Original Article

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Controlling Working Crowds: The Impact of Digitalization on Worker Autonomy and Monitoring Across Hierarchical Levels

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Abstract: This study investigates the impact of information and communication technologies (ICT) on worker autonomy and monitoring using the second wave of the German Linked Personnel Panel, a linked employer-employee data set. From a theoretical point of view, the impact of ICT on workplace organization is ambiguous. On the one hand, the fast diffusion of ICT among employees makes it possible to monitor professional activities, leading to greater centralization. On the other hand, ICT enable employees to work more autonomously, so that workplace organization becomes more decentralized. Based on ordinary least squares and instrumental variable estimates, we find that ICT promotes both centralization and decentralization tendencies. Furthermore, managerial employees are more affected by ICT-induced monitoring and autonomy than their non-managerial counterparts. Finally, the effect of digital ICT on employee autonomy is more pronounced than the corresponding effect on employee monitoring. Again, this does especially hold for managerial employees. All in all, our results support the view that unlike prior technological revolutions digitalization primarily affects the employment prospects and working conditions of employees at medium and higher hierarchical levels.

Keywords: information and communication technologies (ICT), workplace organization, worker autonomy, worker monitoring
JEL Classification: L22, M54, O33

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1 Introduction

In the digital age, firms are motivated to find ways in which new technologies promote business longevity and competitiveness. One way to implement new technologies is to integrate them in work processes. Allowing employees to use modern technological tools, such as information and communication technologies (ICT), promises higher performance levels (Aral/Weill 2007). Thus, it is a common practice to integrate technical tools in the daily work life of employees. ICT and its resulting scope of application, such as the gathering of knowledge and data or the ease to communicate with others (e.g. through email and mobile devices), lead to far-reaching changes of work environments that are difficult to determine yet. While almost all German firms use computers today (94% in 2017), the shares of firms using very recent ICT inventions are substantially smaller. For example, social media technologies are utilized by 46% (2017), cloud computing by 17% (2016), and Big Data technologies by 6% (2015) (Statistisches Bundesamt, Destatis 2018). These and other digital ICT devices, such as the internet, laptops, tablet computers or smart phones, represent technologies of the digital transformation that are likely to change organizational processes and structures.

The objective of the present paper is to explore the impact of using digital ICT devices on workplace organization and especially on the allocation of decision rights among employees at different hierarchical levels. From a theoretical point of view, the impact of ICT on workplace organization is ambiguous. On the one hand, theory suggests that ICT enable employees to get access to new information and knowledge, which in turn allows them to work more autonomously. On the other hand, massive data storage and permanent accessibility via digital devices offer an attractive opportunity for firms to raise their monitoring activities. An intensive control of employees' activities or performance, however, diminishes individual autonomy as employees tend to adapt their working behavior in order to meet corporate goals. Our empirical investigation, therefore, aims at finding an answer to the question of whether digital ICT use either promotes worker empowerment or worker monitoring, or whether digital ICT even allow the implementation of both of these two seemingly opposite management practices.

Although most economic studies on the impact of ICT on firm organization highlight the forthcoming incidence of decentralization measures, we argue in this paper that centralization measures may accompany decentralization practices, so that a mix of both might also be applied. A gain in autonomy through the use of ICT might get entangled in a knot of worker monitoring policies for the purpose of controlling working crowds. To shed more light on this issue, we first want to find out if both worker autonomy and monitoring can be observed, which

management policy prevails and, finally, whether all employees are equally affected, irrespective of their hierarchical position.

We expect digital ICT to have a substantial impact on both policies of decision rights assignment. Moreover, we presume that worker autonomy and monitoring are not equally affected by the use of digital ICT, i.e. the autonomy effect might dominate the monitoring effect or vice versa. Finally, it is possible that the use of digital ICT leads to different decision rights assignment effects across hierarchical levels. More precisely, the effect of digital ICT on worker autonomy or monitoring might depend on whether the concerned individuals are managerial or non-managerial employees. This reasoning builds on recent studies highlighting that today digitalization complements complex working tasks executed by high-skilled workers, while simultaneously substituting for routine working tasks executed by medium-skilled workers (Gibbs 2017; Wolter et al. 2016).

To address this topic empirically, we utilize data of the Linked Personnel Panel (LPP), which is a new linked-employer-employee data set on human resources, corporate culture and management practices in German establishments of the processing industry and the service sector. The LPP is representative for German establishments with at least 50 employees. The employer and employee surveys are ideally suited to answer our research questions on the impact of digital ICT on workplace organization, as they provide direct measures of digital ICT (use of computers, the internet, laptops, tablet computers or smart phones for professional activities), worker autonomy (amount of job autonomy, opportunity to work from home) and monitoring (use of appraisal interviews, performance evaluations, written performance targets). Furthermore, the LPP provides a rich set of additional variables at both the individual and the establishment level that can be applied to control for worker and firm characteristics. Finally, we merge the LPP data with the respective wave of the IAB Establishment Panel to control for additional establishment characteristics not included in the LPP, thereby avoiding to suffer from an omitted variables bias.

From a methodological point of view, we apply at first the conventional ordinary least squares (OLS) estimation approach. In order to account for endogeneity issues, we additionally apply an instrumental variables (IV) estimation approach. The main results of our study can be summarized as follows. First, we find empirical evidence for the argument that both centralization and decentralization tendencies in the form of employee monitoring and autonomy occur simultaneously as a consequence of using digital ICT. Furthermore, the ICT-induced monitoring and autonomy effects are not equally distributed across hierarchical levels. We find that managerial employees are more affected by ICT-induced monitoring and autonomy than their non-managerial counterparts. Finally, the effect

of digital ICT on employee autonomy is more pronounced than the corresponding effect on employee monitoring. Again, this does especially hold for managerial employees. All in all, our results support the view that unlike prior technological revolutions digitalization primarily affects the employment prospects and working conditions of employees at medium and higher hierarchical levels.

Our contribution to the empirical literature can be summarized as follows: First, unlike existing empirical studies, we examine the impact of digital ICT on workplace organization, thereby explicitly addressing the potential different effects across hierarchical levels. Second, while most other studies rely on firm-level data, we make use of linked employer-employee data. This enables us to emphasize the employee perspective rather than the establishment perspective. This is important as comparable studies typically focus on the firm perspective, when investigating the impact of ICT on workplace organization. Third, we contrast the paradox of managing worker autonomy and monitoring (e.g. Gilbert/Sutherland 2013; Robertson/Swan 2003) and argue that both seemingly opposing policies may occur simultaneously from using digital ICT. Consequently, we ask whether one effect dominates the other. Finally, our estimation strategy does not only provide evidence based on conditional correlations. In fact, we additionally account for potential endogeneity issues regarding our main explanatory variables, so our estimates can be interpreted as causal effects.

We proceed as follows. In Section 2, we discuss basic theoretical considerations with regard to the impact of ICT on worker autonomy and monitoring. Moreover, we summarize and discuss prior empirical work. Section 3 outlines the data, variables and descriptive results. In Section 4, we map the empirical investigation based on linked employer-employee data. Section 5 offers some concluding remarks.

2 Theoretical considerations and related literature

2.1 ICT and the battle between worker autonomy and monitoring

Investigating the impact of technology on working processes and workplace organization is a classical topic of industrial economics and industrial sociology (Pfeiffer 2010). The fast diffusion of modern technologies leads more and more to a digitalization of workplace organization and has subsequent effects on the labor market. Technological change can might have a repressive effect on human

labor and leads to the recent phenomenon of job polarization as documented by Autor et al. (2006, 2008), Autor and Dorn (2013) for the United States, and Spitz-Oener (2006) and Dustmann et al. (2009) for Germany. Job polarization is mainly explained by the routine-biased technological change (RBTC) showing a decline in the demand for routine tasks compared to non-routine tasks (Autor et al. 2003, 2006; Gibbs 2017; Spitz-Oener 2006). Routine intensive tasks are more likely to be technologically substituted. To some extent, modern technologies are already used as a substitute for human work (Lazear/Gibbs 2015) and RBTC decreases the demand for medium-skilled occupations relative to high-skilled and low-skilled occupations (Autor et al. 2003; Autor et al. 2006, 2008; Goos et al. 2014; Goos/Manning 2007; Autor/Dorn 2013).

However, existing job profiles are not completely disappearing from the job market. They are changing as there is a shift in the employment structure away from routine occupations (Lorenz/Stephany 2018; Acemoglu/Autor 2011; Goos et al. 2014). Furthermore, while Frey and Osborne (2013) estimate that half of the US labor force is highly susceptible to computerization in the near future, Bonin et al. (2014) show that in Germany only 12% of employees hold jobs that are likely to be automated. Thus, digitalization leads to a substitution of certain tasks due to automation processes, while other tasks are in a complementary relationship to digital technologies (Gibbs 2017; Weber 2017; Wolter et al. 2016). The technological devices considered in this study, i.e. computers, the internet, laptops, tablet computers, and smart phones, are seen as assisting technologies rather than substitutes to human labor.

The emphasis to implement technological systems is constantly growing. Firms are raising their IT investments to enhance productivity at the firm and individual level (Bertschek 2012; Draca et al. 2007; Kretschmer 2012). As a result, firms' structures are affected (Bloom et al. 2014; Garicano 2000). Next to promising improvements in speed and capabilities of ICT (Lazear/Gibbs 2015) allowing an increasing degree of networking and an enormous central data storage, producer prices of digital tools are decreasing. The producer price of notebooks, for instance, decreased in Germany from 2010 to 2016 by 40% (Statistisches Bundesamt 2017) making IT investments more likely to be profitable. The increasing demand in ICT is also explained by a notable decrease in coordination, information and communication costs (Malone 1997; Brynjolfsson/Hitt 2000; Garicano 2000).

Moreover, following Moore's law that the performance of processors, memory and many other elements of computer hardware are improving at an exponential rate (Brynjolfsson/McAfee 2016), computer power is estimated to increase a thousand fold until 2040 (Eberl 2017) allowing the emergence of new working tasks. A survey has shown that on average 61% of German firms give their employees

mobile devices allowing connection to the internet, as a way to provide access to e-mail, corporate documents, and business software (Statistisches Bundesamt 2016). This value is steadily increasing with a firm's number of employees. Implementing digital tools such as mobile ICT in working processes is nothing new, but current developments of ICT and the increasing spread of a broadband infrastructure lead to changes in workplace organization at an unprecedented speed (Arnold et al. 2016).

On the one hand, ICT promote the diffusion of wired and wireless communication and coordination within a firm (Bloom et al. 2014), enabling employees to establish an instant, time and place independent virtual communication to coordinate working processes. By using e-mails, the internet or smart phones, for instance, employees may connect internal with external working processes. Moreover, intranets and inter-firm networks facilitate communication within and between firms (Smeets 2017) and online platforms enable a digital mediation between firms and customers (Maier et al. 2017; Ohnemus et al. 2016). On the other hand, information channels are shortened and simplified. Employees may inform themselves instantly and independently about how to carry out a task. Bloom et al. (2014) argue that communication technologies enable a centralization of workplace organization, whereas information technologies promote a more decentralized workplace organization. The organization of work is thus redefined spatially and temporally, leaves predefined operational structures and provides employees with more autonomy. In addition, ICT also enables improved monitoring of employees. To constantly monitor workers, employers can use data generated by a frequent use of mobile digital tools by employees. Since the implementation of new ICT seems to influence the daily work of employees as well as internal operating processes of a firm, it is consistent to highlight the complex relationship between ICT usage and workplace organization.

From a theoretical point of view, workplace organization can change from a Tayloristic workplace organization to a more Holistic organization (Lindbeck/Snower 2000). The former entails a workplace organization characterized by a pyramidal hierarchical structure, task specialization, monitoring, and centralization of knowledge and responsibilities. The latter presents a workplace organization with a flat hierarchical structure, multitasking, more flexibility and autonomy for the employee, and a decentralization of knowledge and decision-making authority (Martin 2011; Lindbeck/Snower 2000; Osterman 2000). It became difficult by the introduction of ICT to define a clear impact on the restructuring of organizations (Castells 1998). To clarify what type of workplace organization prevails – decentralization or centralization – or if a mix of both is appearing, we consider in this study autonomy and monitoring, and contrast it to ICT use.

Innovative ICT offer new useful arrangements with more autonomy in terms of task execution, working time or working place (Gibbs 2017). A decentralization of workplace organization appears (Bloom et al. 2014). Management practices such as self-managed working time or working from home are likely to interact with intrinsic motivation and reciprocity (Beckmann et al. 2017; Rupietta/Beckmann 2018). A gain in autonomy enhances intrinsic motivation, as it is perceived by employees as a positive incentive to achieve results through their own striving (Bader/Kaiser 2017, Gilbert/Sutherland 2013). Employees that are allowed to work more autonomously find greater job satisfaction and attain a higher performance (Caroli et al. 2001; Greenan/Walkowiak 2005; Lindbeck/Snower 1996, 2000). Especially ICT such as the internet or e-mail that facilitate access to information and knowledge, contribute to the development of a motivational working environment including employee autonomy over working time and place (Martin 2017).

The scope of decision-making authority increases as the employee is getting more and more knowledgeable and may be assigned with more responsibilities (Smeets 2017). As knowledge can be acquired at a favorable price (Garicano 2000), a nurse, for instance, may conduct own cost-effective diagnostics with the help of new technologies, thus works more independently due to technologically induced decentralization procedures. However, recent studies show that the implementation of ICT can also lead to a decrease in autonomy (Manzei/Schmiede 2014). The digital interconnection of working processes may increase workloads. In German firms, 65% of employees perceive a consolidation of work through technological innovations (Arnold et al. 2016). Even if firms allow flexible work arrangements or promote employee work-life balance, overload of work usually persists (Kärreman/Alvesson 2009; Kellogg 2011; Reid 2015). A higher workload, speeding up processes, a high level of responsibilities and work pressure may influence the individual performance of employees negatively and let the benefits of ICT on autonomy fade (Boltanski/Chiapello 2005; Huws 2006). With this in mind, firms need to provide a proper incentive scheme and choose the optimal allocation of knowledge and decision making authority.

On the one hand, we notice that the use of ICT can promote autonomy. On the other hand, ICT may also lead to greater centralization. Monitoring in terms of appraisal interviews, management by objectives or performance evaluations, is often the default management practice (Harris/White 1987) and appears especially in highly automated jobs (Gibbs 2017). In this case, managers favor to make most or all decisions on their own. Employees only have to perform their prescribed tasks. The job of a delivery truck driver, for instance, is optimized in a way that only a few skills are required to fulfill the repetitive tasks. Little autonomy is needed, and the business process is simple to monitor. Recently,

monitoring instruments become more important in firms, which is confirmed by a study of Straub (2016) according to which the amount of appraisal interviews and performance evaluations steadily increased from 2012 to 2015 in German firms.

Interestingly, monitoring sometimes persists next to arrangements providing employees with autonomy. Managers have to grant employees autonomy within a set of formal rules and procedures (Wageman 1995) along with the information that monitoring may reduce the goal-orientated behavior of employees, trust and consequently employees' performance (Taylor 2010). In general, the joint implementation of autonomy and monitoring is paradoxical as the latter presents a negative incentive that may oppose the positive effect of the former. The literature is still vague on the phenomenon of the autonomy and control paradox (Robertson/Swan 2003). However, autonomy practices are increasingly accompanied by employee monitoring. Control mechanisms foster a competitive work environment with scarce promotion opportunities (Alvesson 2001; Empson 2017; Galanter/Palay 1990; Michel 2007). Especially new technologies such as ICT make it possible to monitor employees activities instantly, to evaluate employees in new ways, and to reward employees performance accordingly (Gibbs 2017; Dewettinck/Buyens 2006). Firms also start to employ less visible forms of monitoring or stimulate employees to engage in self-monitoring and self-regulating behavior that stands in line with their organizational goals (Mazmanian et al. 2013; Michel 2011). Input-based (hours worked or tasks accomplished) or output-based performance (productivity or sales) can be measured (Lazear/Gibbs 2015). An organizational innovation that focuses on employee performance rather than hours worked is the so called 'Results Only Work Environment' (ROWE) as shown in Moen et al. (2011a, 2011b). This practice combines employee autonomy and output-based monitoring by allowing employees to execute their tasks whenever and wherever they prefer as long as the employees achieve their performance targets.

In addition to the assumption that workplace organizations will become more and more decentralized in the near future, there is a growing tendency to control employees more strictly, which, however, corresponds to greater centralization. This leads us to the assumption that both policies – centralization and decentralization – may appear simultaneously. Next to a gain in autonomy, employees have to tackle a greater workload and a higher intensity of monitoring activities in parallel. Moreover, employees may be affected differently by autonomy and monitoring management practices. A recent study from Bender et al. (2018) shows that a plant's productivity is mainly driven by the human capital of the highest-paid workers, i.e. the managers. A higher skill level is required to cope with an increase in decision-making authority (Gibbs 2017; Lindbeck/Snower 2000) and to reach higher management practice scores (Bender et al. 2018). This reasoning suggests

that if digital ICT increases individual autonomy and monitoring, managerial employees are more likely to be confronted with these management practices than non-managerial employees, especially because of the complementarity between ICT usage, skills, knowledge and responsibility.

In the next subsection, we discuss recent empirical studies that highlight the relationship between ICT and workplace organization.

2.2 Previous empirical evidence

Empirical results tend to promote the common and often stated understanding that firms are currently implementing a more decentralized working environment. Nevertheless, recent findings are often ambiguous and thus underline the necessity of further research to prevent a polarizing discussion. The following background discussion will state different important findings related to the research topic and summarizes the current status of the scientific debate.

Brynjolfsson and Hitt (1998) concentrate on the relationship between IT and organizational design as well as on its consequences on firm productivity. The authors analyze in depth what types of organizations are most likely to gain from future decreases in the cost of IT. This is accomplished by using a newly created cross-sectional survey of organizational practices conducted in 1995 and 1996, matched to a panel of IT investment and productivity metrics over the 1987–1994 time period. The data set contains information of approximately 380 large U.S. firms. To determine a proxy for decentralization, they focused on self-managing teams, the pace or method of work or individual control, and on information about team incentives and skill acquisition. IT measures, such as total capital stock of IT, computing power and the number of PCs, were derived from the Computer Intelligence Infocorp Installation Database. Next to a baseline production function regression and corresponding robustness checks, an instrumental variables estimation model has been conducted. Evidence has been found that firms with greater decentralization of decision rights show a greater demand for IT, and higher benefits from IT investments are derived by firms using more decentralized work systems.

Acemoglu et al. (2007) concentrate on new technologies and decentralization of firms as well. The authors analyzed the principal-agent model to determine the optimal degree of decentralization. The more the principal knows about technologies, the lower the degree of delegation. Two French data sets have been considered – the 'Changements Organisationnels et Informatisation' (COI) covering over 4,000 manufacturing firms and the 'Enquête Réponse' (ER) covering under 3,000 French establishments, as well as one UK data set – the 1998 'Workplace Employee Relations Survey' (WERS). As a key measure of decentralization,

information on the existence of profit centers, delayering and the degree of autonomy a plant manager enjoys from headquarters in investment decisions has been considered. ICT was measured by an indicator of proximity to the technological frontier. The econometric model is estimated by probit maximum likelihood. Further robustness checks are carried out by using logit and linear probability specifications. The findings show that firms closer to the technological frontier are more likely to choose decentralization as they are dealing with new and relatively unknown technologies.

Rasel (2016) examines the relationship between IT use, workplace organization and productivity for firms of different size. The unique unbalanced panel data set of 3288 small and medium-sized firms as well as 595 larger firms from the manufacturing and service sector in Germany includes measures of IT such as enterprise resource planning (ERP), supply chain management (SCM) and customer relationship management (CRM). Moreover, the share of employees using computers for work has been used. Organizational design is represented by measures taking into account the existence of profit centers, the loss of responsibility and self-managed working groups. Pooled OLS estimates reveal that IT is used more intensively by small and medium-sized firms with a decentralized workplace organization, but only larger firms gain from the combination of IT and decentralization.

Some studies focused on flexible work practices as these HR practices are more and more enhanced due to the intensive use of ICT (Bloom/Van Reenen 2006; Hill et al. 2008). While some studies find evidence for a positive effect of flexible work practices on employee effort or performance, productivity and innovation (Bloom et al. 2015; Beckmann et al. 2017) and thus support the concept of a more decentralized workplace organization, others found that constant availability through modern ICT outside the regular working hours can cause work-family conflicts, job dissatisfaction and health-related problems (Boswell/Olson-Buchanan 2007; Askenazy/Caroli 2010). To shed more light on the matter, Viete and Erdsiek (2015) focused their attention on the complementarity between the use of mobile ICT and workplace flexibility. Analyzing data on German manufacturing and service firms from a survey on firms' use of ICT and flexible working practices conducted in 2014 and 2015 by the Centre for European Economic Research, they found evidence that the use of mobile ICT is associated with a gain in productivity in firms using trust-based working time. As an ICT measure, the authors used the share of employees equipped by their firms with mobile devices connecting to the internet. Three generic measures were taken to describe workplace flexibility: working from home arrangements, working time accounts and trust-based working time. Estimations were conducted by using a conventional OLS estimation approach.

All studies mentioned above gear their attention on decentralization measures and underline the importance of a decentralized working environment in order to benefit from technological changes or to cope with modern ICT. Several other studies adopt, however, the assumption that a clear classification between decentralization or centralization cannot easily be undertaken. Colombo and Delmastro (2004), for instance, tried to identify the main factors that influence the assignment of decision-making authority over strategic decisions to a plant manager or its centralization. A questionnaire was mailed to plant managers of Italian manufacturing plants operating in June 1997. Thereby, the analysis could be conducted with information on the organization of 438 Italian manufacturing plants. As an estimation method, ordered probit estimations with random effects are used. Considering ICT, they found that adopting advanced communication technologies seems to favor a decentralization of decision-making. If monitoring is difficult due to great physical distance, decision-making authority is centralized.

Mahr and Kretschmer (2010) extended the line of research regarding the optimal organizational structure by stressing that IT can be complementary to greater centralization, conditional on the corporate learning type carried out within a firm. Building on organizational theory, the authors differentiate between two types of learning: exploration and exploitation. The former refers to the permanent search for new products and markets, whereas the latter focuses on the ongoing improvement of existing product market domains. This approach is comparable to our procedure as exploration is representative for more autonomy and exploitation for more monitoring. The authors used a multi-source panel data set on computers, organizational design, and corporate learning type of over 250 German manufacturing firms. To generate a decentralization measure, information on the decentralization of decision rights and suitable HRM practices is used. As a key measure for IT, the authors used information about the number of computers, gained from Harte-Hanks' CI Technology Database (CITDB). Moreover, a variable has been computed combining tangible fixed assets and IT capital. To test the hypothesis, a production function approach has been applied and OLS estimations were conducted. As a result, Mahr and Kretschmer find that IT is complementary to decentralization if the learning type is exploration. It is complementary to centralization if the learning type focuses on exploitation.

According to Bloom et al. (2014), ICT have at least two distinct components, information technology (IT) and communication technology (CT), which should be considered separately. To determine the effect of IT and CT on firm organization, a new data set has been considered that combines manufacturing plant-level measures of organization and ICT across the United States and Europe. Two other main sources of data were the 'CEP Management and Organization Survey' and the 'Harte-Hanks ICT Panel'. To describe tendencies in organizational structure,

questions about a manager's or a worker's autonomy, as well as a manager's span of control, have been considered. Software data, especially the presence of three specific technologies (CAD/CAM and ERP as measures for information technologies, and Intranet for communication technology) have been used to define IT and CT. The authors applied an OLS estimation model as well as probit maximum likelihood and instrumental variables regressions to find empirical evidence for their hypothesis. The findings show that technologies that lead to low information costs promote a decentralization of the organizational structure, and technologies that lead to low communication costs promote a centralization. In addition to Bloom et al. (2014), Aral and Weill (2007) highlight the same issue that different types of ICT can have distinct implications for performance and organizational capabilities.

To sum up, previous empirical evidence considering the relationship between ICT and organizational design is in general ambiguous. Furthermore, the effects of technological and organizational changes at the employee level are largely neglected. As organizational effects of ICT are not clear to date, our study contributes to a better understanding about how ICT are changing workplace organization while focusing on the employee perspective. In our empirical investigation, we address the following research questions:

- Does digitalization promote more worker autonomy or more monitoring on the employee level, or is digitalization associated with a mix of both?
- In case of a joint implementation of worker autonomy and monitoring caused by digital ICT use, does one policy dominate the other?
- Does the impact of digitalization on worker autonomy and monitoring exist for all employees, or are employees affected differently depending on their hierarchical position?

3 Data, variables and descriptive results

Our empirical analysis is based on data from the Linked Personnel Panel (LPP), a linked employer-employee data set on human resources, corporate culture and management instruments in German establishments (Bellmann et al. 2015; Broszeit/Wolter 2015; Broszeit et al. 2016; Broszeit et al. 2017). The LPP survey project is carried out by the German Institute for Employment Research (IAB), the University of Cologne, and the Centre for European Economic Research (ZEW). Financial supporters are the IAB and the Federal Ministry of Labour and Social Affairs (BMAS). With its debut in 2012/2013, the LPP survey circulates every two years towards its recipients to collect information considering both the employer and employee level. The first part of the LPP survey, the LPP establishment survey,

is conducted face-to-face by TNS Infratest Sozialforschung, whereas the second part, the LPP employee survey, is realized via telephone by the infas Institut für Sozialwissenschaften GmbH.

For representative empirical analyses, two panel waves are currently available. The first wave contains information on 1,219 establishments and 7,508 employees. For the second wave, 771 establishments were successfully recontacted. Concerning employees, 3,271 were willing to participate in the survey again and 4,011 employees were first-time respondents. Thus, in total 7,282 employees have been included in the LPP employee data set of the second wave. All in all, the LPP is representative for German establishments with 50 and more employees in the processing industry and the service sector. All waves may be merged with data from the German IAB Establishment Panel. The IAB Establishment Panel provides information on labor market topics, such as employment, wages, sales, bargaining levels, works councils, profit sharing and investments, and includes more than 15,000 establishments each year (Fischer et al. 2009).

In the present work, we will focus on the employees' perspective captured in the LPP employee survey. The LPP employee survey completes with its questions the establishment survey, the first part of the LPP data set. It covers topics on personal characteristics and employment, HR development, work conditions and work loads, remuneration, loyalty, values and corporate structure. To clarify the digitalization effect on workplace organization, information on the usage of ICT among employees as well as on centralization or decentralization measures is required. The second wave of the LPP employee survey delivers the required information.

In the following descriptive and econometric analysis, ICT is measured by the LPP employee survey question '*Do you use digital information or communication technologies such as computer, the internet, laptop, tablet computer or smart phone for your professional activity?*' The variable *ICT* can take on the value 1 or 0. In addition, we differentiate between lower and higher hierarchical levels by considering the employment status. A survey question asking whether an employee is supervising other workers or not is used in order to construct the dummy variable *supervisor*. Using both variables, we construct interaction terms that enable a differentiation between four different cases: The variable ICT^{11} indicates the case where the employee is a supervisor using ICT, i.e. *ICT* = 1 and *supervisor* = 1, whereas ICT^{10} indicates the case where *ICT* = 1 and *supervisor* = 0. The employee uses ICT, but does not hold a position as a supervisor. The other two variables, ICT^{01} and ICT^{00}, are indicating the case where *ICT* = 0 and the variable *supervisor* equals either 1 or 0. In our regressions, the variable ICT^{00} will be used as a reference group.

Table 1 presents the descriptive statistics for *ICT*, *supervisor*, ICT^{11}, ICT^{10}, ICT^{01} and ICT^{00}. For 6,793 employees, we observe that 79% of the total amount of

Table 1: Descriptive statistics of the main explanatory variables.

Variable	Mean	Std.-dev.	Min-Max
ICT	0.794	0.404	0–1
supervisor	0.298	0.457	0–1
ICT^{11}	0.268	0.443	0–1
ICT^{10}	0.527	0.499	0–1
ICT^{01}	0.030	0.170	0–1
ICT^{00}	0.175	0.380	0–1

Source: Linked Personnel Panel 2014/2015, employee survey. $N = 6,793$.

surveyed employees use digital ICT. In our sample, surveyed employees are more often occupying a position without management responsibility. Only 30% of all identify themselves as a supervisor. Further details are given by the ICT interaction terms: 26.8% of the employees are supervisors using ICT, 3% are supervisors not using ICT. 52.7% are ICT using employees without management responsibility, and 17.5% are employees without management responsibility who are not using ICT. We notice that 89.9% of the supervisors use ICT, whereas only 75.1% of the employees use ICT. In other words, managerial employees are endowed more frequently with ICT than non-managerial employees, confirming the complementarity between digital ICT usage, skills, knowledge, and responsibility. Furthermore, this finding is a first indicator that worker monitoring and worker autonomy might be applied in different intensities among employees. Monitoring activities might increase as ICT enable employees to carry out a larger number of tasks or more specific tasks that need to be controlled. Furthermore, monitoring activities can be conducted at a higher intensity if managers possess the necessary technical equipment. These assumptions lead to a more centralized workplace environment. Next to this, the usage of ICT enables employees to work more autonomously, promoting a decentralization of the workplace organization. However, the overall impact of ICT on workplace organization remains unclear and a more profound research is necessary to shed more light on this issue.

Concerning centralization, we focus on the following survey questions on employee monitoring:

- '*Did you have an appraisal interview with your supervisor last year?*',
- '*Did your supervisor agree with you on the objectives fixed in writing during the appraisal interview?*' and
- '*Is your own performance regularly assessed by a supervisor as part of an agreed procedure?*'

This leads us to construct variables, called *Interview*, *Target* and *Perfeval*, measuring these monitoring policies. The variables take a value of one if the

monitoring activity takes place and zero if not. To create our measure of worker monitoring *Monitoring*, we followed the double-standardization approach (see, e.g. Bresnahan et al. 2002) and converted the scores from the three centralization questions to z-scores by normalizing each score to have a mean of zero and a standard deviation of one. Finally, we generated the sum of the standardized values and standardized the resulting outcome. By using the definition of $STD(x) = (x - \bar{x})/\sigma_x$, our centralized workplace organization variable is defined as

$$Monitoring = STD\{STD(Interview) + STD(Target) + STD(Perfeval)\}.$$

Concerning decentralization, we took into account two survey questions from the LPP employee survey describing job autonomy and empowerment:
– '*Does your job allow you to make a lot of decisions on your own?*' and
– '*Do you work from home for your employer – even if only occasionally?*'

Considering the first question on job autonomy, respondents could choose between 5 grades: 1 = does not apply at all, 2 = does rather not apply, 3 = neutral, 4 = largely applies and 5 = fully applies. A variable called *Job Autonomy* has been created, ranging from 1 to 5. For the second question referring to working from home, we generated a variable *Wfh*, taking a value of one if employees make use of working from home and zero if not. To construct a measure of workers' autonomy, we applied the double-standardization approach on the two decentralization questions describing job autonomy and working from home and generated the variable *Autonomy* as follows:

$$Autonomy = STD\{STD(Job\ Autonomy) + STD(Wfh)\}.$$

By construction, both *Monitoring* and *Autonomy* have zero mean and unit variance. The descriptive statistics of worker monitoring and autonomy can be found in Table 2.

Table 2: Descriptive statistics of worker monitoring and worker autonomy variables.

Variable	Mean	Std.-dev.	Min-Max
Interview	0.502	0.500	0–1
Target	0.353	0.478	0–1
Perfeval	0.488	0.500	0–1
Job Autonomy	3.934	1.031	1–5
Wfh	0.193	0.394	0–1

Source: Linked Personnel Panel 2014/2015, employee survey. $N = 6,793$.

Considering monitoring activities, 50% of the employees indicate that appraisal interviews are conducted, 35% affirm that superiors agreed on objectives fixed in writing during the appraisal interview, and 49% indicate that a performance evaluation has been conducted. Focusing on a worker's autonomy, the mean of the variable *Job Autonomy* is 3.934. 19% of the employees affirm that they are allowed to work from home, even if only occasionally. The survey questions used in our empirical analysis are appropriate questions to describe the distribution of decision making authority among employees and monitoring activities within a firm. To the best of our knowledge, so far no study has combined information on ICT usage across hierarchical levels with information on worker autonomy or worker monitoring and revealed an association between ICT usage and workplace organization, thereby focusing on the employee perspective. By using data from the LPP that are combined with data from the IAB Establishment Panel, we would like to reduce this research gap.

4 Methods and econometric estimations

4.1 Econometric model

In order to measure the impact of ICT on monitoring activities from the employee perspective, we specify the following OLS regression model as a first econometric strategy:

$$Monitoring = \alpha_0 + \alpha_1 ICT^{01} + \alpha_2 ICT^{10} + \alpha_3 ICT^{11} + X\beta + \epsilon, \quad (1)$$

The dependent variable *Monitoring* measures the monitoring activities an employee faces while pursuing his professional activity, where monitoring refers to an employee's experiences with appraisal interviews, written target agreements and regularly performance evaluations. Our main explanatory variables are three of the four ICT interaction terms, i.e. ICT^{01}, ICT^{10} and ICT^{11}. The coefficients α_1, α_2 and α_3 must be interpreted relative to the excluded reference group ICT^{00}. The matrix X denotes a set of control variables explained below. ϵ is the stochastic error term with zero mean and finite variance.

Analyzing eq. (1), we assume that the use of ICT in general promotes an increase in monitoring activities. ICT leads to more monitoring for non-managerial workers if $\alpha_2 > 0$, while $\alpha_3 > 0$ indicates increasing monitoring activities for ICT-using managerial workers. More monitoring activities indicate centralization tendencies. In contrast, $\alpha_2 < 0$ ($\alpha_3 < 0$) would indicate that using ICT leads to less monitoring for non-managerial workers (managerial workers),

thus promoting decentralization tendencies. As the interaction term ICT^{01} refers to managerial employees who are not using ICT for their professional activities, we assume that monitoring is limited due to the absence of ICT use, and expect α_1 to be smaller in absolute terms than α_2 and α_3.

Our econometric strategy to measure the impact of ICT on workers' autonomy is similar as in the prior econometric model. We consider here the autonomy variable described in Section 3 as dependent variable. The ICT interaction terms serve again as main explanatory variables. We specify the following OLS model:

$$Autonomy = \gamma_0 + \gamma_1 ICT^{01} + \gamma_2 ICT^{10} + \gamma_3 ICT^{11} + X\beta + \epsilon, \quad (2)$$

where *Autonomy* provides information on an individual's amount of job autonomy and the incidence of working from home.

ICT increases autonomy for non-managerial employees if $\gamma_2 > 0$, while $\gamma_3 > 0$ indicates that ICT promotes autonomy of supervisors. More employee autonomy indicates decentralization tendencies. Conversely, $\gamma_2 < 0$ ($\gamma_3 < 0$) would suggest that using ICT contributes to decrease the autonomy of non-managerial employees (supervisors), thus promoting centralization tendencies. Since γ_1 measures the autonomy effect for supervisors without ICT usage relative to their non-managerial counterparts, we expect γ_1 to be positive. Even in the absence of ICT usage, employee autonomy should increase with individual hierarchical status.

To test the relationship between our dependent and main explanatory variables, we include a rich set of control variables. Working on data from the LPP data set entails the enormous advantage to use a rich variety of potential controls, especially as the LPP data set may be merged to the IAB Establishment Panel. Thus, X contains an extensive set of individual- and establishment-level control variables for which we provide definitions and descriptive statistics in the appendix. We included as controls individual characteristics such as age, gender and nationality, but also job characteristics, i.e. employment status (full-time or part-time, permanent or fixed-term), actual working hours or working conditions. We also add establishment-level information such as firm size, type of firm structure, sector affiliation and region, remuneration agreements, and leadership strategy. Finally, we considered control variables from the IAB Establishment Panel describing the presence of works councils, the share of low and high skilled workers, the ownership of a firm, and existing working contracts.

4.2 Basic results from the OLS estimations

Tables 3 and 4 present the benchmark OLS results. Each table depicts a different dependent variable and refers either to eqs. (1) or (2). The results are received

Table 3: OLS estimates of worker monitoring.

Model	(1)	(2)	(3)	(4)	(5)	(6)
ICT	0.651***		0.308***		0.213***	
	(0.024)		(0.032)		(0.036)	
ICT^{01}		0.161***		0.097		0.136**
		(0.060)		(0.065)		(0.068)
ICT^{10}		0.629***		0.314***		0.217***
		(0.027)		(0.034)		(0.039)
ICT^{11}		0.766***		0.376***		0.333***
		(0.032)		(0.040)		(0.045)
LPP EE	no	no	yes	yes	yes	yes
LPP	no	no	no	no	yes	yes
IAB EP	no	no	no	no	yes	yes
$\alpha_1 = \alpha_3$						7.73***
						[0.0055]
$\alpha_2 = \alpha_3$						11.48***
						[0.0007]
R^2	0.0686	0.0726	0.1655	0.1655	0.2871	0.2871
N	6,793	6,793	6,130	6,130	4,208	4,208

Source: Linked Personnel Panel 2014/2015, IAB Establishment Panel 2014.
Notes: The dependent variable is the double standardized monitoring variable *Monitoring* referring to three questions on appraisal interviews, fixed targets agreements and performance evaluations. All columns are estimated by ordinary least squares (OLS) with robust standard errors in parentheses. The values in square brackets represent *p*-values. The tests on equality of coefficients are *F*-tests. *, **, and *** indicate significance at the 10%, 5% and 1% level, respectively.

by using OLS, thereby estimating robust standard errors. Three different stages are estimated by adding step by step different sets of control variables. The first set includes no control variables. The second set includes control variables based on employee level information describing socio-demographic characteristics or personality traits, job and workplace conditions, corporate culture, workplace contracts or the big 5 personality traits. The third set of control variables consists of variables that have been generated by using questions from the LPP employer survey and the IAB Establishment Panel. The number of observations is declining due to limited data availability. At the beginning, we count 6,793 observations, at the second stage 6,130 and at the third stage 4,208 observations.

In Table 3, the empirical results are displayed for the worker monitoring variable *Monitoring*. As theory predicts, ICT is associated with greater monitoring of employees. In column (1), the variable ICT has a highly significant and positive impact. The size of the coefficient is 0.651, meaning that the monitoring intensity – in the form of appraisal interviews with the supervisor, written target agreements and regular performance assessments – for employees using digital ICT

Table 4: OLS estimates of worker autonomy.

Model	(1)	(2)	(3)	(4)	(5)	(6)
ICT	0.636***		0.103***		0.039	
	(0.026)		(0.030)		(0.035)	
ICT^{01}		0.368***		0.205***		0.206***
		(0.048)		(0.053)		(0.062)
ICT^{10}		0.512***		0.089***		0.023
		(0.029)		(0.033)		(0.039)
ICT^{11}		1.041***		0.377***		0.317***
		(0.034)		(0.038)		(0.044)
LPP EE	no	no	yes	yes	yes	yes
LPP	no	no	no	no	yes	yes
IAB EP	no	no	no	no	yes	yes
$\gamma_1 = \gamma_3$						3.02*
						[0.0825]
$\gamma_2 = \gamma_3$						77.93***
						[0.0000]
R^2	0.0655	0.1189	0.2870	0.2871	0.2913	0.2914
N	6,793	6,793	6,130	6,130	4,208	4,208

Source: Linked Personnel Panel 2014/2015, IAB Establishment Panel 2014.
Notes: The dependent variable is the double standardized autonomy variable *Autonomy* referring to two questions on job autonomy and working from home. All columns are estimated by ordinary least squares (OLS) with robust standard errors in parentheses. The values in square brackets represent *p*-values. The tests on equality of coefficients are *F*-tests. *, **, and *** indicate significance at the 10%, 5% and 1% level, respectively.

devices is 0.651 standard deviations higher than for non-ICT users. Adding control variables from the LPP employee survey (column (3)) as well as from the LPP employer survey and the IAB Establishment Panel (column (5)) does not change the significance level, but reduces the magnitude of the coefficient from 0.651 over 0.308 to 0.213.

In the next step, we examine the coefficients of the ICT interaction terms. We observe that all estimates of the ICT interaction terms are positive and remain significant after controlling for individual- and establishment-level characteristics. The estimation results lead to the following implications. First, $\alpha_2 > 0$ indicates that within the group of non-managerial employees monitoring is stronger for ICT users than for non-ICT users. Second, $\alpha_3 > \alpha_1$ ($F = 7.73$, $p = 0.0055$) indicates that among managerial employees monitoring is more pronounced for ICT users than for non-ICT users.[1] Third, $\alpha_3 > \alpha_2$ ($F = 11.48$, $p = 0.0007$) implies that within the

1 This result is not surprising given that the large majority of supervisors actually uses ICT (about 90%), while the share of supervisors not using ICT is relatively low (about 10%). For this

group of ICT users managerial employees are more intensively monitored than non-managerial employees.[2]

The empirical results are in line with our theoretical assumptions. First, the use of mobile ICT is associated with more monitoring for employees, irrespective of their hierarchical status. This underlines the assumption that digital ICT use leads to a redesign of the workplace organization in a way that working processes and their corresponding outcomes can be controlled more efficiently. Second, among the ICT users monitoring is more intense for managerial than for non-managerial employees. This implies that digitalization affects the working conditions not only for employees at lower hierarchical levels, but especially for employees at medium or higher hierarchical levels.

An alternative way in which ICT may affect workplace organization is by promoting worker autonomy. To the extent that the usage of ICT increases the possibility to gain knowledge, we would expect it to increase the degree of worker autonomy. We examine the relationship between ICT, hierarchical status and worker autonomy in more depth in Table 4.

After adding control variables at the individual and establishment level, we notice that the coefficient of the variable *ICT* turns insignificant (column (5)). This result is not in line with the assumption that using ICT promotes employee empowerment. More differentiated findings can be obtained from the interaction term specification according to equation (2). The corresponding estimation results are displayed in columns (2), (4) and (6). We can see that the estimated coefficients of the variables ICT^{01} and ICT^{11} are positive and highly significant, while the coefficient of the variable ICT^{10} is positive and only significant as long as it is not controlled for establishment characteristics. These estimation results lead to the following implications. First, as the hypothesis that $\gamma_2 = 0$ cannot be rejected, there is no evidence that among non-managerial workers ICT users gain in

reason, this final result has to be interpreted with some caution. As a robustness check, we also conducted some alternative approaches to deal with the problem of the low share of non-ICT using managerial employees. First, we excluded the group of non-ICT using supervisors from the sample and focused on the remaining groups. Second, we restricted the sample to certain subsets, in which the share of non-ICT using supervisors is slightly higher than in the entire sample (blue collar workers, certain industries and firm size groups, certain educational and hierarchical levels). The estimation results remain virtually the same as those presented in Table 3. This does also hold for the corresponding estimates on employee autonomy displayed in Table 4.

2 As expected, we find as a final estimation result that α_1 is positive (meaning that non-ICT using supervisors are more likely to be monitored than non-ICT using subordinates), but smaller in magnitude than α_2 and α_3.

autonomy relative to non-ICT users. Second, $\gamma_3 > \gamma_1$ ($F = 3.02$, $p = 0.0825$) indicates that within the group of supervisors the use of ICT is associated with more empowerment. Third, $\gamma_3 > \gamma_2$ ($F = 77.93$, $p = 0.0000$) implies that within the group of ICT users managerial employees gain more in autonomy than non-managerial employees.[3]

Comparing our findings with the theoretical considerations explained in Section 2, we may state that digital ICT does not increase employees' autonomy in general. In fact, employees are affected differently, depending on their hierarchical position. More precisely, only ICT-using managerial employees benefit from receiving more autonomy, while the autonomy of ICT-using non-managerial employees does not appear to be affected. This finding highlights the importance of a complementarity between digital ICT, skills, knowledge, and responsibility.

4.3 Instrumental variables estimation

The parameter estimates in eqs. (1) and (2), i.e. α_i and γ_i ($i = 1, 2, 3$) are only unbiased and consistent if the ICT interaction terms ICT^{01}, ICT^{10}, and ICT^{11} are strictly exogenous. However, this exogeneity assumption is not unlikely to be violated caused by endogeneity issues, such as omitted variables, simultaneity, and selectivity. For example, digital ICT devices are unlikely to be randomly assigned to both managerial and non-managerial employees. In fact, managerial and non-managerial employees are likely to differ systematically with respect to the assignment of digital ICT devices based on observed and unobserved factors. In these cases, the ICT interaction terms are itself functions of a set of individual characteristics, so they have to be treated as endogenous explanatory variables in the monitoring or autonomy function displayed in eqs. (1) and (2).

An appropriate response to the potential endogeneity of the ICT interaction terms is a structural model approach that allows for observed and unobserved individual characteristics. Specifically, we can estimate the following four-equation system:

$$DRA = \delta_0 + \delta_1 ICT^{01} + \delta_2 ICT^{10} + \delta_3 ICT^{11} + X\beta + \mu \tag{3}$$

$$ICT^{01} = \phi_0 + \phi_1 \overline{ICT^{01}} + \phi_2 \overline{ICT^{10}} + \phi_3 \overline{ICT^{11}} + X\beta + \nu_1 \tag{4}$$

$$ICT^{10} = \lambda_0 + \lambda_1 \overline{ICT^{01}} + \lambda_2 \overline{ICT^{10}} + \lambda_3 \overline{ICT^{11}} + X\beta + \nu_2 \tag{5}$$

3 Finally, γ_1 exhibits the expected positive sign indicating that even without ICT usage supervisors have the opportunity to work more autonomously than non-managerial employees.

$$ICT^{11} = \theta_0 + \theta_1\overline{ICT^{01}} + \theta_2\overline{ICT^{10}} + \theta_3\overline{ICT^{11}} + X\beta + \nu_3 \quad (6)$$

Here, eq. (3) is the structural equation, while the remaining equations are the reduced-form (or first-stage) equations. *DRA* (Decision Rights Allocation) indicates *Monitoring* or *Autonomy*, respectively. Apart from the complete set of control variables X, the reduced-form equations include three exclusion restrictions, i.e. $\overline{ICT^{01}}$, $\overline{ICT^{10}}$, and $\overline{ICT^{11}}$, which are used as identifying instrumental variables. The parameters are estimated using the two-stage least squares estimator (2SLS), where the coefficients δ_i $(i = 1, 2, 3)$ in the structural equation are of particular interest.

To be valid instruments, the exclusion restrictions must significantly determine the ICT interaction terms ICT^{01}, ICT^{10}, and ICT^{11} without being correlated with the error term μ in the structural equation. In the present case, we choose group-specific mean values as technical identifying instrumental variables.[4] The categories for generating the group-specific mean values are age group, gender, worker status (blue vs. white color worker), nationality, and educational level.[5]

One might argue that educational graduation may to some extent be correlated with the error term in eq. (3), so the categories of educational level might fail to meet the exogeneity assumption. For example, individuals might select themselves into certain educational levels. Furthermore, teams may be segregated with respect to education. However, Charlot and Decreuse (2005) show that self-selection in education is inefficient. This indicates that the self-selection problem may not endanger our exogeneity assumption. Moreover, an individual's educational level is likely to be largely determined by exogenous factors, such as personality traits, individual talent, IQ, or family background. This is shown, for example, by Migali and Zucchelli (2017) who explore the impact of personality traits on high school dropouts, by Kajonius and Carlander (2017) for the effect of personality traits on educational attainment, by Pfeiffer and Reuss (2008) who theoretically analyze the impact of formation of skills in early childhood on human capital formation, by Mendolia and Siminski (2017) for the relationship between family background and education, and by Dustmann (2004) who examines the impact of parental background on secondary track choice and subsequent educational achievements. Altogether, this makes educational level to be

4 The idea to use group-specific means as exclusion restrictions is quite common and has been applied, for example, in Woessmann and West (2006).

5 The variable "educational level" captures educational graduations ranging from no educational degree to university degree (no educational degree, apprenticeship training, off-the-job training, professional / master craftsmen school, university of applied sciences, university degree).

an intuitive candidate for satisfying the assumption of conditional orthogonality with the error term in eq. (3).

The group-specific mean values must be calculated separately for each of the considered groups (i.e. ICT-using supervisors, ICT-using non-managerial employees, supervisors without ICT usage, non-managerial employees without ICT usage) according to selected individual characteristics that are objective and clearly definable to be suitable candidates to meet the exogeneity assumption. For example, $\overline{ICT^{11}}$ represents the share of supervisors using digital ICT devices classified with respect to age group, gender, worker status, nationality, and educational level. $\overline{ICT^{11}}$ is positively correlated with ICT^{11} by construction, but there is no reason to expect that the average number of supervisors using digital ICT devices within each of these cells has an influence on an individual's probability to be monitored or being endowed with autonomy in any other way than through its effect on ICT^{11}. In other words, $\overline{ICT^{11}}$ satisfies the relevance condition by construction and should also meet the exogeneity assumption regarding the determination of *DRA*, thus representing a valid instrument for ICT^{11}. The reasoning for the remaining group-specific mean values $\overline{ICT^{01}}$ and $\overline{ICT^{10}}$ applies accordingly.

The estimation results of our instrumental variables approach are displayed in Table 5. Columns (1) to (3) display the first-stage regression results according to eqs. (4) to (6), while the second-stage results according to equation (3) are displayed in columns (4) and (5). At first, we see that the exogeneity test rejects the null hypothesis of exogenous explanatory variables.[6] This indicates that the OLS estimates are indeed inconsistent and emphasizes the necessity to account for endogenous explanatory variables by applying an IV approach. Moreover, the first-stage regression results confirm the relevance of the group-specific mean values in determining the corresponding interaction term. Furthermore, from the summary statistics of the first-stage regressions we get highly significant *F*-statistics for the coefficients of $\overline{ICT^{01}}$, $\overline{ICT^{10}}$, and $\overline{ICT^{11}}$ which also exceed the commonly applied rule of thumb of 10 ($\overline{ICT^{01}}$: $F = 20.59$, $\overline{ICT^{10}}$: $F = 58.98$, $\overline{ICT^{11}}$: $F = 39.21$). This additionally underlines the relevance of our applied instruments. Since the econometric model is just-identified, a test of over-identifying exclusion restrictions cannot be performed, which prevents testing the exogeneity assumption of the applied instruments.

6 The applied exogeneity test is Wooldridge's heteroskedasticity-robust score test that allows to test whether all the supposed endogenous regressors are in fact exogenous. The null hypothesis is that the variables to be instrumented are uncorrelated with the error term of the structural equation. See Wooldridge (1995).

Table 5: IV estimates of worker monitoring and autonomy.

Model	(1)	(2)	(3)	(4) Monitoring	(5) Autonomy
$\overline{ICT^{01}}$	0.992***	0.073	−0.029		
	(0.130)	(0.179)	(0.109)		
$\overline{ICT^{10}}$	0.045*	0.754***	−0.043		
	(0.027)	(0.070)	(0.054)		
$\overline{ICT^{11}}$	0.046	−0.162	0.814***		
	(0.030)	(0.100)	(0.084)		
ICT^{01}				−0.387	0.129
				(0.312)	(0.413)
ICT^{10}				0.194	0.370*
				(0.193)	(0.221)
ICT^{11}				0.655**	1.331***
				(0.261)	(0.296)
LPP EE	yes	yes	yes	yes	yes
LPP	yes	yes	yes	yes	yes
IAB EP	yes	yes	yes	yes	yes
Exog.				6.351*	15.228***
test				[0.095]	[0.001]
$\delta_1 = \delta_3$				8.33***	7.51***
				[0.0039]	[0.0061]
$\delta_2 = \delta_3$				4.62**	14.79***
				[0.0316]	[0.0001]
R^2	0.0803	0.1904	0.1797	0.2567	0.1881
N	4,208	4,208	4,208	4,208	4,208

Source: Linked Personnel Panel 2014/2015, IAB Establishment Panel 2014.
Notes: The dependent variables are the double standardized monitoring and autonomy variables as defined in Section 3. Columns (1)–(3) present the first-stage regression results of the IV estimation, while the second-stage results are displayed in columns (4) and (5). The values in parentheses represent robust standard errors. The values in square brackets represent p-values. The tests on equality of coefficients are χ^2-tests. The test on exogeneity of the variables to be instrumented is a robust score test according to Wooldridge (1995). *, **, and *** indicate significance at the 10%, 5% and 1% level, respectively.

The IV estimates deviate to some extent from the corresponding OLS estimates introduced in the previous subsection. While the OLS estimates for each of the three ICT interaction terms in the monitoring specification are positive and statistically significant, we can see from column (4) that δ_3, i.e., the estimated coefficient for the interaction term ICT^{11} is the only remaining significant IV estimate. These findings lead to the following conclusions. First, in contrast to the OLS estimates, monitoring among non-managerial employees is no longer more pronounced for ICT users than for their non ICT-using counterparts. Second, $\delta_3 > 0$ and $\delta_3 > \delta_1$

($F = 8.33$, $p = 0.0039$) indicate that ICT-using managerial employees are stronger monitored than their non-ICT-using counterparts. Third, $\delta_3 > 0$ and $\delta_3 > \delta_2$ ($F = 4.62$, $p = 0.0316$) imply that within the group of ICT users managerial employees are more intensively monitored than non-managerial employees.

Regarding the autonomy specification, there are also some differences between the OLS and IV estimates. At first, unlike γ_1, δ_1 is no longer statistically significant, meaning that among employees who do not use mobile ICT devices, managerial employees do no longer gain in autonomy at work relative to non-managerial employees.[7] Furthermore, while γ_2 was found to be insignificant, δ_2 is now statistically significant at the 10% level. Only the parameter estimate for ICT^{11} is positive and highly significant in both specifications the OLS and the IV model. From these results, we can conclude the following. First, since $\delta_2 > 0$ and $\delta_3 > \delta_1$ ($F = 7.51$, $p = 0.0061$), ICT users gain in workplace autonomy relative to non-ICT users. This holds for both managerial and non-managerial employees. Second, $\delta_3 > \delta_2$ ($F = 14.79$, $p = 0.0001$) implies that among ICT users managerial employees gain more in autonomy than non-managerial employees.

All in all, our empirical findings suggest that digital ICT indeed promote both worker monitoring and autonomy rather than only one of these practices. Despite the paradox of managing worker autonomy and monitoring, firms obviously do not renounce the application of both management strategies while augmenting the diffusion of ICT among employees. Thus, centralization and decentralization tendencies in firms appear to occur simultaneously. Furthermore, our estimation results imply that mobile ICT increase monitoring and autonomy primarily for managerial employees, while non-managerial employees are affected by ICT usage to a much lesser extent in this regard. This result complements the finding of Bender et al. (2018), according to which a plant's productivity is mainly driven by managers rather than non-managerial employees. Finally, we find that the effect of digital ICT on employee autonomy is much more pronounced than the corresponding effect on employee monitoring (see Table 5, columns (4) and (5): 1.331 > 0.655). Again, this does especially hold for managerial employees rather than non-managerial employees. This finding can be explained by the attempt to find the right balance between autonomy and monitoring. When employee autonomy exceeds employee monitoring, motivation and performance of managerial employees are likely to increase, thereby fostering the complementary relationship between digital ICT, skills, knowledge, and responsibility. Altogether, our empirical results are consistent with other studies showing that, unlike prior technological revolutions, digitalization primarily affects the employ-

7 As above, this result has to be interpreted with some caution because of the relatively low share of managerial employees not using ICT.

ment prospects and working conditions for employees at medium and higher hierarchical levels.

4.4 Robustness checks

We conducted a series of robustness tests, where we utilize alternative dependent variables that are related to our main dependent variables *Monitoring* and *Autonomy*. As an alternative to *Monitoring*, we created a variable *Monitoring Intensity* measuring the amount of employee monitoring. This variable simply sums up the three scores from the monitoring questions used before. Hence, *Monitoring Intensity* can take on a value between 0 and 3, thus *Monitoring Intensity* $\in [0, 3]$.

As an alternative to *Autonomy*, we generated another autonomy variable called *Autodigi*. This variable is based on the following LPP employee survey question on autonomous work structuring: *'Do technological innovations have given you more freedom to decide how to structure your work?'* The question offers four possible answers ranging from not applicable to fully applicable, so *Autodigi* $\in [1, 4]$. Note that *Monitoring Intensity* is a count variable measured at a cardinal scale, while *Autodigi* is an ordinally scaled variable.[8]

The estimation results of these robustness checks are summarized in Table 6. Apart from the estimation results for the alternative dependent variables specifications, Table 6 contains the results for two additional autonomy variables *Job Autonomy* and *Wfh*. Recall that these two variables have already been used to generate our main autonomy variable *Autonomy*. The reason for running separate regressions for *Job Autonomy* and *Wfh* is that these two variables are quite heterogeneous, so our aim is here to verify which autonomy aspect is related to ICT use or whether both are related to ICT use.

The IV results for the *Monitoring Intensity* specification are very similar to the IV estimations resulting from our main variables specification. Hence, the interpretations and implications are the same as for the *Monitoring* specification. Most importantly, the use of digital ICT increases the monitoring of managerial employees rather than non-managerial employees. Moreover, the results from the *Autodigi* specification are in line with the IV estimates of the *Autonomy* specification, stating that digital ICT promote autonomy for both managerial and

8 Definitions and descriptive statistics of the variables *Monitoring Intensity* and *Autodigi* can be found in the appendix.

Table 6: Robustness checks.

Model	(1) Monitoring Intensity	(2) Autodigi	(3) Autodigi	(4) Job Autonomy	(5) Job Autonomy	(6) Wfh
ICT^{01}	−0.475	0.385	0.215*	1.266***	0.430***	−0.421**
	(0.383)	(0.449)	(0.128)	(0.456)	(0.107)	(0.202)
ICT^{10}	0.238	0.608***	0.943***	0.344	0.053	0.085
	(0.237)	(0.210)	(0.064)	(0.277)	(0.059)	(0.074)
ICT^{11}	0.802**	0.280	1.035***	0.419	0.328***	0.628***
	(0.321)	(0.283)	(0.070)	(0.344)	(0.065)	(0.117)
LPP EE	yes	yes	yes	yes	yes	yes
LPP	yes	yes	yes	yes	yes	yes
IAB EP	yes	yes	yes	yes	yes	yes
Exog.	6.329*	5.141		4.242		58.699***
test	[0.096]	[0.161]		[0.236]		[0.000]
$\delta_1 = \delta_3$	8.31***	0.05	42.26***	3.50*	0.91	21.97***
	[0.0039]	[0.8277]	[0.0000]	[0.0612]	[0.3395]	[0.0000]
$\delta_2 = \delta_3$	4.57**	1.96	5.34**	0.09	42.74***	26.98***
	[0.0325]	[0.1611]	[0.0208]	[0.7699]	[0.0000]	[0.0000]
R^2	0.2569	0.1618	0.0791	0.1708	0.0912	0.2807
N	4,208	4,208	4,208	4,208	4,208	4,208

Source: Linked Personnel Panel 2014/2015.
Notes: The estimation results displayed in columns (1), (2), (4) and (6) refer to second-stage IV estimations. The variable *Monitoring Intensity* measures the amount of employee monitoring using information on whether an employee is concerned with appraisal interviews, fixed targets agreements and/or performance evaluations. The variable *Autodigi* measures an employee's perceived autonomy with regard to work structuring. *Job Autonomy* and *Wfh* are defined in Section 3. Columns (3) and (5) are estimated using an ordered probit regression model. The values in parentheses represent robust standard errors. The values in square brackets represent *p*-values. The tests on equality of coefficients are χ^2-tests. The test on exogeneity of the variables to be instrumented is a robust score test according to Wooldridge (1995). The R^2 in columns (3) and (5) is the *Pseudo* – R^2. *, **, and *** indicate significance at the 10%, 5% and 1% level, respectively.

non-managerial employees, where managerial ICT users benefit more from additional autonomy than non-managerial ICT users. Note that this interpretation is based on the estimates of the ordered probit model displayed in column (3) rather than the IV estimates displayed in column (2). We refer to column (3), because according to the exogeneity test, the exogeneity assumption of the ICT interaction terms cannot be rejected.

Regarding our main result, the estimation results for the single dependent variables *Job Autonomy* and *Wfh* are consistent with the results of the *Autonomy*

specification (see columns (5) and (6)).[9] Digital ICT improve job autonomy and the probability to work from home especially for managerial ICT users, who benefit more from increased job autonomy and working from home episodes than their non-managerial counterparts. In this regard, therefore, both autonomy dimensions are related to digital ICT use.

However, we obtain contradictory parameter estimates for the interaction term ICT^{01} that captures the autonomy effect for managerial employees who do not use digital ICT devices. While the estimated coefficient for ICT^{01} is positive and highly significant in the *Job Autonomy* specification, it is significantly negative in the *Wfh* specification. The positive effect in the *Job Autonomy* specification simply indicates an extended job autonomy for managerial employees not using ICT relative to their non-managerial counterparts. The second effect emphasizes the importance of digital ICT for working from home arrangements. Managerial employees who do not use ICT are less likely to work from home than their non-managerial counterparts. However, among ICT-using employees, managerial employees are more likely to work from home than their non-managerial counterparts.

5 Conclusions

In times of digitalization, firms are encouraged to implement modern technological tools into the daily working life of employees. Innovative information and communication technologies (ICT), for instance, enable a cheaper access to work related knowledge and a faster communication among employees. Thus, using these ICT for professional activities promises higher performance levels. In addition, work organizations become more and more flexible as the use of ICT decreases the need to define total working hours (e.g. resulting in self-managed working time), work places (e.g. resulting in working from home) and task execution. However, digital ICT and its possible application to collect data, record working time or track real-time locations – to name only a few examples – foster the attractiveness of employee monitoring, e.g. via performance targets and performance appraisals. On the one hand, this means that new work arrangements due to the use of digital ICT may increase an employee's autonomy. On the other hand, however, monitoring activities might increase as well.

9 For the variable *Job Autonomy*, we refer to the results from the ordered probit model displayed in column (5), because the exogeneity test does not reject the exogeneity assumption of the ICT interaction terms in the IV specification displayed in column (4).

The objective of this paper is to highlight the impact of using digital ICT devices on workplace organization. More precisely, we explore whether using digital ICT leads to more monitoring or autonomy, or to an increase in both management practices across hierarchical levels. Prior studies call attention to a forthcoming decentralization of work structures, but neglect to analyze work practices that lead to a more centralized workplace organization. However, with an increase in today's monitoring possibilities, it is important to juxtapose decentralization and centralization measures such as autonomy and monitoring, to find out which policy prevails and if there are differences regarding the impact of using ICT on worker autonomy and monitoring across hierarchical levels.

Using new linked employer-employee data from the German Linked Personnel Panel and the IAB Establishment Panel, we applied both an ordinary least squares and an instrumental variables estimation approach to account for endogeneity issues. Our main empirical results can be summarized as follows. First, we find that digital ICT promote both employee monitoring and autonomy, so centralization and decentralization tendencies occur simultaneously. Second, managerial employees are more affected by ICT-induced monitoring and autonomy than their non-managerial counterparts. Finally, the effect of digital ICT on employee autonomy is more pronounced than the corresponding effect on employee monitoring. Again, this does especially hold for managerial employees. All in all, our results support the view that unlike prior technological revolutions the digital transformation primarily affects the employment prospects and working conditions of employees at medium and higher hierarchical levels. This is different to other technological revolutions during which less skilled employees at lower hierarchical level were primarily concerned.

Our study on the impact of digital ICT use on workplace organization highlights the employee perspective, thereby concluding that digital ICT promote both employee autonomy and monitoring. However, this does not necessarily mean that firms benefit from a joint implementation of autonomy and monitoring practices as a response to ICT diffusion. For future research, it would be interesting to extend our analysis by asking whether a joint implementation of worker autonomy and monitoring policies has the potential to increase firm performance. Specifically, there may be direct and indirect effects of implementing digital ICT on firm performance, where the indirect effects may be mediated by worker autonomy and monitoring.

Our empirical results lead to a number of questions that can be dealt with in future work. A first question is whether there is a need for more interdisciplinary work to cover complex organizational processes. In the near future, firms are required to improve their knowledge about upcoming and revolutionary digital technologies such as blockchain or artificial intelligence. As a consequence,

in order to understand the interrelation between complex digital technologies and organizational adjustment processes, it will be necessary to combine the knowledge and experiences of ICT experts, organizational sociologists, and organizational economists.

Another future question is whether the dichotomous categorization in centralized and decentralized work organization is able to completely cover the organizational problems, which arise through the adoption of new digital technologies. In this context, our empirical results show that the traditional management continuum with autonomy and monitoring as rivaling management practices (Gilbert/Sutherland 2013), meaning that firms could either choose to increase employee autonomy or employee monitoring, fails to adequately map the reality of today's workplace organization. Instead, modern workplace organizations that are influenced by the implementation of digital technologies can be characterized by the joint use of instruments of employee autonomy and employee monitoring. An example of the joint application of autonomy and monitoring practices is the previously mentioned 'Results Only Work Environment' (ROWE) as discussed in Moen et al. (2011a,b). As a result, it does not appear unusual to observe decentralized firms applying typical policies of centralization or centralized firms adopting typical policies of decentralization.

In this context, the interplay between worker autonomy and monitoring might be affected by improvements of existing technologies or new inventions of real-time monitoring technologies. If workers perceive an imbalance in favor of monitoring relative to autonomy, negative effects for the firm are not unlikely to occur. For example, excess monitoring might significantly increase the workers' stress level and job dissatisfaction. In addition, the workers' intrinsic motivation might be crowded out, leading to lower performance levels. As a consequence, firms are encouraged not to lose sight of the beneficial effects of worker autonomy.

Finally, it would be interesting to ask whether digitalization has the potential to fundamentally change the organization of work or even challenge organizational frontiers. For example, in the theoretical section we describe how the adoption of digital technologies leads to a routine-biased technological change (RBTC), meaning that routine tasks are likely to be automated, while at the same time the demand for non-routine tasks will increase. As a result, digital technologies are likely to increase the relevance of cooperation among employees and all forms of teamwork. Furthermore, digital technologies are also likely to increase the necessity for employees to work on interdependent tasks. Finally, it is also possible that entire organizational structures change due to the implementation of digital technologies. For example, given that digitalization is associated with increased cooperation requirements among co-workers, it appears quite natural to assume that firms implement flexible network structures, where cross-

functional teams are incorporated into the formal organizational structure and decentralized cooperation with stakeholders, such as suppliers and customers, is possible. Altogether, therefore, it can be expected that digitalization has the potential to change the organization of work and firms to an extent that clearly outperforms the corresponding consequences of prior industrial revolutions.

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Appendix: Definitions and descriptive statistics

Variable	Definition	Mean	Std.-dev.	Min–Max
Monitoring variable (robustness check)				
Monitoring intensity	Dummy variable indicating the amount of employee monitoring	1.348	1.221	0–3
Autonomy variable (robustness check)				
Autodigi	*Do technological innovations have given you more freedom to decide how to structure your work?*	1.540	1.222	0–4
LPP EE control variables				
Age 25–39	Dummy variable indicating employees aged between 25 and 39	0.211	0.408	0–1
Age 40–54	Dummy variable indicating employees aged between 40 and 54	0.488	0.500	0–1
Age 55+	Dummy variable indicating employees aged 55 and above	0.275	0.446	0–1
Female	Dummy variable indicating female employees	0.290	0.454	0–1
Fixed-term contract	Dummy variable indicating employees with a fixed-term working contract	0.043	0.203	0–1
Part-time work	Dummy variable indicating part-time workers	0.136	0.343	0–1
Multitasking	*In my job I execute very different tasks.*	4.196	0.944	1–5
Physical demanding task	*My work is physically demanding.*	2.373	1.487	1–5
Blue collar worker	Dummy variable indicating separating blue collar from white collar workers	0.368	0.482	0–1
Hours actually worked	Number of hours actually worked per week	40.811	8.729	1–90
Shift work	Dummy variable indicating employees with a shift work arrangement	0.306	0.461	0–1

(continued)

(continued)

Variable	Definition	Mean	Std.-dev.	Min–Max
Risk tolerance	Ordinally scaled variable indicating individual willingness to take risks (0 = extremely risk avers, 10 = extremely willing to take risks)	5.682	1.824	0–10
Fair treatment	*My supervisor treats me with respect in all aspects of my work.*	3.944	0.932	1–5
German nationality	Dummy variable indicating employees of German nationality	0.976	0.152	0–1
Envy	*I get angry if other people are undeservedly better than me.*	2.633	1.295	1–5
Compassion	*I have a feeling of guilt if I am undeservedly better than other people.*	2.329	1.166	1–5
Bad working conditions	*I am working under bad conditions such as noise, extreme temperatures, unpleasant lighting or smell.*	2.819	1.557	1–5
Lifetime employment	*I would like to work in this firm for the rest of my working life.*	4.108	1.128	1–5
Importance	*This firm is of great importance for me personally.*	3.761	1.177	1–5
Firm problems	*I consider the problems of the firm as if they were my own.*	2.806	1.313	1–5
Affiliation	*I am strongly affiliated to my firm.*	3.901	1.159	1–5
Emotional commitment	*I am emotionally committed to my firm.*	3.796	1.201	1–5
Part of the family	*I feel as being 'part of the family' in this firm.*	3.776	1.206	1–5
Turnover intention	*How often did you thought of changing your current employer during the last 12 months?* (1 = every day, 5 = never)	4.412	0.920	1–5
Understanding	*The employees fully understand the company's goals.*	3.791	1.026	1–5
Trust	*Our supervisors trust their subordinates.*	3.850	0.992	1–5

(continued)

(continued)

Variable	Definition	Mean	Std.-dev.	Min–Max
Appreciation	*Our supervisors are appreciative of their subordinates.*	3.772	0.983	1–5
Discrimination	*No employee is discriminated due to sex, age, nationality, religious affiliation, handicap, sexual orientation, or skin color.*	4.195	1.146	1–5
Extraversion 1	*I am someone who is communicative.*	4.144	0.866	1–5
Extraversion 2	*I am a convivial companion.*	3.897	0.909	1–5
Extraversion 3	*I am a reserved person.* (reversed)	3.043	1.136	1–5
Conscientiousness 1	*I am someone who does a thorough job.*	4.508	0.583	1–5
Conscientiousness 2	*I am someone who tends to be lazy.* (reversed)	4.362	0.796	1–5
Conscientiousness 3	*I am someone who executes tasks efficiently.*	4.240	0.591	1–5
Neuroticism 1	*I am a worrier.*	3.260	1.159	1–5
Neuroticism 2	*I am a nervous person.*	2.503	1.102	1–5
Neuroticism 3	*I am a relaxed person who can handle stress.* (reversed)	2.347	0.922	1–5
Openness 1	*I am someone who produces new ideas.*	3.679	0.881	1–5
Openness 2	*I am someone who values artistic experiences.*	3.235	1.185	1–5
Openness 3	*I am someone who has a lively imagination.*	3.555	1.034	1–5
Openness 4	*I am eager for knowledge.*	4.145	0.773	1–5
Agreeableness 1	*I am someone who is sometimes a little rude to other people.* (reversed)	3.749	1.107	1–5
Agreeableness 2	*I am someone who can forgive.*	4.205	0.725	1–5
Agreeableness 3	*I am someone who treats others with respect.*	4.233	0.632	1–5
LPP control variables				
U form	Dummy variable indicating firms with a functional organization structure	0.740	0.439	0–1

(continued)

(continued)

Variable	Definition	Mean	Std.-dev.	Min–Max
M form	Dummy variable indicating firms with a divisional organization structure	0.100	0.301	0–1
Firm size 50–99	Dummy variable indicating firms with 50–99 employees covered by social security	0.320	0.467	0–1
Firm size 100–249	Dummy variable indicating firms with 100–249 employees covered by social security	0.336	0.473	0–1
Firm size 250–499	Dummy variable indicating firms with 250–499 employees covered by social security	0.176	0.381	0–1
Metal, electronics, vehicle manufacturing	Dummy variable indicating firms in the metal working sector, in the electrical industry or in vehicle manufacturing	0.284	0.451	0–1
Trade, traffic, news	Dummy variable indicating firms in the trade, traffic, or news sector	0.154	0.362	0–1
Firm-related and financial services	Dummy variable indicating firms that offer firm-related or financial services	0.152	0.359	0–1
Information and communication, other services	Dummy variable indicating firms that offer information and communication services or other services	0.075	0.264	0–1
Eastern Germany	Dummy variable indicating firms that are located in Eastern Germany	0.357	0.479	0–1
Southern Germany	Dummy variable indicating firms that are located in Southern Germany	0.198	0.399	0–1
Western Germany	Dummy variable indicating firms that are located in Western Germany	0.268	0.443	0–1
Hierarchy	Number of hierarchical levels in a firm	2.952	1.039	1–7

(continued)

(continued)

Variable	Definition	Mean	Std.-dev.	Min–Max
HR level	Dummy variable indicating whether or not the human resources executive / chief human resources officer (CHRO) is a member of the executive board	0.456	0.498	0–1
PFP	Dummy variable indicating whether a collective agreement permits variable remuneration components for employees covered by collective agreement	0.613	0.487	0–1
Extra payment	Dummy variable indicating whether an establishment/ office generally makes voluntary payments, which are not contractually agreed (e.g. by collective agreement, work contract) such as special payments or one-time payments for special achievements of the entire staff	0.373	0.484	0–1
HR Staff	Number of employees in the human resource department of the corresponding establishment/office	10.175	56.337	0–870
Independent firm	Dummy variable indicating firms that are economically independent	0.750	0.433	0–1
Cost leader	Dummy variable indicating firms that rather describe their business model strategy as a cost leadership strategy	0.065	0.247	0–1
Quality leader	Dummy variable indicating firms that rather describe their business model strategy as a quality leadership strategy	0.298	0.458	0–1

(continued)

(continued)

Variable	Definition	Mean	Std.-dev.	Min–Max
IAB EP control variables				
Council	Dummy variable indicating firms with a works council	0.674	0.469	0–1
Low skill	Share of low skilled workers	18.614	24.550	0–99.526
High skill	Share of high skilled workers	10.313	14.157	0–86.207
Man owner	Dummy variable indicating whether a firm is led by managers or not	0.681	0.467	0–1
Fixed term	Share of employees with a fixed-term working contract	6.886	11.345	0–96.269
Temps	Share of employees with a temporary working contract	3.720	7.631	0–73.260
Part time	Share of employees with a part-time working contract	14.174	19.845	0–100
Apprentice	Share of apprentices	4.110	4.009	0–34.343
Women	Share of female employees	31.758	24.328	0–98.182
Midi	Number of employees receiving a gross monthly salary between 451 and 850	0.867	3.908	0–83,380
One euro job	Share of One-Euro-Jobs	0.232	6.392	0–177.143
Mini	Number of employees receiving a maximal remuneration of 450 per month or being employed for a maximum of two months or 50 days per year	3.008	7.683	0–87.475

Source: Linked Personnel Panel 2014/15 and IAB Establishment Panel, own calculations.