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. We find indeed evidence for the argument that both centralization and decentralization tendencies might appear simultaneously. If modern digital technologies are used for work, worker monitoring is increasing for all employees, but only managerial employees gain in autonomy. The use of instrumental variables estimation tightens our results in a manner that ICT increases both worker autonomy and monitoring, but only for managerial employees, where the ICT effect on autonomy exceeds the corresponding ICT effect on monitoring. All in all, our results support the view that digitalization unlike prior technological revolutions primarily affects the employment prospects and working conditions for employees at higher hierarchical levels.

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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), for instance, promises higher performance levels (Aral et al. 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.

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 work more autonomously. An increase in employees' autonomy in terms of task execution, working time or working place is likely to foster work motivation, which in turn promotes individual performance. 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 these two seemingly opposite management practices.

Although most economic studies of the impact of ICT on firm organization highlight the forthcoming incidence of decentralization measures, we argue in this paper that centralization measures may dominate decentralization practices, and 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 decision rights assignment policies. 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 high-skill work, while simultaneously substituting for middle-skill work (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.

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. All in all, we find empirical evidence for the argument that both centralization and decentralization tendencies might appear simultaneously as a consequence of using digital ICT. According to the OLS estimates, digital ICT are positively associated with worker monitoring, irrespective of the hierarchical level. In contrast, digital ICT are positively associated with worker autonomy, but only for managerial employees and not for non-managerial employees. The IV estimates tighten our results in a manner that ICT increases both worker autonomy and monitoring, but only for managerial employees and not for non-managerial employees. Moreover, we find that within the group of managerial employees the ICT effect on autonomy exceeds the corresponding ICT effect on monitoring. Altogether, our results are in line with the view that digitalization unlike prior technological revolutions primarily affects the employment prospects and working conditions for employees at 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 the LPP, a new German linked employer-employee data set. Third, the use of the LPP 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. Fourth, we contrast the paradox of managing worker autonomy and monitoring introduced by Gilbert and Sutherland (2013) and argue that both seemingly opposing policies may result 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

The fast diffusion of modern technologies and IT systems promotes more and more a digitalization of the working environment. The digital transformation occurs on three interdependent levels (Mikfeld 2016). The first level is marked by technological changes, promising an increase in an employee's ability to perform at a higher level. First of all, improvements in speed and capabilities of ICT are constantly recorded (Lazear and Gibbs 2015: 190), allowing an increasing degree of networking (Internet of Everything) and an enormous central data storage (Big Data, clouds). Communication technologies promote the spread of wired and wireless communication and coordination within a firm (Bloom et al. 2014). Intranets and inter-firm networks facilitate communication within and between firms (Smeets 2017). Following Moore's law that the performance of processors, memory and many other elements of

computer hardware will be improving at an exponential rate (Brynjolfsson and McAfee 2016), computer power is estimated to increase a thousand fold until 2040 (Eberl 2017).

Next to ICT, the application of robotics and sensor systems allows the implementation of artificial intelligence and algorithms that solve complex problems (Mikfeld 2016). To some extent, modern technologies are already used as a substitute for people (Lazear and Gibbs 2015: 194). Simple and low-qualified activities are replaced by new technologies to enhance a computerisation of labour (Hirsch-Kreinsen 2016). There will be a decline of employment in routine-intensive occupations (Frey and Osborne 2013) and a higher demand for skilled labor (Bresnahan et al. 2002). Today, high-skill work is complemented by new technologies and middle-skill work is endangered to be substituted. Employees need to focus more on tasks that are difficult to automate and avert tasks that are easy to automate (Gibbs 2017).

New products, services, organizational structures or business models may flourish on the second level - leading the economy from old to 4.0 (Mikfeld 2016). The quality of decisions, products and services will improve as firms reduce the uncertainty and variation in production by applying new technologies that perform identically every time (Gibbs 2017, Lindbeck and Snower 2000). Moreover, hierarchical firm structures have to be reconsidered and realigned in a more agile way as flexibility and innovation speed is increasing. On the third level, cultural changes such as the need for more autonomy or work-life-blending have to be considered in order to meet the expectations of working digital natives (Mikfeld 2016).

As there is an increasing emphasis on the implementation of IT systems such as ICT, firms are constantly raising their IT investments to enhance productivity at the firm and at the individual level (Bertschek 2012, Draca et al. 2007, Kretschmer 2012). From 2010 to 2016, producer prices for notebooks, for instance, decreased by 40% in Germany (Statistisches Bundesamt 2017) making IT investments more profitable. A survey has shown that on average 61% of German firms give their employees mobile devices that connect to the Internet, as a way to provide access to email, corporate documents, and business software (Statistisches Bundesamt 2016). This value is steadily increasing with a firm's number of employees. For instance, 94% of German firms employing 250 or more workers distribute mobile devices for professional activities. The increasing demand for ICT within a firm may also be explained by a notable decrease in coordination, information and communication costs (Malone 1997, Brynjolfsson and Hitt 2000).

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 relationship between ICT usage and workplace reorganization. From a theoretical point of view, work organization can change from a 'Talyoristic' work organization to a more 'Holistic' organization. The former entails a work organization characterized by task specialization, a pyramidal hierarchical structure, monitoring and centralization of knowledge and responsibilities. The latter presents a work organization with multi-tasking, job rotation, decentralization of knowledge and decision-making authority, team work, more flexibility for the employee and greater communication between workers (Martin 2011, Lindbeck and Snower 2000, Osterman 2000). To clarify what type of workplace organization prevails - decentralization or centralization - or if a mix of both is appearing, we consider in this study worker autonomy and monitoring and contrast it to ICT use.

Autonomy, empowerment or self-management enhances intrinsic motivation as it is perceived by employees as a positive incentive to achieve results through their own striving (Bader and Kaiser 2017, Gilbert and Sutherland 2013). Employees that are allowed to work autonomously, find greater job satisfaction and attain a higher performance. With this in mind, firms need to provide a proper incentive scheme and choose the optimal distribution of knowledge and decision making authority. Thus, a change of the workplace organization may foster a greater freedom in organizing one's own work, and lead to an increasing interest in the job and a higher performance (Caroli et al. 2001, Greenan and Walkowiak 2005, Lindbeck and Snower 1996, 2000).

Innovative ICT offer new useful arrangements with more autonomy in terms of task execution, working time or working place (Gibbs 2017). Knowledge can be acquired at a favorable price (Garicano 2000). 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). A nurse, for instance, may conduct cost-effectively own diagnostics with the help of new technologies, thus works more independently due to technological decentralization procedures. Jobs become more decentralized and are complemented by technology. A higher skill level as well as problem-solving and social skills are required to cope with an increase in decision making authority (Gibbs 2017). Employees have to learn, develop, test and apply their own ideas and solutions (Gibbs 2017, Lindbeck and Snower 2000). This reasoning suggests that if digital ICT increases individual autonomy, managerial employees are more likely to benefit from enhanced autonomy than non-managerial employees, especially because of the assumed complementarity between ICT usage, skills, knowledge, and responsibility.

On the one hand, we notice that the use of ICT can promote autonomy, but, on the other hand, ICT may also lead to greater centralization. New technologies such as ICT make it possible to monitor employees' activities,

to evaluate employees in new ways, and to reward employees' performance accordingly (Gibbs 2017, Dewettinck and Buyens 2006). Technologies such as Radio Frequency Identification (RFID) or Location-based Services (LBS) can be applied to record working time or to access in real time the current location of employees (Krause 2016). Input-based (hours worked or tasks accomplished) or output-based performance (revenue, costs or profits) can be measured (Lazear and Gibbs 2015) and the evaluation might be quantitative or qualitative. Monitoring appears especially in highly automated jobs. In this case, managers favor to make most or all decisions on their own. Processes are going to be optimized and, as only few or no decisions have to be made, employees only have to perform their prescribed tasks (Gibbs 2017). The job of a delivery truck driver, for instance, is optimized in a way that only few skills are required to fulfill the repetitive tasks. Little autonomy is needed, and the business process is simple to monitor.

As monitoring is often the default management practice (Harris and White 1987), 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 oriented 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. Comparing the nurse and the delivery truck driver example, it depends, for instance, on the specific industry if more autonomy or monitoring is needed. Moreover, the culture of the organization, the presence of different levels or functions, the personality, maturity or competence of managers and employees, as well as leadership and risk tolerance play an important role to determine whether a manager should adopt autonomy and/or monitoring management practices (Gilbert and Sutherland 2013).

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 4000 manufacturing firms and the 'Enquête Réponse' (ER) covering under 3000 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 and 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 and Olson-Buchanan 2007, Askenazy and 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 be-

tween 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 and 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 in 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 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

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. $N = 6,793$.

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

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. $N = 6,793$.

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.

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. The corresponding survey questions investigate the application of appraisal interviews, the occurrence of written target agreements and a regularly performance evaluation. 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. ϵ is the stochastic error term with zero mean and finite variance.

Analyzing equation (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 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 negative or insignificant.

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:

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

where *Autonomy* represents our dependent variable, providing 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. Finally, not using ICT at all should lead to an irrelevant impact on workplace organization, i.e. we expect γ_1 to be insignificant.

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 Equation (1) or (2). The results are received by using OLS, thereby estimating robust standard errors. Three different stages are executed by adding step by step different sets of control variables. The first 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 second 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 3,477 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 devices is 0.65 standard deviations higher than for non-ICT users. Adding control variables from the LPP employee survey (column (3)) or 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 0.186.

In the next step, we examine the coefficients of the ICT interaction terms. The coefficient of the variable ICT^{01} turns insignificant after controlling for individual characteristics, whereas the coefficients of ICT^{10} and ICT^{11} remain significant positive at the 1% level. This result is robust to including further control variables from the LPP and the IAB Establishment Panel. Both have a positive sign and take on the values of 0.179 and 0.325 (column (6)), indicating a strong positive impact of using ICT on monitoring activities for both supervisors and non-supervisors (relative to the reference group of non-managerial workers without digital ICT usage). All in all, therefore the OLS results suggests that the use of mobile ICT is associated with more monitoring for employees, irrespective of their hierarchical status.

The empirical results are in line with our theoretical assumptions. The application of digital ICT on both hierarchical levels may be used to monitor managerial and non-managerial employees more efficiently. This underlines the assumption that digital ICT use leads to a redesign of the workplace or-

Table 3: OLS estimates of worker monitoring

Model	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
ICT	0.651***		0.308***		0.186***	
	(0.024)		(0.032)		(0.039)	
ICT^{01}		0.161***		0.097		0.109
		(0.060)		(0.065)		(0.074)
ICT^{10}		0.629***		0.314***		0.179***
		(0.027)		(0.034)		(0.042)
ICT^{11}		0.766***		0.376***		0.325***
		(0.032)		(0.040)		(0.050)
LPP EE	no	no	yes	yes	yes	yes
LPP	no	no	no	no	yes	yes
IAB EP	no	no	no	no	yes	yes
R^2	0.0686	0.0726	0.1655	0.1655	0.2814	0.2815
N	6,793	6,793	6,130	6,130	3,477	3,477

Source: Linked Personnel Panel 2014/2015. *Notes:* The dependent variable is the double standardized monitoring variable *Monitoring* referring to three questions on appraisal interview, fixed targets agreements and performance evaluation. All columns are estimated by ordinary least squares (OLS) with robust standard errors in parentheses. *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.

ganization in a way that working processes and their corresponding outcomes can be controlled more efficiently.

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 and worker autonomy in more depth in Table 4, where the estimates of the variable *Autonomy* are displayed. After adding control variables at the individual and establishment level, we notice that the coefficient of the variable ICT turns insignificant (column (5)).

Thus, we don't observe empirical evidence here that underlines the assumption that using ICT would promote an empowerment of workers. In columns (2), (4) and (6), we consider the impact of the ICT interaction terms. The variable ICT^{01} is significant positive at the 1% level as well as the variable ICT^{11}. The estimated coefficient of the variable ICT^{10} is positive significant on the 1% level as long it is not controlled for establishment characteristics. In contrast to the precedent results, the crucial point is here to be situated at a higher hierarchical level, i.e., to be a supervisor. Only supervisors seem to gain in job autonomy or may benefit from the opportunity

Table 4: OLS estimates of worker autonomy

Model	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
ICT	0.636***		0.103***		0.046	
	(0.026)		(0.030)		(0.038)	
ICT^{01}		0.368***		0.205***		0.192***
		(0.048)		(0.053)		(0.066)
ICT^{10}		0.512***		0.089***		0.021
		(0.029)		(0.033)		(0.042)
ICT^{11}		1.041***		0.377***		0.342***
		(0.034)		(0.038)		(0.048)
LPP EE	no	no	yes	yes	yes	yes
LPP	no	no	no	no	yes	yes
IAB EP	no	no	no	no	yes	yes
R^2	0.0655	0.1189	0.2870	0.2871	0.3100	0.3104
N	6,793	6,793	6,130	6,130	3,477	3,477

Source: Linked Personnel Panel 2014/2015. *Notes:* The dependent variable is the double standardized autonomy variable called *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. *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.

to work from home, irrespective of whether they utilize mobile ICT or not.

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

4.3 Robustness checks

We conducted a series of robustness tests presented in Tables 5 and 6. For the first robustness check, a second monitoring variable *Monitoring Intensity* is created, measuring the amount of employee monitoring. This variable simply consists of the sum of the three scores from the monitoring questions used before. *Monitoring Intensity* can take on a value between 0 and 3, thus *Monitoring Intensity* $\in [0, 3]$. According to Table 5, the empirical findings reinforce our basic results. Both dependent variables describing employee monitoring support the hypothesis that using digital ICT leads to an increase

Table 5: OLS estimates of worker monitoring: robustness check

Model	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
ICT	0.794***		0.378***		0.225***	
	(0.030)		(0.039)		(0.047)	
ICT^{01}		0.198***		0.120		0.134
		(0.073)		(0.080)		(0.090)
ICT^{10}		0.768***		0.386***		0.217***
		(0.034)		(0.042)		(0.051)
ICT^{11}		0.934***		0.462***		0.393***
		(0.039)		(0.049)		(0.060)
LPP EE	no	no	yes	yes	yes	yes
LPP	no	no	no	no	yes	yes
IAB EP	no	no	no	no	yes	yes
R^2	0.0683	0.0723	0.1653	0.1653	0.2813	0.2813
N	6,793	6,793	6,130	6,130	3,477	3,477

Source: Linked Personnel Panel 2014/2015. *Notes:* The dependent variable is the monitoring variable *Monitoring Intensity* measuring the amount of employee monitoring and referring to three questions on appraisal interview, fixed targets agreements and performance evaluation. All columns are estimated by ordinary least squares (OLS) with robust standard errors in parentheses. *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.

in monitoring activities, i.e., digitalization supports centralization tendencies from the employee's perspective. Moreover, we get very similar results for the ICT interaction terms as before. The use of digital ICT is associated with more worker monitoring, irrespective of the hierarchical level.

The second robustness check refers to our estimations on worker autonomy. For this purpose, we generated a further autonomy variable called *Autodigi*. It 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 from not applicable to fully applicable.

Comparing the empirical results with our basic results on worker autonomy in Table 4, we obtain a close match considering the estimates for ICT. In Table 6, the coefficients of ICT have a positive sign and are significant on the 1% level (column (1), (3) and (5)). The idea that the use of ICT is associated with increased worker autonomy appears to have some empirical content. By contrast, the coefficients of the ICT interaction terms deliver different results. While the coefficient of ICT^{01} in Table 4 (column (6)) is positive and highly significant, we get here an insignificant result. Moreover, the coefficient of ICT^{10} - insignificant in the precedent analysis - turned sig-

Table 6: OLS estimates of worker autonomy: robustness check

Model	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
ICT	1.128***		0.945***		0.891***	
	(0.042)		(0.051)		(0.064)	
ICT^{01}		0.195*		0.148		0.205
		(0.104)		(0.112)		(0.137)
ICT^{10}		1.114***		0.963***		0.917***
		(0.046)		(0.054)		(0.069)
ICT^{11}		1.247***		1.012***		0.992***
		(0.049)		(0.059)		(0.076)
LPP EE	no	no	yes	yes	yes	yes
LPP	no	no	no	no	yes	yes
IAB EP	no	no	no	no	yes	yes
R^2	0.0515	0.0527	0.0693	0.0694	0.0771	0.0772
N	6,793	6,793	6,130	6,130	3,477	3,477

Source: Linked Personnel Panel 2014/2015. *Notes:* The dependent variable is the autonomy variable called *Autodigi* measuring the perceived autonomy with regard to work structuring. All columns are estimated by an ordered probit regression model with robust standard errors in parentheses. *, **, and *** indicate significance at the 10%, 5% and 1% levels, respectively.

nificant at the 1% level. These changes do not appear unexpectedly. We interpret these empirical findings by referring to the difference between individual perceptions and the actual state. Whereas the variable *Autodigi* indicates only individual perceptions about gaining more autonomy regarding work structuring, the variable *Autonomy* in Table 4 describes actual facts - such as if the job allows workers to make decisions on their own or if the employer allows working from home. Thus, it is not surprising that more autonomy induced by ICT cannot be perceived by managerial employees not using ICT. Furthermore, both managerial and non-managerial employees perceive an increase in autonomy while using ICT for their professional activity. However, the data based on real facts does not support this perception. In this case, an increase in autonomy depends only on the hierarchical status of the employees.

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

4.4 Instrumental variables estimation

The parameter estimates in equations (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 equations (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:

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

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

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

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

Here, equation in (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.[1] The categories for generating the group-specific mean values are age group, gender, worker status (blue vs. white color worker), and occupational group. For example, $\overline{ICT^{11}}$ represents the share of supervisors using digital ICT devices among all supervisors of the same age group,

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

gender, worker status, and occupational group. $\overline{ICT^{11}}$ is positively correlated with ICT^{11} by construction. Furthermore, 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 7. First of all, we see that the exogeneity test always rejects the null hypothesis of exogenous explanatory variables. This indicates that the OLS estimates are indeed inconsistent and emphasizes the necessity to account for endogenous explanatory variables by applying an IV approach. Furthermore, the first-stage regression results displayed in columns (1) to (3) of Table 7 confirm the relevance of the group-specific means values in determining the corresponding interaction term. 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.

The IV estimates reveal a quite similar pattern for both dependent variables indicating monitoring activities and employee autonomy. As long as we only control for individual characteristics, ICT usage significantly increases monitoring activities as well as employee autonomy for both managerial and non-managerial employees. However, once we additionally control for establishment characteristics, only the ICT effects for managerial employees remain statistically significant, while the corresponding ICT effects for non-managerial employees becomes insignificant.

All in all, our empirical findings suggests that digital ICT indeed promotes both worker monitoring and autonomy, and not only one of these practices. However, this does only hold for managerial but not for non-managerial employees. 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 appear to occur simultaneously. According to our IV estimation results, the digital ICT effect on the autonomy of managerial employees is more pronounced than the corresponding effect on monitoring. This finding can be explained by the attempt to find the right balance between autonomy and monitoring. When worker autonomy exceeds monitoring, the motivation and performance of managerial employ-

Table 7: IV estimates of worker monitoring and autonomy

Model	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
				Monitoring		**Autonomy**	
$\overline{ICT^{01}}$	0.986***	0.105	-0.026				
	(0.176)	(0.202)	(0.142)				
$\overline{ICT^{10}}$	0.039	0.825***	-0.072				
	(0.031)	(0.078)	(0.054)				
$\overline{ICT^{11}}$	0.038	-0.095	0.704***				
	(0.035)	(0.106)	(0.083)				
ICT^{01}				-0.167	-0.176	0.102	0.239
				(0.521)	(0.455)	(0.859)	(0.497)
ICT^{10}				0.658***	0.273	0.476**	0.478
				(0.203)	(0.262)	(0.210)	(0.294)
ICT^{11}				1.477***	0.637**	2.016***	1.462***
				(0.328)	(0.319)	(0.344)	(0.348)
LPP EE	yes	yes	yes	yes	yes	yes	yes
LPP	no	no	no	no	yes	no	yes
IAB EP	no	no	no	no	yes	no	yes
Exog.				15.397***	7.19**	36.812***	14.607***
test				[0.002]	[0.034]	[0.000]	[0.002]
R^2	0.0592	0.1253	0.1783	0.0332	0.2595		0.1711
N	6,130	6,130	6,130	6,130	4,208	6,130	4,208

Source: Linked Personnel Panel 2014/2015. *Notes:* The dependent variables are the double standardized monitoring variable *Monitoring* referring to three questions on appraisal interview, fixed targets agreements and performance evaluation, and the double standardized autonomy variable *Autonomy* referring to two questions on job autonomy and working from home. Columns (1)-(3) display the first-stage regression results belonging to the second-stage results displayed in column (4). Columns (4)-(5) present the IV estimations of the second stage for the monitoring variable. Columns (6)-(7) present the IV estimations of the second stage for the autonomy variable.The values in parentheses represent robust standard errors. The values in square brackets represent p-values. *, **, and *** indicate significance at the 10%, 5% and 1% level, respectively.

ees 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 digitalization unlike prior technological revolutions primarily affects the employment prospects and working conditions for employees at higher hierarchical levels.

5 Conclusions

The digitalization of workplace organization encourages firms to implement modern technological tools into the daily working life of employees. Innovative information and communication technologies, for instance, enable a cheaper access to work relative knowledge and a faster communication among employees. 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 (work-life blending), work places (home office) and task execution. However, digital ICT and its possible application to collect data, to record working time or to track real-time locations - to name only a few examples - foster the attractiveness of employee monitoring. This means that, on the one hand, new work arrangements due to the use of digital ICT may increase an employee's autonomy, but, on the other hand, monitoring activities might increase as well.

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 of 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 an ordinary least squares and, additionally, an instrumental variables estimation approach to account for endogeneity issues. From the OLS estimations, we conclude that using digital ICT is positively associated with monitoring activities, independent of the employee's hierarchical position. However, using digital ICT is only associated with an increase in worker autonomy for employees at a

higher hierarchical level. Thus, only managerial employees seem to gain in autonomy when using ICT for their professional activity. The IV estimation approach leads to more detailed results: The use of digital ICT increases worker autonomy and monitoring, but only for managerial employees and not for non-managerial employees. The digitalization of workplace organization in the form of a diffusion of digital ICT among employees seems only to affect managerial employees. In sum, our empirical results are in accordance with the view that the employment prospects and working conditions of employees at higher hierarchical levels are primarily affected by the digital transformation. This is different to other technological revolutions during which less skilled employees at lower hierarchical level were concerned.

One contribution of our study consists of highlighting the impact of digital ICT use on workplace organization from the employee perspective. Our findings suggest that digital ICT promotes both worker 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 the question if 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.

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6 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
Supervisor	Dummy variable indicating employees with leadership competencies	0.298	0.457	0–1
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

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Variable	Definition	Mean	Std.-dev.	Min–Max
Shift work	Dummy variable indicating employees with a shift work arrangement	0.306	0.461	0–1
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

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Variable	Definition	Mean	Std.-dev.	Min–Max
Trust	*Our supervisors trust their subordinates.*	3.850	0.992	1–5
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				

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Variable	Definition	Mean	Std.-dev.	Min–Max
U form	Dummy variable indicating firms with a functional organization structure	0.740	0.439	0–1
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

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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
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

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Variable	Definition	Mean	Std.-dev.	Min–Max
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.