, therefore had to learn and understand how to use it and are in this sense principally less tech-savvy (Tapscott 1998; Prensky 2001).

Previous studies have shown that women are less likely than men to have access to digital technologies at work and that women assess their digital competences as worse than those of men (Initiative D21 2020). Ohlert and Boos (2019) showed that women are underrepresented in sectors with intensive application of digital technologies in Germany and that this aspect of gender segregation has intensified terms recently. Further, this aspect of gender segregation is associated with disadvantages regarding pay (ibid.). While some empirical studies confirm essential differences in ICT use between generations (DIVSI 2012), other studies show that differences between digital natives and digital immigrants in of technology use cannot be empirically proven (Jandura/Karnowski 2015). We therefore test the relationships between gender and age compositions in firms and the application of different digital technologies.

2.2.6 Competitive pressure

Digital transformation is commonly associated with the potential to enhance competitiveness across a wide range of industries. In the manufacturing sector, the strong development of robotics and sensor technology is seen as an advantage for an advanced information flow that optimizes the production, supply chain and quality of the products. In addition, for all industries, advantages can be achieved from modern communication and cooperation possibilities through digital technology, which enables better networking among employees, facilities, logistics, products and customers (Arntz et al. 2016b). Numerous sources refer especially to the new availability of data in real time, which is considered to be a competitive advantage (Ittermann et al. 2015, p.15; BMAS 2016, p.16; Schröder 2016, p.6). Hence, if firms ignore these technologies, competitive disadvantages could occur, which can under certain circumstances lead to disruptive changes in captured market share (Bower/Christensen 1995). Therefore, establishments in competitive environments will usually respond to promising technological innovations by introducing them themselves. Furthermore, digitalization can be viewed as a specific facet of globalization, as it accelerates worldwide communication and mobility. This development is likely to come with an increase in competitive pressure and hence with an increased likelihood of using digital technologies (BMAS 2016, p.26; Icks et al. 2017, p.VI). In contrast to these arguments, it has been pointed out that companies are subject not only to competitive external pressure to improve their products and market position but also to pressure to secure their current position and to avoid costly risks due to a short-term orientation. The introduction of new, costly digital technology could therefore be the exception rather than the rule (Hirsch-Kreinsen 2015, p. 24).

Previous findings showed that 37 percent of German firms consider competitive advantages due to digital offerings to customers a goal that can be achieved by digital technologies (BMWi 2018, p.52 ff.).

However, according to this self-assessment of employers, competitive advantages are not the most important achievement of digitalization: general improvement of customer communication and the development of success-relevant knowledge in the company were deemed most important. Expected competitive advantages towards competitors due to the use of digital technologies are higher among companies that operate in the ICT sector than in other sectors (e.g., through the possibility of individualization of products and services). These advantages are lowest among companies in the healthcare sector (ibid.).

Particularly with regard to Germany, many publications emphasize the necessity of implementing digitalization strategies for the country to remain internationally competitive in terms of digital change and "Industrie 4.0" concepts, i.e., extensive technological interconnection (agiplan et al. 2015, p. 41; Wischmann et al. 2015, p.28; BMAS 2016, p.21; Lerch et al. 2017, p.2). This would affect, for example, the German manufacturing industry, which could only remain competitive in the medium to long term through networked production facilities, which can be realized through internet-based applications (Schröder 2016, p.9 ff.). Although the relevance of extensive interconnection through digital technology is emphasized in many publications, previous German empirical findings are contradictory. Based on a representative firm survey, it has been shown that only approximately one-fifth of all medium-sized companies actually have a comprehensive digitalization strategy that also includes interconnection and data exchange among systems, processes and products. Among the companies that follow such a strategy, only 13 percent state that they have implemented it due to competitive pressure (Saam et al. 2016, p.20 f.). Icks et al. (2017, p.21 ff.) report a similar situation with regard to the medium-sized manufacturing industry: competitive pressure is only one among many drivers for internal and external interconnection.

In summary, theoretic considerations primarily suggest an expansion of digital technologies due to competitive pressure. Previous findings, however, point to contradictions between the often-assumed importance of competitive pressure and its assessment in firm surveys.

2.3 Digitalization - unified process or dual segmentation process for technologies?

General debates often gloss over the fact that digitalization constitutes a very broad term that comprises various different technologies. However, expectations or assumptions about "digitalization" might depend substantially on the specific technologies that are subsumed under the umbrella term. Considering various digital technologies raises the question of whether digitalization progresses in a *uniform process* whereby all digital technologies diffuse and operate in a similar fashion. In contrast, it can be argued that digitalization is a *differentiated process* where the implementation of different technologies depends on specific social and organizational contexts. In that sense, we test the hypothesis that digitalization unfolds in a ***dual segmentation process***. First, the adoption of digital technologies generally depends on organizational structures, and second, the relationships between organizational structures and specific digital technologies are heterogeneous. For example, the specific applied technologies are likely to differ across industries. Hence, we analyse establishments' probability of using seven different digital technologies and compare their structural determinants.

We distinguish between “basic digital technologies” such as computerized stationary devices and mobile devices and more “specific digital technologies” such as computerized process optimization (software, algorithms, etc.), the usage of social networks for recruiting, the usage of social networks for internal and external communication, digital awarding of contracts and the usage of digital sales channels for distribution.

3. Data, Variables and Methods

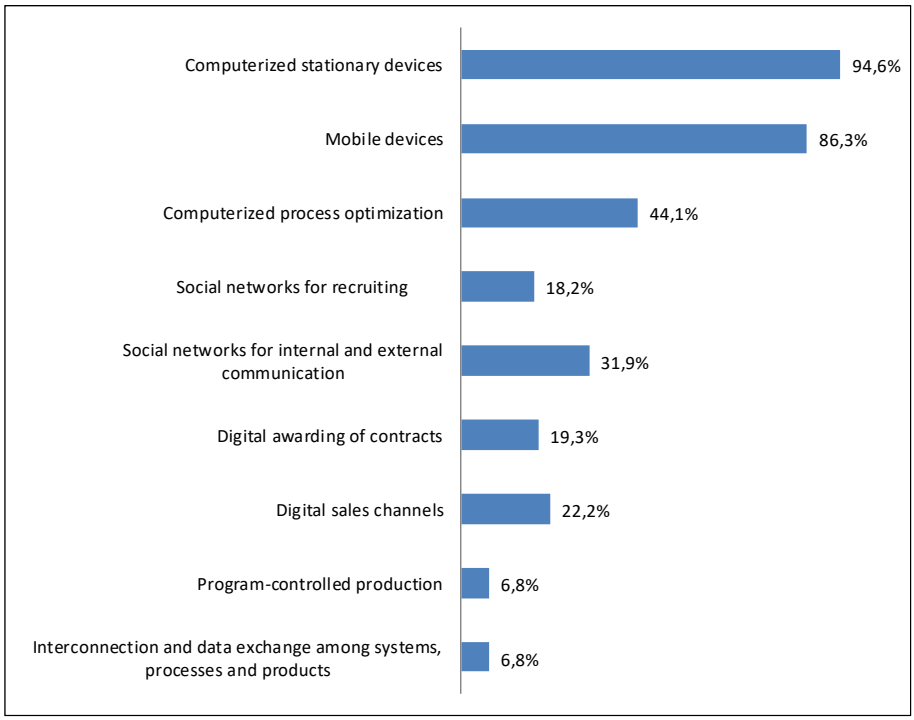
3.1 Data

The IAB Establishment Panel is a representative annual survey of German establishments, covering information on a variety of establishment structures and human resource practices (Fischer et al. 2009; Ellguth et al. 2014). The sample unit is the establishment, which refers to a firm’s head office or a local subsidiary. The survey sample is based on the employment statistics as of 30 June of each year and covers all establishments with at least one employee liable to social security. The sample is random and stratified by industry, region and establishment size. Approximately 16,000 establishments take part in the survey each year. For our empirical analyses, we use the cross section from 2017 because it covers establishments’ usage of modern digital technologies for the first time. The sample contains 15,108 establishments that provide information about their usage of digital technologies.

3.2 Variables

The dependent variables of interest are whether establishments use different digital technologies. The survey captures this information for nine types of technologies: 1) stationary computerized devices (e.g., desktop computers, electronic check stands and CAD systems); 2) mobile devices (e.g., laptops, notebooks, smartphones, tablets, and data glasses); 3) software, algorithms, and internet interfaces for process optimization (e.g., big data analyses and cloud computing systems); 4) social networks for recruiting; 5) social networks for internal and external communication; 6) digital awarding of contracts (on internet platforms); 7) digital sales channels; 8) program-controlled production (e.g., industrial robots and CNC machines); and 9) interconnection and data exchange among systems, processes and products (e.g., smart factories, drones, cyber-physical systems, and the Internet of Things). The respective dependent variable takes a value of zero when the technology is not used or a value of 1 when the technology is used by an establishment.

Figure 1: Firms' usage of digital technologies



Source: IAB Establishment Panel 2017, own calculations

Not surprisingly, the use of stationary computer devices is widespread. Approximately 95 percent of German establishments make use of computers or other computerized stationary systems. Similarly, a large majority of firms applied mobile devices (approximately 86 percent) by 2017. Their application increased quickly in the preceding years (Viete/Erdsiek 2015). Apart from these basic technologies, means of computerized process optimization, with approximately 44 percent, represent the next-most widespread type of technologies. This category covers a broad range of software and interfaces, such as big data analyses, cloud computing systems and ERP software. Social networks are used by approximately 32 percent of firms for internal and external communication and by approximately 18 percent for recruitment of workers. Digital processes of awarding contracts are relevant to approximately 19 percent of firms, and digital sales channels are used by approximately 22 percent of German firms.

We suggest that firms' usage or non-usage of these technologies is determined by the specific structural characteristics of firms as well as by their competitive environment. Here, the following firm characteristics are considered. Establishment size is differentiated into four classes with respect to the total number of employees in the firm (less than 10, 10 to 49, 50 to 249, and 250 or more). We consider nine sectors: agriculture, manufacturing, construction, trade, finance, hotels and restaurants, health, other services and the public sector. Establishment age is captured in 4 groups: foundation before 1990, foundation in the 1990s, foundation in the 2000s and foundation since 2010. Firms' industrial relations settings are considered by the non-/existence of collective bargaining agreements at the

sector or firm level and by the non-/existence of worker co-determination by a works council. Firms' competitive situations are captured by a self-assessment of competitive pressure on the firm and additionally by a statement regarding whether the firm exports goods internationally. Further, we consider the structure of the workforce regarding qualification groups, the share of women, the share of older workers (50+) and the shares of different types of flexible employment (part-time workers and fixed-term contracts). A description of the sample is presented in appendix table 1.

3.3 Methods

To identify the structures that determine firms' usage or non-usage of digital technologies, we estimate probit regressions. Marginal effects are reported to evaluate the effects of firm characteristics on firms' probability of using the respective technology. The IAB Establishment Panel allows consideration of a comprehensive set of explanatory variables. As we consider several structural characteristics of firms in the analysis, the respective associations can be interpreted to represent relationships that exist among otherwise similar firms. This is particularly relevant regarding the shares of specific groups in a firm, as they are usually correlated with the structural characteristics of firms due to the selection of workers into firms.

4. Results

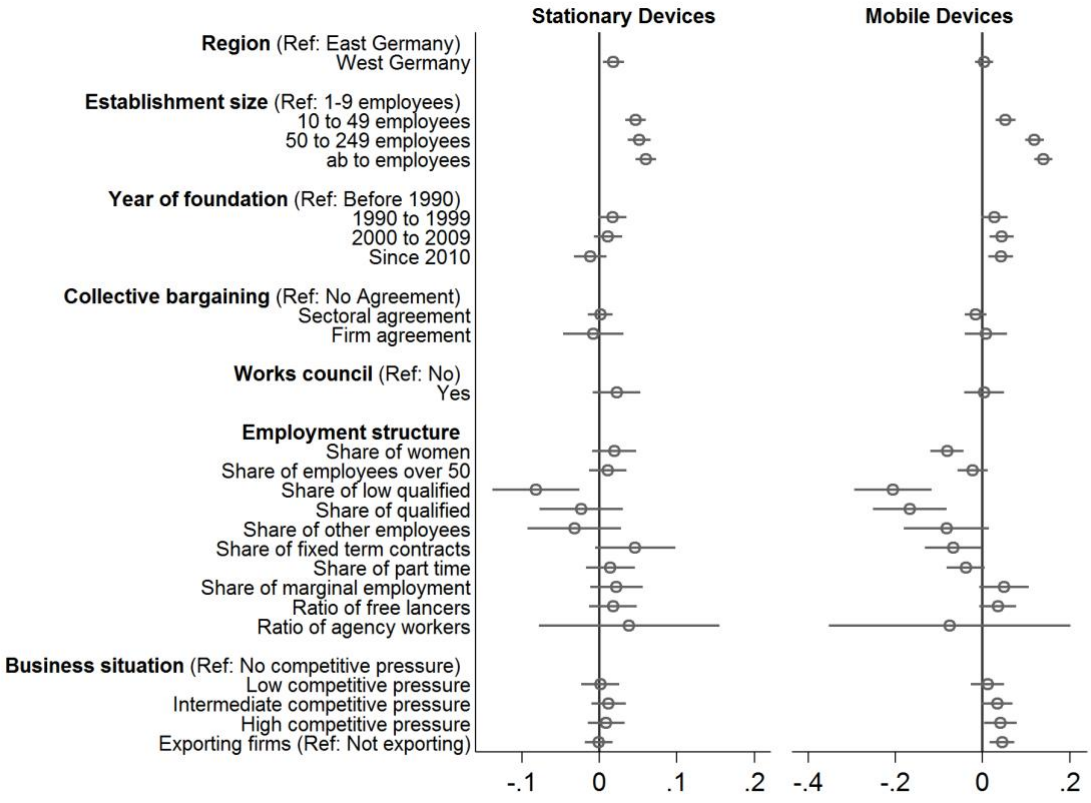
4.1 Segments of technology diffusion

Stationary computers and mobile devices are widespread among firms (see figure 1). Therefore, the primary interest is which firms do not use these technologies. Regarding the use of stationary devices, there are two findings (see figure 2). Compared to that in very small firms, the usage of computers is more likely in larger firms. Additionally, establishments with a higher share of low-skilled workers have a lower probability of using stationary computers. The other considered characteristics do not affect the usage of computers in firms because they are used universally. The use of stationary computers is also widespread in all sectors, and thus, there are no relevant differences in usage by sector (see appendix table 2).

There is somewhat more variation in the usage of mobile devices across firms. We find that larger firms and more recently founded firms are more likely to have adopted this kind of technology (figure 2). Collective bargaining agreements and works councils do not make a difference. Further, there are negative relations between the usage of mobile devices and the share of women and the share of low-skilled workers in a firm. The shares of workers employed in flexible forms of employment are not significantly related to the probability of using mobile devices. The probability of using mobile devices is, however, higher in firms facing high stated competitive pressure, as well as in exporting firms, which are assumed to face more intensive competition than non-exporting firms. Compared to the other sectors, the highest probability of using mobile devices is found in the information and communication sector, and the lowest is found among hotels and restaurants (see appendix figure 2). Compared to that in the manufacturing of capital goods, the use of mobile devices is significantly more likely in the

production of consumer goods, construction, transport and warehousing, finance and scientific or self-employed services.

Figure 2: Determinants of basic technologies



Source: IAB Establishment Panel 2017, own calculations.

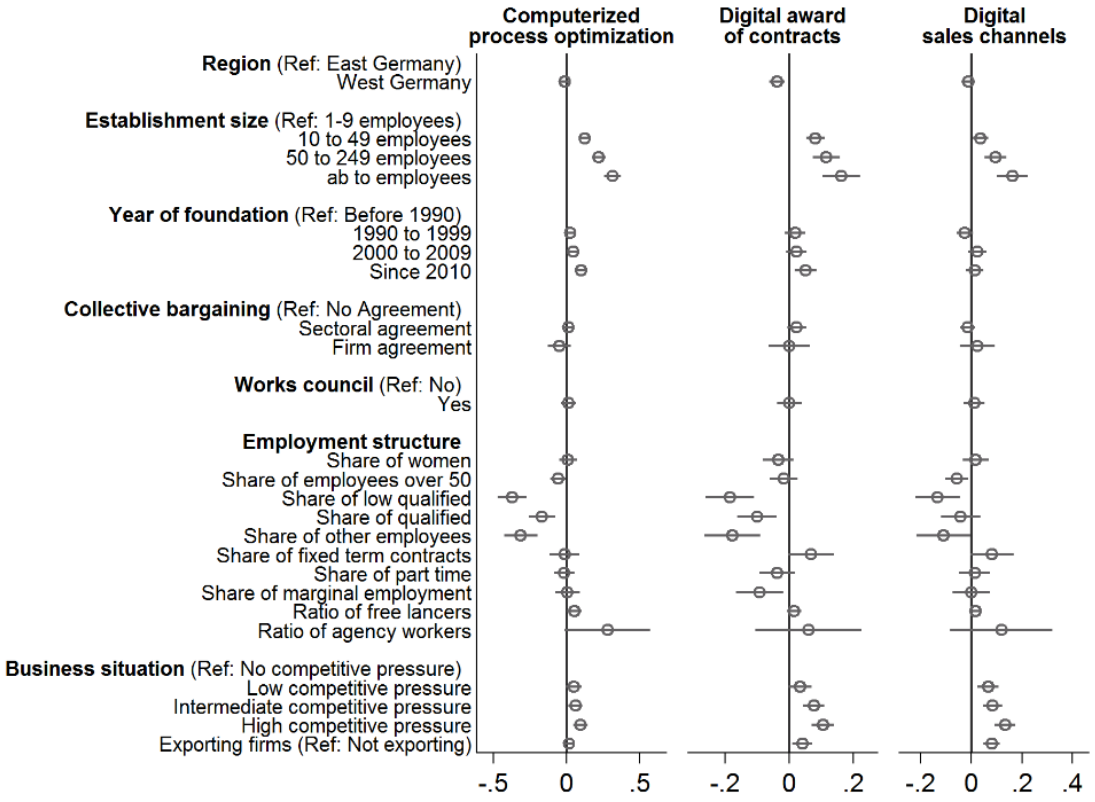
Comments: Spikes represent confidence intervals at the 95% level. The share of highly qualified employees is the reference group regarding skill levels.

Measures of computerized process optimization are a core area of progress by digital technologies in recent years. They are used by almost half of the establishments in Germany (figure 1). These technologies comprise software, algorithms and internet interfaces for process optimization, including big data analyses and cloud computing systems. A prominent example of such a technology is SAP ERP software, which is used to optimize the quantities and timing of inputs and outputs of production and firms' services. One of Germany's most successful tech firms provides this software. Further, we analysed firms' usage of digital contracting and sales channels, which are similar to software for process optimization because they organize specific parts of the stream of inputs and outputs online.

We observe similar findings regarding these three advanced digital technologies (figure 3). The larger an establishment is, the more likely it is to adopt these technologies. Further, the probability of application is higher for firms that were founded in the two most recent decades, but not for firms founded in the 2000s or the 1990s, than for even older firms. On average, there are no decisive

differences between firms with or without collective bargaining and with or without a works council. Industrial relations might, however, have an impact within single sectors, but this is not apparent here.

Figure 3: Determinants of advanced technologies



Source: IAB Establishment Panel 2017, own calculations.

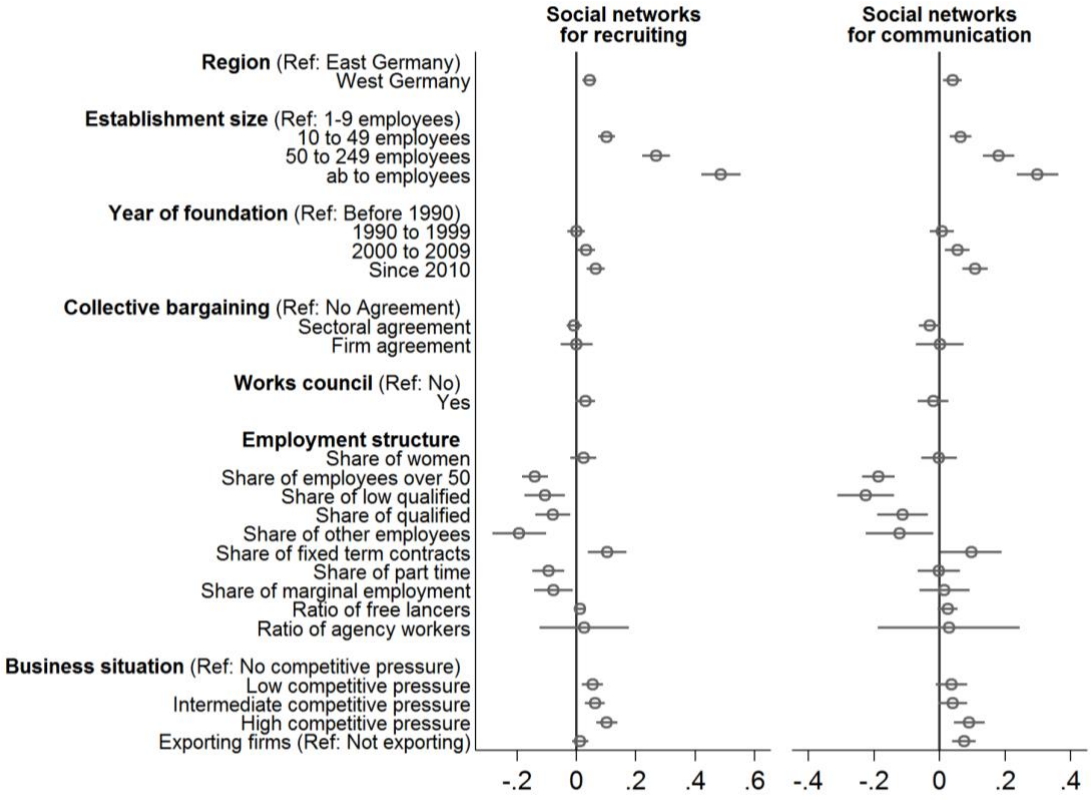
Comments: Spikes represent confidence intervals at the 95% level. The share of highly qualified employees is the reference group regarding skill levels.

Regarding employment structure, we find lower probabilities of technology usage in firms with higher shares of low-qualified workers. Additionally, a higher share of older workers is negatively associated with the usage of digital sales channels. There are no significant relations between flexible forms of employment and the diffusion of the three advanced technologies among firms. Higher stated competitive pressure, as well as export activity, is associated with significantly higher probabilities of using software for digital contract awarding and digital sales channels but not regarding general process optimization.

For most of the examined sectors, there are no significant differences in the usage of computerized process optimization. This aspect is, however, particularly likely to be found in the information and communication sector as well as in finance and scientific and professional services. Its probability is particularly low for hotels and restaurants. Compared to the manufacturing of capital goods, digital

awarding of contracts is significantly less likely in the manufacturing of food products, hotels and restaurants, education, the health sector and non-profit organizations. Digital sales channels are particularly likely to be used in the production of consumer goods, wholesale, trade, information and communication and financial services. They are less likely in mining, health, non-profit organizations and the public sector (see appendix figure 2).

Figure 4: Determinants of social networks



Source: IAB Establishment Panel 2017, own calculations.

Comments: Spikes represent confidence intervals at the 95% level. The share of highly qualified employees is the reference group regarding skill levels.

In traditional firms (as opposed to platform organizations), social networks are usually not part of the core processes of production or services, but they have the specific purposes of improving communication, marketing and personnel recruitment. In contrast to the other reported technologies, social networks are used to a significantly larger extent in West Germany than in East Germany (figure 4). Further, as for most digital technologies, we see significantly positive relations with firm size, more recent foundation, the share of highly qualified employees and the extent of competitive pressure. However, the application of social networks is less likely in firms with a higher share of older workers and more likely when there is a higher share of fixed-term employees. The usage of social networks

for recruiting is also negatively associated with the share of part-time workers and marginal employment. There is no significant relation with institutions of industrial relations.

Social networks are particularly likely to be used for recruiting in the information and communication sector as well as in the finance sector and other services. Social networks are also particularly likely to be used for communication in information and communication and finance, as well as in the trade sector, hotels and restaurants, professional and other services and non-profit organizations (see appendix figure 2).

4.2 Digitalization—unified process or dual segmentation?

We find that the diffusion of modern digital technologies is significantly related to firm structures. Overall, the observed patterns are very consistent across different types of technologies. All of the analysed technologies are more likely to be used in large firms than in small firms. Newly founded firms are more likely to use digital technologies, and competitive pressure seems to foster the use of digital technologies. There are clear negative relations between the shares of low- and intermediate-qualified employees and the usage of digital technologies, and this finding underlines the complementarities of these technologies with highly qualified workers. We do not find significant relations between collective bargaining or the presence of works councils and the diffusion of digital technologies for any of the examined technologies. Hence, firms with and without these institutions introduce digital technologies to a similar extent on average. Higher competitive pressure is consistently associated with the usage of digital technologies. The information and communication, financial services and professional services sectors are the forerunners regarding most of the examined technologies. With the exception of the use of social networks for communication, usage of digital technologies is rather low among hotels and restaurants. Social networks are generally used for communication more often in service sectors than in manufacturing. Digital channels for contract awarding and sales are applied sparsely in healthcare.

Table 1: Summary of results on determinants of firms' usage of digital technologies

Determinants	Stationary devices	Mobile devices	Computerized process optimization	Social networks for recruiting	Social networks for internal & external communication	Digital award of contracts	Digital sales channels
Firm size	+	+	+	+	+	+	+
Sector (variation)	0	Large	Large	Small	Large	Medium	Large
Firm age	0	+	+	+	+	Only since 2010	0
Industrial relations	0	0	0	0	(-)	0	0
Exporting firm	0	+	0	0	+	+	+
Competitive pressure	0	+	+	+	+	+	+
West Germany	+	0	0	+	0	-	0
Employment structure, shares of:							
Qualification levels in the firm	Low (-) 0 (Ref) High 0	Low (-) Qualified (-) (Ref) High Other (-)	Low (-) Qualified (-) (Ref) High Other (-)	Low (-) Qualified (-) (Ref) High Other (-)	Low (-) Qualified (-) (Ref) High Other (-)	Low (-) Qualified (-) (Ref) High Other (-)	Low (-) 0 (Ref) High Other (-)
Women	0	Female (-)	0	0	0	Female (-)	0
Contract type	0 0	Fixed term (-) 0	0 0	Fixed term (+) Part time (-)	Fixed term (+) 0	0 Part time (-)	0 0
Older Workers	Older (+)	0	0	Older (-)	Older (-)	0	0

Source: IAB Establishment panel 2017, own calculations and own summarized depiction: + positive relationship, - negative relationship, 0 no statistically significant relationship; for combined variable groups (employment structure) only discernible positive and negative relationships are depicted; combined assessment of relationships for sectors.

5. Conclusions

This paper posited that digitalization in German firms unfolds in a differentiated process creating particular segments within digital transformation. Our results confirm that the realization of technological potential within firms is shaped by structural limitations as well as by structural drivers of change. The strong relationship between firm size and technology diffusion points to severe constraints of small firms regarding technological change. This can be explained by limited possibilities to fund necessary investments but also by fewer possibilities to benefit from such investments on a large scale. Further, there seem to be particularly strong limitations for hotels and restaurants and in part for the sectors of education, healthcare and non-profit organizations. The observed distinct diffusion of digital technologies across firm sizes and sectors together suggests that heterogeneity of productivity and employment conditions are likely to increase further in these segments.

The results confirm that competition is a driver of technological change, as otherwise similar firms are significantly more likely to introduce digital technologies when they face more competitive pressure. The same trend becomes evident for firms that export their goods and services internationally. While international exports may coincide with a larger extent of competitive pressure, the results also suggest that digitalization is a specific facet of globalization, as it accelerates worldwide communication and trade. While the use of digital technologies is generally more likely the younger that a firm is, the youngest firms (start-ups) are particularly ahead in the usage of digital contract awarding and tools of computerized process optimization. Hence, younger firms have proven to be an additional driver of the diffusion of new technologies.

The clear relationship between the qualification structure within firms and the extent of technology diffusion suggests, on the one hand, that technological change generates increasing demands for highly qualified workers. This relationship also implies that low-qualified workers are less likely to find employment in sectors and firms with a high degree of digitalization, which on average pay substantially higher wages. Therefore, low-qualified workers face disadvantages due to limited access to digital technologies. Similarly, we expected women and older workers to be underrepresented in firms using digital technologies. However, as we controlled for sectors and a number of firm structures, the remaining associations between firms' gender and age compositions and the extent of technology usage are confined to specific technologies. Firms with a higher share of women have a lower probability of using mobile devices but use other technologies with similar probabilities. Firms with a higher share of older employees have a lower probability of using digital sales channels and social networks for recruitment or communication.

Unions and works councils neither seem to directly foster the introduction of new technologies nor obstruct it. This is remarkable, as unions have engaged in the digitalization debate. The introduction of the same technologies can, however, be accompanied by different management strategies and hence diverse consequences for working conditions. Therefore, further research should examine whether unions and works councils actively shape the way of dealing with new technologies rather

than their introduction, e.g., to limit the extent of “Digital Taylorism”, monitoring of workers or intensification of workload.

The observed structural associations between firm structures and new technologies are very consistent overall across different types of technologies. Hence, the diffusion of different digital technologies is likely to progress in the same segments in the economy and be similarly restricted in other segments. This suggests that the introduction of different digital technologies is driven by similar segment-specific drivers and limitations. There are some technology-specific associations with different sectors, such as a high usage of social networks for communication in service sectors and a low usage of digital channels for contract awarding and sales in healthcare.

Overall, our findings underline that the recent wave of digital transformation so far has not progressed seamlessly and comprehensively. While a comprehensive diffusion has been reached for older technologies such as personnel computers, the application of more specific technologies is confined to limited spheres, in particular in the ICT sector and among large firms that can put tools such as big data analysis to efficient uses. However, small and medium-sized firms in other sectors have not embarked on an intensive digitalization. This distinct development of digitalization across segments of the economy is likely to coincide with increasing differentiation and inequalities across firms. Since labour market segmentation of individuals among skill levels, gender and other characteristics is correlated with the structural dimensions of digitalization, working conditions may increasingly rely on access to technology in the workplace.

6. References

Acemoglu, D. / Autor, D. (2011) Skills, tasks and technologies: Implications for employment and earnings. In: O. Ashenfelter / D. Card (Hg.). Handbook of labor economics, Volume 4B. Amsterdam, S. 1043-1171

agiplan/ Fraunhofer IML / Zenit (2015) Erschließen der Potenziale der Anwendung von Industrie 4.0 im Mittelstand. Dortmund: Studie im Auftrag des BMWi.

Ahlers, E. (2018) Die Digitalisierung der Arbeit. Verbreitung und Einschätzung aus Sicht der Betriebsräte. WSI-Report Nr 40, Mai 2018.

Apt, W./ Bovenschulten, M./ Priesack, K./ Weiß, C. / Hartmann, E. A. (2018) Einsatz von digitalen Assistenzsystemen im Betrieb. Im Auftrag des Bundesministeriums für Arbeit und Soziales. Berlin, Institut für Innovation und Technik.

Arntz, M./ Gregory, T./ Jansen, S. / Zierahn, U. (2016a) Tätigkeitswandel und Weiterbildungsbedarf in der digitalen Transformation. Mannheim: Zentrum für Europäische Wirtschaftsforschung.

Arntz, M./ Gregory, T./ Lehmer, F./ Matthes, B. / Zierahn, U. (2016b) Dienstleister haben die Nase vorn. Arbeitswelt 4.0 - Stand der Digitalisierung in Deutschland. Nürnberg, Institut für Arbeitsmarkt- und Berufsforschung

Autor, D. H./ Katz, L. F. / Krueger, A. B. (1998) Computing inequality: Have computers changed the labor market? In: Quarterly Journal of Economics, 113 (4), S. 1169-1214

Baukrowitz, A. (2006) Informatisierung und Reorganisation. Zur Rolle der IT jenseits der Automatisierung. In: A. Baukrowitz/ T. Berker/ A. Boes/ S. Pfeiffer/ R. Schmiede / M. Will (Hg.). Informatisierung der Arbeit - Gesellschaft im Umbruch. Berlin, S. 98-115

Benner, C. (2002) Work in the New Economy: Flexible Labor Markets in Silicon Valley. Malden, Blackwell Publishing

BMAS (2016) Weißbuch Arbeiten 4.0. Berlin, Bundesministerium für Arbeit und Soziales

BMWi (2018) Monitoring-Report Wirtschaft DIGITAL 2018. Berlin, Bundesministerium für Wirtschaft und Energie

BMWi/ ZEW / Bitkom (2010) Informations- und Telekommunikationstechnologien als Wegbereiter für Innovationen. Fünfter Nationaler IT Gipfel 2010. Dresden.

Boes, A./ Kämpf, T./ Langes, B. / Lühr, T. (2015) Landnahme im Informationsraum. Neukonstituierung gesellschaftlicher Arbeit in der „digitalen Gesellschaft". In: WSI-Mitteilungen, 68 (2), S. 77-85

Bonin, H./ Gregory, T. / Zierahn, U. (2015) Übertragung der Studie von Frey/Osborne (2013) auf Deutschland. Endbericht - Kurzexpertise Nr. 57. Mannheim, ZEW.

Bower, J. L. / Christensen, C. M. (1995) Disruptive technologies: catching the wave. In: Harvard Business Review, 69 (1), S. 19-45

Cholotta, K. / Kirchner, S. (2017) Wie eine Arbeitswelt loser Kopplung den Sozialstaat herausfordert. Werkheft 04 - Sozialstaat im Wandel. Berlin, Bundesministerium für Arbeit und Soziales.

Dengler, K. / Matthes, B. (2015) Folgen der Digitalisierung für die Arbeitswelt. Substituierbarkeitspotenziale von Berufen in Deutschland. In: IAB-Forschungsbericht 11/2015

Dengler, K. / Matthes, B. (2018) Substituierbarkeitspotenziale von Berufen. Wenige Berufsbilder halten mit der Digitalisierung Schritt. In: IAB-Kurzbericht 04/2018

DGB (2017) DGB Index Gute Arbeit. Verbreitung, Folgen und Gestaltungsaspekte der Digitalisierung in der Arbeitswelt. Auswertungsbericht auf Basis des DGB-Index Gute Arbeit 2016. Berlin, Institut DGB-Index Gute Arbeit.

DiMaggio, P. J. / Powell, W. W. (1983) The Iron cage revisited - Institutional isomorphism and collective rationality in organizational fields. In: American Sociological Review, 48 (2), S. 147–160

DIVSI (2012) DIVSI Milieu-Studie zu Vertrauen und Sicherheit im Internet. Hamburg, Deutsches Institut für Vertrauen und Sicherheit im Internet.

Dolata, U. (2015) Volatile Monopole. Konzentration, Konkurrenz und Innovationsstrategien der Internetkonzerne. In: Berliner Journal für Soziologie, 24 (4), S. 505-529

Dörre, K. (2002) Kampf um Beteiligung : Arbeit, Partizipation und industrielle Beziehungen im flexiblen Kapitalismus eine Studie aus dem Soziologischen Forschungsinstitut Göttingen (SOFI), 1. Aufl. Edition, Wiesbaden: Westdt. Verl.

Eichhorst, W./ Hinte, H./ Rinne, U. / Tobsch, V. (2016) Digitalisierung und Arbeitsmarkt: Aktuelle Entwicklungen und sozialpolitische Herausforderungen. In: IZA Standpunkte Nr. 85

Ellguth, P. / Kohaut, S. (2019) Tarifbindung und betriebliche Interessenvertretung: Ergebnisse aus dem IAB-Betriebspanel 2018. In: WSI-Mitteilungen, 72290-297

Ellguth, P./ Kohaut, S. / Möller, I. (2014) The IAB establishment panel - methodological essentials and data quality. In: Journal of Labour Market Research, 47 (1-2), S. 27-41

Fischer, G./ Janik, F./ Müller, D. / Schmucker, A. (2009) The IAB Establishment Panel – Things Users Should Know. In: Schmollers Jahrbuch, 129 (1), S. 133-148

Frey, C. B. / Osborne, M. A. (2013) The Future of Employment: How Susceptible are Jobs to Computerization? Oxford, University of Oxford.

Georg, A./ Katenkamp, O. / Guhlemann, K. (2017) Digitalisierungsprozesse und das Handeln von Betriebsräten. In: Arbeit, Zeitschrift für Arbeitsforschung, Arbeitsgestaltung und Arbeitspolitik 26 (2) (2), S. 251-274

Haipeter, T. (2018) Digitalisierung, Mitbestimmung und Beteiligung – auf dem Weg zur Mitbestimmung 4.0? In: H. Hirsch-Kreinsen/ P. Ittermann / J. M. S. Niehaus (Hg.). Digitalisierung industrieller Arbeit: Die Vision Industrie 4.0 und ihre sozialen Herausforderungen. Baden-Baden, S. 303-322

Haipeter, T./ Bosch, G./ Schmitz-Kießler, J. / Spallek, A.-C. (2019) Neue Mitbestimmungspraktiken in der digitalen Transformation der „Industrie 4.0“: Befunde aus dem gewerkschaftlichen Projekt „Arbeit 2020 in NRW“. In: Industrielle Beziehungen. Zeitschrift für Arbeit, Organisation und Management, 26 (2-2019), S. 130-149

Hammermann, A. / Stettes, O. (2016) Qualifikationsbedarf und Qualifizierung. Anforderungen im Zeichen der Digitalisierung. IW policy paper 2016/03. Köln.

Hannan, M. T. / Freeman, J. (1984) Structural Inertia and Organizational Change. In: American Sociological Review, 49 (2) (2), S. 149-164.

Helmrich, R./ Tiemann, M./ Troltsch, K./ Lukowski, F./ Neuber-Pohl, C./ Lewalder, A. C. / Güntürk-Kuhl, B. (2016) Digitalisierung der Arbeitslandschaften. Keine Polarisierung der Arbeitswelt, aber beschleunigter Strukturwandel und Arbeitsplatzwechsel. Bonn, Bundesinstitut für Berufsbildung

Hirsch-Kreinsen, H. (2015) Digitalisierung von Arbeit: Folgen, Grenzen und Perspektiven. Soziologisches Arbeitspapier. Dortmund, Wirtschafts- und Sozialwissenschaftliche Fakultät, Technische Universität Dortmund. Nr. 43/2015

Hirsch-Kreinsen, H. (2018) Arbeit 4.0: Pfadabhängigkeit statt Disruption. Soziologisches Arbeitspapier. Dortmund, Wirtschafts- und Sozialwissenschaftliche Fakultät, Technische Universität Dortmund. Nr. 52/2018

Hirsch-Kreinsen, H. (2019a) Industrie 4.0. In: B. Blättel-Mink/ I. Schulz-Schaeffer / A. Windeler (Hg.). Handbuch Innovationsforschung. Wiesbaden, S. 1-16

Hirsch-Kreinsen, H. (2019b) Industry 4.0 - A Path-Dependent Innovation. Soziologisches Arbeitspapier. Dortmund, Wirtschafts- und Sozialwissenschaftliche Fakultät, Technische Universität Dortmund. Nr. 56/2019

Howcroft, D. / Taylor, P. (2014) ‘Plus ca change, plus la meme chose?'—researching and theorising the ‘new’ new technologies. In: New Technology, Work and Employment, 29 (1), S. 1-8

Icks, A./ Schröder, C./ Brink, S./ Dienes, C. / Schneck, S. (2017) Digitalisierungsprozesse von KMU im Verarbeitenden Gewerbe. IfM-Materialien Nr. 255. Bonn, IfM Bonn.

IG Metall (2017) Arbeit und Innovation. Wir machen Zukunft, https://www.igmetall.de/download/20170515_IGM_Imagebrosch_re_finale_Ansichtsdatei_8e0dbbf34d34f80da69bcf1f1fc248436fbb7eab.pdf (Visited: 12.02.2020)

Initiative D21 (2020) Digital Gender Gap. Lagebild zu Gender(un)gleichheiten in der digitalisierten Welt. Berlin, Initative D21.

Ittermann, P./ Niehaus, J. / Hirsch-Kreinsen, H. (2015) Arbeiten in der Industrie 4.0. Trendbestimmungen und arbeitspolitische Handlungsfelder. In: Studie der Hans-Böckler-Stiftung Nr. 308

Jandura, O. / Karnowski, V. (2015) Digital Natives vs. Digital Immigrants – fruchtbares empirisches Konzept für die Kommunikationswissenschaft oder populärwissenschaftliche Fiktion? In: Publizistik, 60 (1), S. 63-79

Keller, B. / Seifert, H. (2018) Atypische Beschäftigungsverhältnisse in der digitalisierten Arbeitswelt. In: WSI-Mitteilungen, 71 (4), S. 279-287

Kern, H. / Schumann, M. (1984) Das Ende der Arbeitsteilung?: Rationalisierung in der industriellen Produktion: Bestandsaufnahme, Trendbestimmung. München, Beck

KfW (2019) Going Digital: The Challenges Facing European SMEs. European SME Survey 2019.

Kirchner, S. / Beyer, J. (2016) Die Plattformlogik als digitale Marktordnung. Wie die Digitalisierung Kopplungen von Unternehmen löst und Märkte transformiert. In: Zeitschrift für Soziologie 45(5)324–339

Kirchner, S. / Matiaske, W. (2019) Digitalisierung und Arbeitsbeziehungen in betrieblichen Arbeitswelten: Zwischen revolutionären Wandel und digitalem Inkrementalismus. In: Industrielle Beziehungen, 26 (2), S. 125-129

Klebe, T. (2019) Mitbestimmung. Algorithmen sind ein Fall für den Betriebsrat. In: Böckler Impuls Ausgabe 10/2019

Kollmann, T./ Hensellek, S./ Jung, P. B. / Kleine-Stegemann, L. (2019) Deutscher Start-Up Monitor 2019. Mehr Mut, neue Wege. Berlin, Bundesverband Deutsche Startups e.V.

Kuhlmann, M./ Rüb, S. / Winter, S. (2019) Konflikte um Mitbestimmung und Überwachung im digitalen Umbruch. In: Mitteilungen aus dem SOFI, Ausgabe 30 (13. Jahrgang), S. 6-9

Lam, A. (2006) Organizational Innovation. In: J. Fagerberg / D. C. Mowery (Hg.). The Oxford Handbook of Innovation. Oxford University Press., S. 115-147

Lerch, C./ Jäger, A. / Maloca, S. (2017) Wie digital ist Deutschlands Industrie wirklich? Arbeit und Produktivität in der digitalen Produktion. Mitteilungen aus der ISI-Erhebung - Modernisierung der Produktion 71.

Lichtblau, K./ Schleiermacher, T./ Goecke, H. / Schützdeller, P. (2018) Digitalisierung der KMU in Deutschland. Konzeption und empirische Befunde. Köln, IW Consult.

Liker, J. K./ Haddad, C. J. / Karlin, J. (1999) Perspectives on Technology and Work Organization. In: Annual Review of Sociology, 25575-596

Ludwig, T./ Kotthaus, C./ Stein, M./ Durt, H./ Kurz, C./ Wenz, J./ Doublet, T./ Becker, M./ Pipek, V. / Wulf, V. (2016) Arbeiten im Mittelstand 4.0 – KMU im Spannungsfeld des digitalen Wandels. In: HMD Praxis der Wirtschaftsinformatik, 53 (1), S. 71-86

Mintzberg, H. (1979) The structuring of organizations: a synthesis of the research. Englewood Cliffs, N.J., Prentice-Hall

Oerder, K./ Behrend, C. / Stokic, J. (2018) Betriebsrat 4.0: Digitalisierung aus Sicht der Betriebsräte und deren Potential als Gestalter der digitalen Arbeitswelt in NRW. FGW-Impuls Digitalisierung von Arbeit, 7. Düsseldorf, Forschungsinstitut für gesellschaftliche Weiterentwicklung e.V. (FGW).

Ohlert, C. / Boos, P. (2019) Auswirkungen der Digitalisierung auf Geschlechterungleichheiten. Eine empirische Untersuchung auf der Branchenebene. Berlin, Harriet Taylor Mill-Institut für Ökonomie und Geschlechterforschung der Hochschule für Wirtschaft und Recht.

Ortmann, G./ Windeler, A./ Becker, A. / Schulz, H.-J. (1990) Computer und Macht in Organisationen: mikropolitische Analysen. Opladen, Westdt. Verl.

Öz, F. (2019) Digitalisierung in Kleinbetrieben: Ergebnisse aus Baugewerbe, Logistik und ambulanter Pflege. Forschung Aktuell, No. 02/2019. Gelsenkirchen, Institut Arbeit und Technik (IAT), Westfälische Hochschule.

Pfeiffer, S. (2017) The Vision of "Industrie 4.0" in the Making-a Case of Future Told, Tamed, and Traded. In: Nanoethics, 11 (1), S. 107-121

Pongratz, H. / Bormann, S. (2017) Online-Arbeit auf Internet-Plattformen. Empirische Befunde zum ‚Crowdworking' in Deutschland. In: Arbeits- und Industriesoziologische Studien, 10158-181

Prensky, M. (2001) Digital Natives, Digital Immigrants Part 1. In: On the Horizon, 91-6

Robinson, L./ Cotten, S. R./ Hiroshi, O./ Quan-Haase, A./ Mesch, G./ Wenhong, C./ Schulz, J./ Hale, T. M. / Stern, M. J. (2015) Digital inequalities and why they matter. In: Information, Communication & Society, 18 (5), S. 569–582

Saam, M./ Viete, S. / Schiel, S. (2016) Digitalisierung im Mittelstand: Status Quo, aktuelle Entwicklungen und Herausforderungen. Forschungsprojekt im Auftrag der KfW Bankengruppe. Mannheim, ZEW - Zentrum für Europäische Wirtschaftsforschung.

Schöpper, H./ Lodemann, S./ Doerries, F. / Kersten, W. (2018) Digitalisierung deutscher KMU im Branchenvergleich. In: Industrie 4.0 Management, 201838-42

Schröder, C. (2016) Herausforderungen von Industrie 4.0 für den Mittelstand. Bonn, Friedrich-Ebert-Stiftung.

Schröder, M./ Steinhorst, U. / Winter, M. (2019) Hybrides Projektmanagement – Einbindung agiler Arbeitsweisen im Rahmen der fortschreitenden Digitalisierung. In: M. Schröder / K. Wegner (Hg.). Logistik im Wandel der Zeit – Von der Produktionssteuerung zu vernetzten Supply Chains: Festschrift für Wolfgang Kersten zum 60. Geburtstag. Wiesbaden, S. 829-844

Sorge, A. / Streeck, W. (1988) New Technology and Industrial Relations: The Case for an Extended Perspective. In: R. Hyman / W. Streeck (Hg.). New Technology and Industrial Relations. Oxford, S. 19–47

Spath, D./ Ganschar, O./ Gerlach, S./ Hämmerle, M./ Krause, T. / Schlund, S. (2013) Produktionsarbeit der Zukunft - Industrie 4.0. Stuttgart, Fraunhofer IAO.

Srnicek, N. (2017) Platform Capitalism, Cambridge

Stettes, O. (2016) Arbeitswelt der Zukunft: Wie die Digitalisierung den Arbeitsmarkt verändert. IW-Analysen, No. 108. Köln, Institut der deutschen Wirtschaft Köln.

Streeck, W. (1991) On the Institutional Conditions of Diversified Quality Production. In: E. Matzner / W. Streeck (Hg.). Beyond Keynesianism. The Socio-Economics of Production and Full Employment. Aldershot, S. 21–61

Tapscott, D. (1998) Net kids: die digitale Generation erobert Wirtschaft und Gesellschaft. Wiesbaden, Gabler

verdi (2018) Digitalisierung: Besser mit Tarifvertrag!, https://bund-laender.verdi.de/++file++5a7196bee58deb05d5fc6c36/download/2018-01-25_Flugblatt_Digitalisierung_Tarifvertrag_V2.pdf (Visited: 29.05.2020).

Viete, S. / Erdsiek, D. (2015) Mobile Information and Communication Technologies, Flexible Work Organization and Labor Productivity: Firm-Level Evidence. ZEW Discussion Paper No. 15-087. Mannheim, Zentrum für Europäische Wirtschaftsforschung.

Wajcman, J. (2010) Feminist theories of technology. In: Cambridge Journal of Economics, 34 (1), S. 143-152

Will-Zocholl, M. / Kämpf, T. (2016) Branchenanalyse Informations- und Telekommunikationsbranche. Study Nr.320, März 2016, Hans Böckler Stiftung.

Wischmann, S./ Wangler, L./ Botthof, A./ iit-Berlin / 4.0, A. f. I. (2015) Industrie 4.0. Volks- und betriebswirtschaftliche Faktoren für den Standort Deutschland. Eine Studie im Rahmen der Begleitforschung zum Technologieprogramm AUTONOMIK für Industrie 4.0. Berlin, Bundesministerium für Wirtschaft und Energie.

Woywode, M. / Beck, N. (2014) Evolutionstheoretische Ansätze in der Organisationslehre – Die Population Ecology-Theorie. In: A. Kieser / M. Ebers (Hg.). Organisationstheorien. Stuttgart, S. 256-294

ZEW (2015) Industrie 4.0: Digitale (R)Evolution der Wirtschaft. IKT-Report. Unternehmensbefragung zur Nutzung von Informations- und Kommunikationstechnologien. Mannheim, Zentrum für Europäische Wirtschaftsforschung.

7. Appendix

Table A1: Description of firm sample

Variable	Mean/Percentage	Std. Dev.
West Germany	0.79	0.40
Number of employees in the firm		
less than 10	(Reference)	
10 to 49	0.27	0.44
50 to 249	0.05	0.22
250 or more	0.01	0.09
Sector		
Agriculture	0.04	0.19
Construction	0.11	0.31
Trade	0.20	0.40
Finance	0.03	0.17
Hotels and restaurants	0.07	0.26
Health	0.11	0.31
Other services	0.30	0.46
Public sector	0.06	0.24
Manufacturing	(Reference)	
Foundation of the firm		
Before 1990	(Reference)	
1990s	0.21	0.41
2000s	0.25	0.43
2010s	0.24	0.42
No collective bargaining	(Reference)	
Sectoral collective bargaining	0.25	0.43
Firm collective bargaining	0.02	0.15
Works council	0.08	0.27
Share of low qualified	0.20	0.27
Share of qualified	0.51	0.30
Share of other employees	0.23	0.21
Share of women	0.47	0.32
Share fixed-term contract	0.04	0.13
Share part time	0.35	0.29
Share of older workers	2.51	10.35
Exporting firm	0.19	0.40
No competitive pressure	(Reference)	
Low competitive pressure	0.19	0.39
Medium competitive pressure	0.39	0.49
High competitive pressure	0.29	0.45
Number of observations	15,108	

Source: IAB Establishment Panel 2017, own calculations.

Figure A1-A3: Probability of digital technology usage by sector