Paper to be presented at

DRUID15, Rome, June 15-17, 2015

(Coorganized with LUISS)

Combining Information Technology and Decentralized Work Organization:

SMEs versus Larger Firms

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Abstract

This paper examines whether information technology (IT) and decentralized and incentive-based work organization are complementary only for large firms or also for smaller firms. Empirical evidence for complementarity between IT and decentralization is mainly based on large firms. Using data from a sample of 3288 SMEs and of 595 larger firms from the manufacturing and service sector in Germany, I can observe firms? IT intensity in terms of enterprise software and computer use and whether firms have a decentralized work organization. I find that SMEs with decentralized and incentive-based work practices tend to use IT more intensively.

Moreover, for the sample of SMEs, IT and work organization are individually associated with higher productivity but the combination of IT and decentralization does not yield a productivity premium. Contrarily, for the sample of larger firms, the results show that the productivity of IT depends positively on decentralization. The findings suggest that combining IT and decentralized workplace organization seems to be a successful strategy only for larger firms.

Jelcodes:D21,D24

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Anonymous Version*

June 2015

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This paper examines whether information technology (IT) and decentralized and incentive-based work organization are complementary only for large firms or also for smaller firms. Empirical evidence for complementarity between IT and decentralization is mainly based on large firms. Using data from a sample of 3288 SMEs and of 595 larger firms from the manufacturing and service sector in Germany, I can observe firms' IT intensity in terms of enterprise software and computer use and whether firms have a decentralized work organization. I find that SMEs with decentralized and incentive-based work practices tend to use IT more intensively. Moreover, for the sample of SMEs, IT and work organization are individually associated with higher productivity but the combination of IT and decentralization does not yield a productivity premium. Contrarily, for the sample of larger firms, the results show that the productivity of IT depends positively on decentralization. The findings suggest that combining IT and decentralized workplace organization seems to be a successful strategy only for larger firms.

Keywords: information technology; decentralized work organization; complementarity; productivity; firm-level data

JEL codes: D22, D24, L20

*Financial support for this research from the German Federal Ministry of Education and Research (BMBF) within the project "The Productivity of IT-based Services" is gratefully acknowledged. The author thanks Irene Bertschek, Michael Kummer, Francois Laisney, Jörg Ohnemus, Michael R. Ward, Michael Zhang and participants at ZEW internal seminars, the PhD seminar in Industrial Organization at the University of Mannheim, the ZEW Summer Workshop for Young Economists 2014 and the EARIE 2014 for valuable comments and Jakub Tecza for helpful research assistance.

1 Introduction

Information and communication technologies (ICT) have been important drivers of productivity growth and innovation over the last 20 years.[1] Moreover, empirical evidence has shown that ICT productivity returns are not identical across firms and countries but they may vary depending on different work organization and human resource practices (e.g. Bresnahan et al. (2002), Bloom et al. (2012)). Thus, a key conclusion from this evidence is that effective use of ICT should be accompanied with appropriate work organization. In particular, workplace practices that allow for decentralized decision-making and reward individual effort have turned out to improve the effective use of ICT. However, most of the empirical evidence is from large firms, mainly due to data availability, and it remains an open question whether the findings on effective implementation of ICT can be generalized for smaller firms. Generally, firms of different size may differ in their ability to employ ICT or they may have made different levels of complementary organizational investments (Tambe and Hitt (2012)).

This paper tests the hypothesis on the complementarity between IT and decentralized work organization for small and medium-sized firms (SMEs) and compares the results from the sample of smaller firms to those from larger firms. The empirical analysis sheds light on the relationship between IT use, decentralized work organization practices and productivity for firms of different size. The data I use is a unique sample of 3288 SMEs and 595 larger firms from the manufacturing and service sector in Germany. It is an unbalanced panel covering the years 2004, 2007 and 2010. For the empirical analysis of the relationship between IT and decentralization and their productivity contributions, I proceed in two steps. First, I analyze by conditional correlation regressions whether firms with decentralized work practices are more IT intensive. Second, I examine the productivity impacts of these two factors by estimating a Cobb-Douglas production function that is augmented by IT and work organization as additional inputs and that allows for interaction effects between these two inputs.

My main measure for firms' IT intensity is the firms' usage intensity of enterprise software systems. The considered enterprise software systems are enterprise resource planning (ERP), supply chain management (SCM) and customer relationship management (CRM), which are among the most widely diffused enterprise software systems. Such systems assist firms in collecting, storing and using information in the value creation process. Therefore, they can be viewed as good proxies to capture the improved information availability through modern IT. Additionally, I take account of firms' IT intensity by the share of employees using mainly computers for work. Decentralized work organization is measured by the existence of a business unit with own profit and loss responsibility and self-responsible team work. Moreover, firms' use of performance pay is used as another measure that reflects decentralization of work and responsibility. Performance pay also indicates whether firms remunerate good performance.

[1] See for a recent literature review, e.g. Draca et al. (2007), Bertschek (2012) and Cardona et al. (2013).

To the best of my knowledge, this paper is the first analysis on complementarity between IT and decentralization that compares findings from smaller firms to larger firms. Even though Tambe and Hitt (2012) compare IT returns between midsize and large firms, they cannot include work organization in their productivity analysis due to data limitations. The comparison between SMEs and larger firms allows examining whether findings from large firms are valid for firms of smaller size, too. There might be reasons to expect the complementarity of IT and decentralization not to be present for small firms because of different IT usage ability and different levels of IT-related complementary investments across firm size, such as skills or appropriate work organization (Tambe and Hitt (2012), Giuri et al. (2008)). Small firms might on average have lower demand for IT-related complements, for instance, due to a lower amount of information that has to be processed and coordinated (Giuri et al. (2008)). Moreover, the paper contributes to a better understanding of the role of IT, work organization and their interactions for explaining productivity differences among firms of smaller size, given that there is few evidence on the productivity contributions of combining these two factors for smaller firms.

My results show that in line with the complementarity hypothesis, SMEs with a decentralized work organization and performance pay use IT more intensively. Large firms are only significantly more IT intensive when using performance pay. Although both, IT and decentralization, are individually associated with higher SME productivity, the results do not reveal robust evidence for a productivity effect from combining IT and decentralization. Only the combination of IT and performance pay is weakly associated with higher productivity for SMEs. In contrast, the results for large firms show a significant productivity effect for the combination of IT and decentralization as it has already been found in prior research. The comparison of the results for SMEs and larger firms suggests that only larger firms benefit from combining IT and decentralized work organization.

The remainder of the paper is organized as follows: In the next section, I give an overview of the key insights from the literature on IT productivity. The third section presents the data and descriptive statistics. Section four illustrates the empirical methods to test for complementarity. Section five discusses the empirical results and section six concludes with suggestions for future research.

2 Literature and Background Discussion

ICT productivity returns have been shown to vary across countries and firms, which has been summarized in the so-called "productivity puzzle" of ICT.[2] One explanation for the measured heterogeneity in the productivity contributions of ICT is seen in different levels of complementary organizational investments, such as workplace organization and business process re-engineering across firms and countries. For instance, Brynjolfsson and Hitt (2003) suggest that a possi-

[2] See for a short discussion about that argument, e.g. Bloom et al. (2010).

ble explanation why estimated IT output elasticities from firm-level studies have often been higher than the IT contribution found with aggregate data from national accounts, might be due to complementary organizational factors. According to the canonical paper on production complementarities by Milgrom and Roberts (1990), organizational factors are defined to be complements when there are nonconvexities with respect to the output function in a firm's decision whether to adopt any or all of a group of activities that complement new technologies.[3] Decentralized work organization is an example for such a complementary factor, that is partly captured by the estimated IT coefficient if it is not explicitly considered in the analysis. This interdependence between ICT and appropriate work practices and organization is summarized in the hypothesis on complementarity between ICT and work organization.

A complementary relationship between IT and a decentralized work organization can be theoretically underpinned by the difficulty to communicate specific knowledge and limits of people's information processing capacity. If knowledge that is valuable for firm performance is held by employees but difficult to transmit, and information overload puts a constraint on the amount of information that can be processed by decision-makers at the top of the hierarchy, then IT is optimally associated with decentralized authority that gives decision rights to lower levels of the hierarchy (Hitt and Brynjolfsson (1997)). Generally, an organizational structure can be characterized as decentralized if not only the top management has decision-making authority but also employees at lower levels of the hierarchy so that decision-making is spread more evenly throughout the firm in contrast to a centralized firm where decisions are only made at the top of the organizational hierarchy.[4] Decentralization of decision rights implies decentralization of information processing and especially large firms may implement it, given limited capacity of individuals for information-processing and decision-making (Radner (1993)). Possible benefits of decentralization are the reduction of information transfer and communication costs or increased speed of reacting to market changes. Since modern IT reduce information access and processing costs, they are seen as one determinant for decentralization.[5]

Several studies, that can incorporate work organization in the empirical analysis of IT productivity, highlight the importance of decentralized work organization and incentive-setting for good performance in order to derive the full potential of IT. One of the first empirical studies on the relationship between IT and workplace organization is by Bresnahan et al. (2002) who find that the productivity of IT in large US firms is higher if firms also use workplace practices that allow

[3] See Brynjolfsson and Milgrom (2013) for an overview of the theory behind organizational complementarities, a definition and empirical studies analyzing complementarities between IT and workplace variables.

[4] See e.g. Bloom et al. (2010) for an overview about the concept of decentralization in economics. The following discussion about decentralization and its relationship to ICT is based on it.

[5] The mechanism of reduced information costs causing firms to decentralize is theoretically formalized by Garicano (2000). In his model, the firm is conceptualized as a cognitive hierarchy that has to solve problems of varying difficulty and optimally decentralizes with decreasing information costs. Based on an extended version of this model, Bloom et al. (2013) show empirically the differential impact of information versus communication technology on the allocation of decision rights within the firm: They show that information technology increases worker and plant manager autonomy in contrast to communication technology that decreases decision autonomy at lower levels of the hierarchy.

for decentralized decision-making by teams and employees. Black and Lynch (2001) show that US plant productivity is improved the higher the share of nonmanagers using the computer and the higher the education level of workers is. Tambe et al. (2012) find that the combination of IT, decentralization and external focus, which captures a firm's intensity to observe the market environment and availability to uncover market opportunities, is associated with significantly higher productivity for moderate-size and large US firms. Bloom et al. (2012) argue that the US advantage in IT-related productivity effects in comparison to Europe, that has been observed from the mid-1990s, can be attributed to differences in used work and human resource practices between the US and Europe: They show that people management practices which foster individual target setting and monitoring, promotions, rewards, hiring and firing are complementary to IT capital and that US-owned firms employ such practices more intensively than European firms. Mahr and Kretschmer (2010) show that that German manufacturers with an explorative learning type have higher IT productivity returns with greater degree of decentralization, while IT and centralization turn out to be complementary for exploitative learning type firms.

Evidence on ICT productivity returns and organizational complementarities in SMEs is still scare. Tambe and Hitt (2012) find on average higher long-run IT returns for large than for midsize US firms, whereas the midsize firms materialize the gains from IT more quickly. Arvanitis (2005) finds for Swiss firms, mainly SMEs, no evidence for complementarity between IT and decentralized workplace practices and that the productivity contribution of flexible and decentralized workplace practices is lower than the contribution of ICT or human capital. Bugamelli and Pagano (2004) argue that complementary investments in organizational capital and human capital have acted as barriers to investment in ICT for Italian manufacturing firms, among them mainly SMEs. Also for Italian, mainly SMEs from the manufacturing sector, Giuri et al. (2008) find that productivity gains from combining IT and organizational change do not seem to be present in small firms.

In empirical studies, ICT capital is often measured by investment in hardware, software and/or telecommunication equipment, possibly used to construct an ICT capital stock variable, or by the number of computers per employee available in the firm. A particular type of information technology applications are enterprise software systems. Enterprise resource planning (ERP), supply chain management (SCM) and customer relationship management (CRM) are three widely employed enterprise software systems. These software systems have changed drastically how firms can store, access, share, exchange and analyze information relevant for business operations. In particular, these systems have increased the speed of information gathering and availability and they feature an integrated database. Consequently, the improved information basis should support firms in making more solid decisions and in particular, in reacting more timely to problems and market trends. While ERP is a general purpose software aimed at managing information from various business processes inside the firm more efficiently, SCM and CRM software provide support for specific business processes of the value chain. SCM software capabilities help organizing the value chain and operations management in contact to suppliers or buyers. CRM software provides tools to systemize customer relationship management with the aim to improve customer satisfaction and customer loyalty.[6]

Few econometric studies assess the performance effects of enterprise software systems using firm-level data from a larger sample of firms.[7] The existing evidence is mixed, although, pointing towards a positive relationship between the use of some of the systems and performance (e.g. Shin (2006), Aral et al. (2006) and Engelstätter (2013). There are only few studies on complementarities between enterprise software systems as particular examples of IT and work organization. López (2012) finds that CRM use and organizational change are complementary in Spanish firms from the manufacturing and service sector, while no significant productivity increase is found for the combination of ERP use with organizational change. Aral et al. (2012) show that the combination of human resource practices, which monitor employees' performance, and performance pay complements special software for human capital management, which is often part of an ERP system.

3 Data

The data used for the analysis comes from three waves of the ICT survey collected from the Centre for European Economic Research (ZEW) with which an unbalanced panel data set is constructed that includes information from the three years 2004, 2007 and 2010.[8] The ICT survey is a firm-level survey with the focus on the diffusion and the use of information and communication technologies of firms from the manufacturing and service sector located in Germany with a firm size starting with five employees. The survey has been until now conducted five times, for the first time in 2000, then in 2002, 2004, 2007 and in 2010. For each wave roughly 4,400 firms were surveyed and the data is stratified according to industries, to three size classes and to two regions (East/West Germany). The survey is constructed as an unbalanced panel. Consequently, some firms were surveyed in each wave, others only in certain waves and others only once. With respect to the topics and questions asked, some questions are repeated in each wave, others were only asked in some of the waves. For the analysis in this paper, I use data from the waves of 2004, 2007 and 2010 because from 2004 onwards information on enterprise software use intensity and information on work organization is available. Hence, the time frame of the data represents the diffusion of ICT after 2000, where at least basic ICT, such as the personal computer, might be already more widely diffused among firms. Firms may also have made different choices of complementary investments so that many combinations of IT and work organization might exist. Due to item-non response of variables used in the empirical analy-

[6] See e.g. Hindricks et al. (2007), Engelstätter (2013) and Bloom et al. (2013) (for ERP) for more information about properties and benefits of enterprise software systems.

[7] However, there is a large literature, generally from the Information Systems (IS) and business studies literature, on qualitative assessments of enterprise software systems and case-study based evidence, often for one specific enterprise software system. This literature is not discussed here.

[8] The data is accessible at the ZEW Research Data Centre: http://kooperationen.zew.de/en/zew-fdz/home.html

sis and an unbalanced panel structure, there are 3883 firms in my estimation sample and an overall number of observations of 5250 is obtained.[9] Thus, the majority of firms in the sample participated only once in the survey.

Since I want to compare results from smaller firms to those from larger firms, I divide the estimation sample according to employment size. Based on international classifications[10], the maximum employment level for a firm to be an SME is not more than 250. Therefore, I classify all firms with at most 250 employees as SMEs. Those firms with exactly 250 employees are included because the descriptive statistics indicate that a large number of firms declare to have 250 employees, which in a telephone-based survey might be said by the interviewee if she does not know the exact number but expects 250 employees as a decent guess.[11] Based on this classification, 3288 firms are classified as SMEs with an overall number of 4487 observations.[12] The remaining 595 firms are classified as large firms with totally 763 observations.

The section on enterprise software systems in the survey covers whether firms use an ERP, a SCM or a CRM software asking the firms for no (0), minor (1) or broad (2) use. Table 1 shows means and standard deviations for the software use intensity and correlations between them. Among the three software systems, ERP is the most intensively used system. This order is plausible because ERP is the most general software among the three systems. Regarding only the average use of the three software systems (not reported in Table 1), i.e. without distinguishing between usage intensity, across all years 62 percent of the firms in the SMEs sample use ERP, followed by 43 percent using CRM and 35 percent using SCM. For the sample of large firms, almost all firms use ERP (mean = 93 percent), and also SCM (mean = 72 percent) and CRM (mean = 72 percent) are widely diffused. Heterogeneity across large firms is present in the usage intensity. The mean usage intensity by large firms is slightly higher for all three software systems in comparison to the small firms. However, at least for SCM and CRM the variation in usage intensity according to the standard deviation is fairly similar for firms of both size categories.

To measure a firm's IT intensity, I construct an IT intensity indicator based on the usage intensity of these three enterprise software systems. I standardize each factor individually through z-scoring and then I sum up the standardized factors and standardize this sum again.[13] The

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[9] This sample is based on a data set that excludes productivity outliers keeping only firms within the first and 99th percentile of the labour productivity distribution. Labour productivity is measured by total sales over the number of employees. In total, 51 observations are dropped.

[10] See e.g. the definition of SMEs by the European Commission: http://ec.europa.eu/enterprise/policies/sme/facts-figures-analysis/sme-definition/

[11] The empirical results presented in section 5 do not change qualitatively when firms with exactly 250 employees are considered in the sample of large firms.

[12] The sector composition of the estimation sample in comparison to the totally available data of firms with at most 250 employees is not significantly different from the complete data set. Thus, it can be assumed that the used sample is representative with respect to the industries. This similarity is valid for large firms, too. Tables not reported; available upon request.

[13] I add the standardized individual software values into an aggregate IT indicator, which implies that each factor gets equal weight in the indicator, because the hypothesis for equality of coefficients among the three standardized software values could not be rejected after a productivity regression when the standardized values are entered into the regression individually.

Table 1: Means, Standard Deviations, and Correlations for Enterprise Software Use

variable	Mean	Std. Dev.	Min.	Max.	ERP	SCM	CRM
SMEs, N = 4487							
ERP	1.03	0.88	0	2	1		
SCM	0.50	0.74	0	2	0.33	1	
CRM	0.60	0.77	0	2	0.28	0.36	1
Large Firms, N = 763							
ERP	1.72	0.58	0	2	1		
SCM	1.07	0.79	0	2	0.25	1	
CRM	0.99	0.75	0	2	0.18	0.29	1

Data Source: ZEW ICT Panel 2004, 2007, 2010.

resulting IT indicator provides for each firm a normalized measure of enterprise software systems usage intensity that relates the individual firm's software intensity to the overall sample mean value and its dispersion. The standardization S is obtained by subtracting the mean μ_x of the respective variable x within the overall sample and by dividing by the sample standard deviation SD_x of the variable:

$$IT = S(S(ERP) + S(SCM) + S(CRM))$$

$S \cong \frac{x-\mu_x}{SD_x}$

Regarding the interpretation of the indicator, this IT measure provides a picture of the intensity of a firm's reliance on information for decision-making and for business process organization.Although this IT indicator captures explicitly only a specific part of the firm's IT use since it only considers enterprise software use, the advantage of its narrow scope is its economic interpretation as proxy for a firm's intensity of technology-supported use of information as an input into the production process. Even if this IT measure based on the enterprise software systems mismeasures a firm's IT intensity as well as the extent of the use of information in business processes, the measurement error is likely to downward bias the estimates for this indicator.[14]

Nonetheless, it still might be that firms with low enterprise software use intensity are IT intensive (Type II error) when they use other types of IT intensively, such as the personal computer (PC). Since the data includes information on a firm's share of employees working mainly at the computer, I use it as an additional measure for a firm's overall IT intensity. The share of employees working mainly with the PC can be interpreted as a measure for IT capital or alternatively for labour heterogeneity (Bertschek and Meyer (2009)).

[14]See Tambe et al. (2012) for a similar argument for their measure of external focus, p. 847.

I measure decentralized work organization by three binary variables. First, I include information on the existence of a business unit with own profit and loss responsibility (BU), such as a profit centre. A similar measure for decentralization is used by Acemoglu et al. (2007) who define a firm as decentralized when its business units are organized as profit centres.[15] This measure of decentralization refers particularly to the extent of decision autonomy and responsibility at the manager level below the central management board. Second, I consider self-responsible team work (TW), which reflects the transfer of decision autonomy to individuals and groups, and not only to managers. Firms' use of team work has also been employed in prior research to measure decentralized and team-oriented workplace practices (e.g. Bresnahan et al. (2002), Tambe and Hitt (2012)). Third, I include the information whether a firm offers performance pay (PP) to its employees as a further measure for decentralized work practices. This measure reflects the firm's use of incentive-setting to reward good performance.

The organizational practices variables were not asked in the wave of the 2007 survey. In order to not loose information on software use and firm performance from 2007, I replace the organizational practices variables in 2007 with the information of 2010. When this information is not available, due to item non-response or the unbalanced panel structure, I replace the 2007 values with information from 2004. This replacement strategy relies on the assumption of organizational factors being quasi-fixed in the short-run, which is usually made in empirical analyses on the effects of organizational practices when only cross-sectional information on those practices is available (see, e.g. Bresnahan et al. (2002) or Bloom et al. (2012)). The work organization variables I use are close to time-invariant in the sample of SMEs as it is indicated by transition probabilities and persistence statistics for those firms with multiple participation in the survey (not reported; available upon request). Thus, the assumption of the work organization practices being quasi-fixed in the period of analysis can be supported by the data. This assumption holds also for large firms.

Table 2 shows descriptive statistics for the three work organization variables. Across all years, 59 percent of the SMEs have self-responsible team work, 53 percent use performance pay, and 28 percent of them have a business unit with own profit and loss responsibility. As for the enterprise software use intensity, the average use of the work practices is higher in the sample of large firms with 70 percent having a business unit with own profit and loss responsibility, 76 percent using performance pay and even 85 percent of the firms offering performance pay.

[15] Acemoglu et al. (2007) provide a description of the decision authority that managers of business units, which are organized as profit centres, have. In particular, managers of profit centres have the responsibility to monitor revenues and costs. See p. 1773 ff.

Table 2: Means, Standard Deviations, and Correlations for Work Organization Variables

Variable	Mean	Std. Dev.	Min.	Max.	Correlations		
					SMEs (N=4487)		
					Business Unit	Team Work	Performance Pay
Business Unit	0.28	0.45	0	1	1		
Team Work	0.59	0.49	0	1	0.19	1	
Performance Pay	0.53	0.50	0	1	0.21	0.15	1
					Large Firms (N=763)		
Business Unit	0.70	0.46	0	1	1		
Team Work	0.76	0.43	0	1	0.17	1	
Performance Pay	0.85	0.36	0	1	0.13	0.12	1

Data Source: ZEW ICT Panel 2004, 2007, 2010.

Like the IT indicator measures only part of a firm's IT use, the variables to measure decentralized work organization capture only a small part of a firm's work organization. Thus, they might mismeasure firms' decentralization degree and if so, the estimates are downward biased. The mismeasurement problem refers in particular to the intensity of the use of the considered work practices, given that the information on work practices I have is only binary and I do not know how many employees within the firm, for instance, are affected by performance pay or what the scope of decision autonomy is that employees have. Nevertheless, firms which use these work practices might on average probably be more likely to also use other work practices that allow decentralized decision-making and reward performance.

Besides information on ICT, the ICT survey covers information on general firm characteristics. Table 3 and Table 4 provide descriptive statistics of further variables used in the empirical analysis. I capture firm performance through deflated value added. Since I do not have exact information, neither on firms' materials and intermediate inputs nor on firm-specific prices, I use industry-wide information on gross value added together with information on the price evolution from the German National Statistics Agency (Destatis) and combine it with firms' reported total sales from the survey to obtain a proxy for real value added.[16] Labour input is measured by the number of employees and capital input is obtained by constructing a capital stock from the available gross investment data.[17]

[16]Further explanations are in the appendix, see A.1.

[17]I use the perpetual inventory method to construct the capital stock. Further explanations for the construction are available from the author upon request.

Table 3: Production Function Variables

Variable	Mean	Std. Dev.	Median	Min.	Max.
			SMEs (N=4487)		
Number of Employees	52	57.15	28	5	250
Capital Stock	183	8920	3	0.006	584 000
Total Sales	10.60	26.10	3.40	0.06	650
Value Added (deflated)	3.39	7.83	1.15	0.02	152
% Firms located in former East Germany	0.33	0.47	0	0	1
% Multi-Plant Group	0.28	0.45	0	0	1
Labour Productivity (Sales per Employee)	0.19	0.34	0.11	0.008	5.59
Value Added per Employee (deflated)	0.06	0.11	0.04	0.001	2.73
			Large Firms (N=763)		
Number of Employees	1 158	2 756.26	550	253	39355
Capital Stock	349	969	105	0.04	12 400
Total Sales	259	745	95	3.79	10 000
Value Added (deflated)	82.30	271	29.60	1.34	5 550
% Firms located in former East Germany	0.17	0.37	0	0	1
% Multi-Plant Group	0.72	0.45	1	0	1
Labour Productivity (Sales per Employee)	0.22	0.27	0.16	0.008	4.44
Value Added per Employee (deflated)	0.07	0.06	0.05	0.002	0.97

Data Source: ZEW ICT Panel 2004, 2007, 2010.
The values of capital stock, sales, value added and the respective per capita values are expressed in million Euros. Deflated values are in prices of 2005.

Table 4: Means and Standard Deviations for Further Firm Characteristics

Variable	Mean	Std. Dev.	Mean	Std. Dev.	Min.	Max.
	SMEs (N = 4487)		*Large Firms* (N = 763)			
% Emp. Working with PC	0.45	0.34	0.41	0.27	0	1
% High-Skilled Employees	0.21	0.26	0.19	0.20	0	1
% Share Exporters	0.51	0.50	0.74	0.44	0	1
% Works Council	0.23	0.42	0.89	0.32	0	1
% Change in Management	0.18	0.39	0.46	0.50	0	1

Data Source: ZEW ICT Panel 2004, 2007, 2010.

4 Empirical Methods

Correlation and productivity analyses are the two most widely used empirical methods to study organizational complementarities.[18] These two methods complement each other because each test has the highest statistical power if the other is weakest (Brynjolfsson and Milgrom (2013)). For the correlation analysis and the productivity analysis, I apply pooled ordinary least squares (OLS) with robust standard errors clustered across firms to account for multiple participation

[18]Athey and Stern (1998) are among the first to discuss an empirical framework to measure organizational complementarities empirically. See Brynjolfsson and Milgrom (2013) for a survey on the theory and econometrics of studying complementarities in organizations.

in the survey. thereby exploiting variation across firms to obtain the coefficient estimates.

4.1 Correlation Analysis

As it has been done in prior work (e.g. Bloom et al. (2012) and Tambe et al. (2012)), I run a conditional correlation analysis between IT (IT) and the three measures for work organization (BU, TW, PP) to study whether firms with self-responsible business units, self-managed teams or performance pay are also more IT intensive. I use the following regression specification:

$$IT_{it} = \omega_{BU} BU_{it} + \omega_{TW} TW_{it} + \omega_{PP} PP_{it} + \delta_l ln(firmsize_{it}) + \lambda' X_{it} + u_{it}$$

where i stands for the individual firm and t for the time period.

In the most basic regression specification, I control for firm size through the logarithm of the number of employees $ln(firmsize)$, for multi-establishment group, for region through a dummy variable if located in East Germany and for a full set of time-interacted industry fixed effects included in the control vector X.[19]

In further regression specifications, the control vector includes further firm characteristics that may be correlated with IT intensity and the workplace organization. The share of high-skilled employees is taken into account of the firm's human capital composition since it has been shown that IT and high-skilled human capital are complementary and are an important factor to explain heterogeneity in IT returns (e.g. Bresnahan et al. (2002), Draca et al. (2007) for a survey). The share of employees working mainly with the computer is an alternative measure to the enterprise software indicator for firms' overall IT intensity. It will likely be positively correlated with decentralized work practices if more IT-intensive firms also adopt more of such work methods. Moreover, firms with a higher share of employees working mainly at the computer are likely to use enterprise software systems more intensively, too.

Firm's exporting activities account for the impact of international activities and exposure to foreign competition as exporters have shown to be more technology intensive and more productive than non-exporters (see, e.g. Bernard et al. (2012), Bertschek et al. (2015)). Moreover, increased foreign import competition has been found to be associated with more decentralization and performance-based pay in US firms (Guadelupe and Wulf (2008)). Existence of a works council is considered as control variable as a measure for employees' voice in decision-making

[19]This regression specification does not suggest the direction of causality between IT and decentralization in light of the view in the literature that IT facilitates and thus causes decentralization. Given the properties of my data, I follow Bresnahan et al. (2002) who estimate firms' short-run demand equations for IT as a function of work organization and human capital. They justify this specification by arguing that IT is the more easily variable factor within the complementary system than the relatively fixed factors of work organization and human capital and that the correlation coefficients provide evidence about complementarities.

and a change in management might have led to higher IT and/or decentralization intensity.

Even though correlations are neither necessary nor sufficient evidence of complementarities (Athey and Stern (1998)), significant and positive ω_{BU}, ω_{TW} and ω_{PP} coefficients can be interpreted as support for complementarity between IT measured by enterprise software systems and work organization because they reflect that work practices allowing for decentralized decision-making and individual authority are associated with more intensive use of enterprise software systems. The correlation analysis can also be interpreted as a factor demand equation where higher IT demand leads to higher demand for decentralization if the two factors are complementary.

4.2 Productivity Analysis

As it is widely used in the IT productivity literature[20] and in work on the complementarity relation between IT and organization (e.g. Bresnahan et al. (2002), Bloom et al. (2012)), I employ a Cobb-Douglas specification that is augmented for IT (IT) and decentralized work organization ($WO = \{BU, TW, PP\}$). The following regression equation formalizes the empirical model:

$$y_{it} = \alpha_c + \alpha_l l_{it} + \alpha_k k_{it} + \alpha_{IT} IT_{it} + \alpha_{WO_j} \sum_j WO_{jit} + \alpha_{IT*WO_j} \sum_j IT_{it} * WO_{jit} + \lambda' X_{it} + u_{it}$$

where $j \; \epsilon \; \{BU, TW, PP\}$, i stands for the individual firm and t for the time period. The dependent variable y is logarithmized real value added. A firm's capital stock is represented by k and labour by l, both inputs are in logarithmic values. α_c represents the constant and u an idiosyncratic error term, which captures all unobserved factors. Both, IT and the work organization variables, are entered in levels individually as well as their interaction. The regression specification features that IT, work organization and their interaction terms are allowed to shift a firm's production frontier, i.e. they are modeled as part of the multi-factor productivity. A positive and significant interaction term α_{IT*WO_j} can be interpreted as support for complementarity between IT and work organization. It reflects whether the IT productivity contribution depends on work organization and thus whether these factors are interrelated with respect to productivity.

Overall, the control variables are the same as in the correlation analysis. All control variables aim at reducing endogeneity concerns due to omitted variables by capturing organizational factors that will likely be relevant for observed firm heterogeneity in IT use, work organization and value added. With respect to the interpretation of the control variables, in the productivity equation, the computer work share, as another measure for a firm's IT intensity than the measure based on enterprise software, accounts also for the possibility that the enterprise software variables do not merely capture the productivity effect of computer work if firms with higher enterprise software use also have higher shares of employees working mainly with the computer.

[20] See for a summary of the econometric framework of IT productivity returns, e.g. Cardona et al. (2013).

5 Empirical Results

5.1 Correlation Analysis for SMEs

Table 5 shows correlations between the IT indicator and the work organization variables. Column (1) presents a baseline estimate for the intensity of the correlation between IT and the existence of a self-responsible business unit controlling only for firm size, regional location, multi-establishment group and industry-interacted year fixed effects. The coefficient estimate of this measure for decentralized work organization is highly significant indicating that firms with a self-responsible business unit use enterprise software systems more intensively. This result remains robust controlling for additional factors of firm heterogeneity (column (2)). Among the control variables, the share of employees working predominantly with the PC and exporting increases a firm's IT intensity statistically significantly. It might seem surprising that the share of high-skilled employees is not significantly positively related to IT intensity, given prior findings on complementarity between IT and high-skilled human capital. This result is mainly due to the high pairwise correlation between this share and the share of employees working mainly at the PC (0.62***). In a regression without the computer work share, the IT intensity as measured by the software indicator and the share of high-skilled employees are significantly and positively correlated (column (8)). These findings reflect that the computer work share captures a significant fraction of a firm's skill intensity.

Table 5: Correlations between Enterprise Software Intensity and Work Organization for SMEs

All Industries, Dependent Variable: Enterprise Software - IT Intensity								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Self-responsible Business Unit (BU)	0.380***	0.330***					0.288***	0.313***
	(0.037)	(0.036)					(0.036)	(0.037)
Team Work (TW)			0.217***	0.180***			0.129***	0.144***
			(0.031)	(0.030)			(0.030)	(0.030)
Performance Pay (PP)					0.225***	0.190***	0.147***	0.155***
					(0.031)	(0.030)	(0.030)	(0.031)
log(Employment)	0.267***	0.246***	0.307***	0.277***	0.287***	0.264***	0.230***	0.218***
	(0.015)	(0.018)	(0.015)	(0.017)	(0.015)	(0.017)	(0.018)	(0.018)
% Emp. Working with PC		0.641***		0.666***		0.674***	0.618***	
		(0.063)		(0.063)		(0.063)	(0.062)	
% High-Skilled Emp.		-0.057		-0.042		-0.047	-0.091	0.213***
		(0.085)		(0.086)		(0.086)	(0.085)	(0.080)
Exporting		0.200***		0.202***		0.198***	0.190***	0.213***
		(0.033)		(0.033)		(0.034)	(0.033)	(0.033)
Works Council		0.045		0.060		0.051	0.050	0.050
		(0.043)		(0.043)		(0.043)	(0.042)	(0.043)
Change in Management		-0.003		0.007		-0.002	-0.000	0.015
		(0.036)		(0.036)		(0.036)	(0.035)	(0.036)
Constant	-1.220***	-1.438***	-1.391***	-1.585***	-1.323***	-1.535***	-1.498***	-1.331***
	(0.091)	(0.090)	(0.090)	(0.089)	(0.091)	(0.089)	(0.088)	(0.090)
Control Variables	yes	yes	yes	yes	yes	yes	yes	yes
Number of Observations	4487	4487	4487	4487	4487	4487	4487	4487
Number of Firms	3288	3288	3288	3288	3288	3288	3288	3288
Adjusted R^2	0.2013	0.2355	0.1869	0.2241	0.1878	0.2250	0.2444	0.2243

Significance levels: * : 10% ** : 5% *** : 1%. Control variables include industry dummy variables based on two-digit classification interacted with a full set of year fixed effects, a dummy variable for location equal to one if the firm is in one new German Bundesland (member state), i.e. formerly East Germany, and a dummy variable if the firm belongs to a multi-plant group. Robust standard errors clustered at the firm level in parentheses.

Columns (3) and (4) show conditional correlations between IT intensity and whether firms use self-responsible team work. Firms with team work are also more IT intensive. Equally, firms offering performance pay use IT more intensively (column (5) and (6)). The positive correlation between IT and the different work organization variables stays significant in a specification including all organizational variables (column (7) and (8)). The coefficient of team work to IT (0.129) is smallest in size, followed by the one for performance pay (0.147) and the one for a self-responsible business unit (0.288, column (7)).

Overall, the correlation analysis provides evidence that firms with work practices that allow decentralized decision-making and emphasize individual incentives tend to use enterprise software more intensively. Therefore, in line with the hypothesis on the complementarity between IT and decentralization, it holds for SMEs that firms with higher IT intensity are more likely to have also adopted a decentralized and incentive-based work organization. However, it cannot be completely ruled out that unobserved factors, such as management ability, bias the estimates or are the true driving force behind the results, even though I control for a large amount of relevant unobserved heterogeneity. Moreover, the values on the adjusted R-Squared of the correlation regressions are only all around 0.19 to 0.24. These rather low values indicate that only a small fraction of the variation in enterprise software use intensity is explained by work organization and the other considered firm characteristics. In the next section, I examine with productivity analyses whether combining IT and decentralized, incentive-based work organization is associated with higher performance.

5.2 Productivity Analysis for SMEs

Table 6 shows the results from different specifications of the productivity regressions to analyze the productivity of IT and decentralized and incentive-based work organization and whether these organizational factors are complementary according to the productivity analysis. Column (1) provides baseline estimates for a standard Cobb-Douglas production function with labour and capital inputs. The coefficients for labour and capital are statistically significant and plausible in magnitude. Column (2) introduces a baseline estimate for the average productivity contribution of IT measured by enterprise software usage intensity for the time periods 2004, 2007 and 2010. The point estimate is about 0.095 and highly significant reflecting that firms with more intense enterprise software use are more productive. Column (3) controls for the share of employees working mainly at the PC as additional measure for a firm's IT intensity. The coefficient of the enterprise software indicator decreases slightly in size to 0.061 but remains highly significant. This significantly positive coefficient supports the hypothesis that firms with higher intensity of technology-supported use of information within the value creation process are more productive. As found in prior analysis (e.g. Bertschek and Meyer (2009)), the estimate for the share of employees working mainly at the computer is significantly positive, too. Altogether, firms with higher IT intensity, either through enterprise software use or employees working mainly with the computer, turn out to be the more productive ones.

Table 6: Productivity Regressions of IT and Work Organization for SMEs

All Industries, Dependent Variable: log(Value Added)	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
IT - Index(ERP+CRM+SCM)		0.095***	0.061***	0.046***	0.040*	0.041*	0.036	0.061***	0.040***
		(0.013)	(0.013)	(0.013)	(0.023)	(0.023)	(0.023)	(0.023)	(0.013)
Self-responsible Business Unit (BU)				0.156***	0.160***	0.158***	0.154***	0.168***	0.151***
				(0.030)	(0.030)	(0.030)	(0.030)	(0.031)	(0.029)
Team Work (TW)				-0.018	-0.020	-0.022	-0.018	-0.009	-0.017
				(0.025)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)
Performance Pay (PP)				0.097***	0.100***	0.097***	0.093***	0.096***	0.090***
				(0.025)	(0.025)	(0.025)	(0.025)	(0.026)	(0.025)
IT * BU					-0.025	-0.026	-0.022	-0.021	
					(0.027)	(0.027)	(0.027)	(0.028)	
IT * TW					-0.018	-0.019	-0.018	-0.023	
					(0.025)	(0.025)	(0.025)	(0.026)	
IT * PP					0.043*	0.043*	0.040	0.040	
					(0.025)	(0.025)	(0.025)	(0.026)	
log(Employment)	0.914***	0.891***	0.910***	0.888***	0.888***	0.888***	0.856***	0.839***	0.856***
	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.018)	(0.019)	(0.020)	(0.019)
log(Capital Stock)	0.126***	0.119***	0.114***	0.111***	0.111***	0.111***	0.105***	0.108***	0.106***
	(0.012)	(0.012)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
% Emp. Working with PC			0.622***	0.595***	0.595***	0.556***	0.542***		0.542***
			(0.057)	(0.057)	(0.057)	(0.063)	(0.062)		(0.062)
% High-Skilled Emp.						0.134	0.108	0.369***	0.106
						(0.083)	(0.084)	(0.080)	(0.084)
Exporting							0.125***	0.140***	0.125***
							(0.028)	(0.028)	(0.028)
Works Council							0.119***	0.117***	0.121***
							(0.035)	(0.035)	(0.035)
Change in Management							0.037	0.051	0.040
							(0.031)	(0.031)	(0.031)
Constant	9.066***	9.266***	9.088***	9.140***	9.150***	9.157***	9.244***	9.394***	9.236***
	(0.149)	(0.151)	(0.146)	(0.146)	(0.146)	(0.146)	(0.146)	(0.149)	(0.146)
Control Variables	yes	yes	yes	yes	yes	yes	yes	yes	yes
Number of Observations	4487	4487	4487	4487	4487	4487	4487	4487	4487
Number of Firms	3288	3288	3288	3288	3288	3288	3288	3288	3288
Adjusted R^2	0.7251	0.7288	0.7408	0.7440	0.7441	0.7443	0.7466	0.7389	0.7466

Significance levels: $*$: 10% $**$: 5% $***$: 1%. Control variables include industry dummy variables based on two-digit classification interacted with a full set of year fixed effects, a dummy variable for location equal to one if the firm is in one new German Bundesland (member state), i.e. formerly East Germany, and a dummy variable if the firm belongs to a multi-plant group. Robust standard errors clustered at the firm level in parentheses.

In column (4), the work organization measures for the existence of a self-responsible business unit, self-managed teams and the use of performance pay are added to the empirical specification. In contrast to other evidence of a positive relationship between group-based work organization variables and productivity (e.g. Bresnahan et al. (2002)), the coefficient of self-managed teams is statistically not significant from zero nor is the interaction term with IT. More similar to my results is the result of Black and Lynch (2001, 2004) who analyze the relationship between the proportion of workers in self-managed teams and labour productivity and who do not find a significant relationship, neither. The other two variables both have a significantly positive coefficient with a large magnitude. Having a self-responsible business unit is associated with approximately 15.6 percent higher productivity (coefficient: 0.156) and using performance pay with roughly 9.7 percent higher productivity (coefficient: 0.097).[21] These coefficients, although not completely equivalent, are similar to prior coefficient estimates on decentralization or performance pay (e.g. Tambe et al. (2012) or Aral et al. (2012), respectively). These results underline the view that decentralization and high-performance workplace practices matter for productivity.[22] The inclusion of the work organization variables decreases the estimates of the software and computer work intensity measures slightly but leaves them significant. This reduction in the

[21]The coefficients for self-responsible business unit and performance pay are similar in separate regressions where only one measure is considered. The coefficient of the team work variable turns positive but is still insignificant; results not reported, available upon request.

[22]See for an empirical analysis of productivity impacts of workplace innovation, e.g. Black and Lynch (2004) for US firms.

magnitude of the IT coefficients, when work organization is taken into account in the productivity analysis, is consistent with the results from the correlation analysis that more IT-intensive firms tend to have a decentralized work organization, too. Thus, when omitting workplace organization in the regression specification, IT captures part of its productivity contribution.

In column (5), I include three pairwise interaction terms between enterprise software use and the three considered work organization variables in order to test for complementarity. The inclusion of the interaction terms reduces the significance of the coefficient on enterprise software, whereas the coefficients for self-responsible business unit and performance pay remain highly significant. This suggests that the return to enterprise software depends on work organization. The coefficients of the interaction between IT and self-responsible business unit and IT and team work are, surprisingly, negative, even though not significant. In contrast, the interaction term between IT and performance pay is positive and weakly significant as column (5) shows.

Controlling also for the share of high-skilled employees to account for skilled human capital (column (6)) does not change the previous results. Specification (7) takes account of additional factors of firm heterogeneity which might drive the results by incorporating exporting activity, the existence of a works council and whether a change in management took place in the survey period. The consideration of these additional control variables lowers the IT coefficient and turns it insignificant, while the individual coefficients on self-responsible business units and performance pay remain significant. This result provides confidence that the work organization variables do not pick up effects of alternative factors that are also positively related to productivity. However, the combination of performance pay and enterprise software use turns insignificant. The coefficient estimates on exporting and on works council are significantly positive, which is in line with prior findings for a positive relationship between productivity and export activities or a works council.

In specification (8), the share of computer employees is omitted to see how the coefficients evolve, given that this measure reflects IT intensity and also partly labour heterogeneity. The coefficients on enterprise software intensity and the share of high-skilled employees increase in size and both become significant. This illustrates that computer work intensity captures a large part of a firm's IT intensity and also skill intensity as found already in the correlation analysis. Specification (9) excludes the interaction terms between IT and work organization to analyze what are the productivity contributions without accounting for combination effects. The coefficient estimates are similar to those in column (5) or (6). Overall, these results show that more IT-intensive firms and firms with decentralized and incentive-based work practices are more productive. However, there is no robust evidence of complementarity between IT and decentralized work organization and only weak support for a complementary relationship between IT and performance pay.

5.3 Discussion of the Results

There are several possible explanations why the interaction term between IT and decentralized work organization is not significantly positive for SMEs in contrast to prior empirical work based on samples of mainly large firms. First, it might be that for smaller firms synergies from combining IT and decentralization are not that strong in comparison to larger firms. The smaller the firm size is, firms usually face less information and can act in more flexible ways so that they need less standardized work routines and possibly benefit less from decentralization (Giuri et al. (2008)). The incremental gain from combining IT with decentralized work organization might be smaller for SMEs than for larger firms, for instance, because of a smaller market share and a smaller sales volume. An alternative explanation could be that employees in SMEs can specialize less in their tasks than employees in large firms because of the smaller workforce. Even if SMEs decentralize formally, e.g. by having self-responsible business units, employees might still have to do multi-tasking. Consequently, in light of constraints on human information processing capabilities, they might benefit less from an improved information basis enabled by IT. Generally, firms of different size might have different abilities to use IT most effectively and empirical evidence has shown that small firms derive smaller marginal products from IT investments than large firms, which is consistent with the hypothesis that large firms are better equipped to benefit from IT-related complementary investments (Tambe and Hitt (2012)).

Another possibility for an insignificant interaction term might be that the indicators used in the empirical analysis to measure IT intensity and decentralization suffer from measurement error and capture only specific channels of the economic effects of IT and decentralization.[23] Particularly, the variables for decentralized work organization are only binary variables. Therefore, they do not capture any intensive margin of decentralization as broader decentralization indicators that are used in prior work with other data sets do. If measurement error is present, the estimates are downward biased. Although this possibility cannot be completely ruled out, the positive and significant output elasticity coefficient estimates for IT and decentralized work organization in isolation, even when controlling for other relevant sources of firm heterogeneity, provide credibility that the measures capture at least to some extent firms' IT and decentralization intensity.

[23]See Section 3 for a discussion of the economic interpretation of the IT and decentralization indicator.

A third possibility why IT combined with decentralization is not significantly related to productivity might be that the benefits of this combination depend on other firm characteristics. These factors are possibly intangibles, given that prior research has demonstrated the role of the corporate learning type (Mahr and Kretschmer (2010)) or external focus (Tambe et al. (2012)) for the productivity effects of IT and decentralization, and of human resource analytics for the effects of IT and performance pay (Aral et al. (2012)). Finally, Tambe et al. (2012) find an insignificant interaction term between IT and decentralization, while their coefficients on IT and decentralization are individually significant. They argue that it might be that most IT-intensive firms have adopted decentralized work practices in recent years so that there are minimal marginal effects on productivity from this combination. This argument might be valid for SMEs, too, given that the time period of the data starting in 2004 is fairly recent and can be seen as rather late for IT equipment adoption, such as enterprise software. However, given that only 28 percent of the SMEs in the sample have an own business unit in contrast to 70 percent in the large firms sample, this argument might be less valid for the sample of SMEs I use for the empirical analysis. Contrarily, one reason for not finding a synergy effect from IT combined with decentralization could be that the SMEs might not have realized gains from the combination yet because a successful implementation of process innovations may take time.

Given the nature of the data and the econometric techniques I can apply, there are some limitations to the interpretation of the results. I can control for a large part of alternative firm heterogeneity that is likely to be relevant for higher levels of IT and decentralized work organization as well as higher productivity levels. This allows me to rule out alternative explanations for the positive association between IT, decentralization and productivity and to reduce endogeneity concerns due to omitted variable bias. One potential source of remaining relevant firm heterogeneity are unobserved individual firm fixed effects that capture quasi-fixed organizational factors such as management ability. However, part of the individual time-invariant firm heterogeneity is captured already by taking explicitly account of workplace organization. Under the additional assumption that the considered work organization practices are positively correlated with management ability, the measures for work organization can be seen as a proxy for management ability so that the bias from omitted management ability will be alleviated.

A direct method in a panel data analysis to check the impact of omitted variable bias on the coefficient estimates of the explanatory variables due to firm fixed effects would be to control for them using fixed effects estimation. The fixed effects estimator is valid under the assumption that the unobserved heterogeneity is correlated with the explanatory variables. This assumption is likely to be the case in my analysis, in particular for IT and decentralization as my main variables of interest. A property of the fixed effects estimator is that it does not provide estimates for fully time-invariant variables and only very imprecise estimates for rather stable variables (Cameron and Trivedi (2009)). Since the IT and organizational variables are close to time-invariant within the sample period for an individual firm with multiple participation and the majority of firms in my sample is only surveyed once, the fixed effects estimator does not seem to be an appropriate estimator for the available data. In general, fixed effects estimated IT coefficients have turned out to be lower than estimates from pooled OLS, which do not consider individual time-invariant firm heterogeneity. One reason for this is that the fixed effects estimator eliminates any IT benefits that are persistent over time at the firm level (Cardona et al. (2013)).

Another source for biased coefficient results might be endogeneity due to simultaneity. If firms with a positive productivity shock adjust their IT levels correspondingly or if more productive firms are more likely to adopt IT and decentralized work organization, the coefficient on IT and work organization will be upward biased. This is particularly likely for the enterprise software coefficient in light of results by Aral et al. (2006) who find that firms with successful ERP adoption keep on adopting SCM and/or CRM. Generally, without explicit knowledge about firm performance at the time of IT adoption or implementation of decentralized work practices or without a meaningful variable that provides exogenous variation for differences in IT intensity and decentralization that could be used for an instrumental variable analysis, making causal interpretations about the impact of IT or work organization on productivity is problematic. Since the data set including all considered variables is not rich enough to apply panel data techniques that allow to control for simultaneity such as the Arellano and Bond System-GMM or the Olley and Pakes estimator, the results should not be interpreted as causal but they reflect empirical relationships. Prior research that could apply such techniques shows that the impact of reverse causality on IT coefficient estimates is rather limited (Tambe and Hitt (2012)).

5.4 Results for Large Firms

Prior research finds evidence for complementarity between IT and decentralized, incentive-based work organization for large firms, mainly from the US. This section illustrates the results with the sample of large firms within the ZEW ICT panel, here classified as firms with more than 250 employees. Overall, there are 595 such firms. The results from the correlation analysis reflect some differences in comparison to those from SMEs. While using self-responsible team work and offering performance pay are significantly correlated with higher enterprise software use intensity, having a self-responsible business unit is not (Table 7). Moreover, the share of employees working mainly with the PC as another measure for a firm's IT intensity is only weakly positively related to software use intensity in a regression with self-responsible business units as work organization variable (column (2)), whereas the positive relation between the share of high-skilled employees and IT is stronger for the large firms in comparison to the SMEs. This positive association between IT and high-skilled employees is consistent with complementarity between IT and human capital.

The results from the productivity analysis differ, too. Like for the SMEs sample, without taking account of possible interactions between IT and work organization, more intensive enterprise software use raises productivity significantly. However, the productivity return to software is almost twice larger than for SMEs (specification (3), Table 8 for large firms; specification (3), Table 6 for SMEs). This finding suggests that larger firms seem to benefit more from enterprise

Table 7: Correlations between Enterprise Software Intensity and Work Organization for Large Firms

All Industries, Dependent Variable: Enterprise Software - IT Intensity								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Self-responsible Business Unit (BU)	0.064	0.026					-0.017	-0.007
	(0.086)	(0.087)					(0.086)	(0.086)
Team Work (TW)			0.237**	0.212**			0.196**	0.200**
			(0.096)	(0.093)			(0.092)	(0.092)
Performance Pay (PP)					0.276**	0.243**	0.220**	0.223**
					(0.112)	(0.109)	(0.106)	(0.107)
log(Employment)	0.187***	0.166***	0.183***	0.161***	0.173***	0.154***	0.150***	0.145***
	(0.043)	(0.044)	(0.043)	(0.043)	(0.044)	(0.044)	(0.044)	(0.044)
% Emp. Working with PC		0.303*		0.289		0.297*	0.283	
		(0.179)		(0.178)		(0.179)	(0.178)	
% High-Skilled Emp.		0.459*		0.435*		0.480*	0.455*	0.590**
		(0.261)		(0.259)		(0.260)	(0.261)	(0.237)
Exporting		0.258**		0.249**		0.244**	0.236**	0.239**
		(0.119)		(0.118)		(0.120)	(0.119)	(0.121)
Works Council		-0.060		-0.057		-0.061	-0.058	-0.050
		(0.136)		(0.136)		(0.135)	(0.135)	(0.137)
Change in Management		0.194***		0.197***		0.182**	0.186***	0.191***
		(0.072)		(0.071)		(0.071)	(0.071)	(0.072)
Constant	-1.175***	-1.455***	-1.261***	-1.528***	-1.297***	-1.559***	-1.618***	-1.519***
	(0.324)	(0.325)	(0.323)	(0.326)	(0.329)	(0.330)	(0.333)	(0.331)
Control Variables	yes	yes	yes	yes	yes	yes	yes	yes
Number of Observations	763	763	763	763	763	763	763	763
Number of Firms	595	595	595	595	595	595	595	595
Adjusted R^2	0.0823	0.1056	0.0914	0.1135	0.0906	0.1125	0.1166	0.1143

Significance levels: $*$: 10% $**$: 5% $***$: 1%. Control variables include industry dummy variables based on two-digit classification interacted with a full set of year fixed effects, a dummy variable for location equal to one if the firm is in one new German Bundesland (member state), i.e. formerly East Germany, and a dummy variable if the firm belongs to a multi-plant group. Robust standard errors clustered at the firm level in parentheses.

software than smaller firms. In contrast to the results from SMEs, work organization does not increase productivity significantly for large firms. Given that the majority of firms in the sample offers performance pay (85 percent) and also has self-responsible team work (76 percent) and self-responsible business units (70 percent), it is plausible that these work organization practices do not explain productivity differences significantly.

Another central difference is that the combination of IT and existence of a self-responsible business unit raises productivity significantly (specification (5) to (8), Table 8). This positive interaction term is consistent with complementarity between IT and decentralization. This result underlines that large firms which combine technology with appropriate workplace organization perform particularly well, whereas work organization in isolation does not explain productivity differences significantly. Given that the correlation between IT and existence of a self-responsible business unit is not significant, the positive and significant interaction term between IT and this organizational practice indicates that firms with a self-responsible business unit, which also use enterprise software intensively, are more productive. These opposing results from the correlation and productivity analysis with respect to the conclusion for complementarity underline the different statistical power properties of each method for testing the existence of organizational complementarities.[24]

Another difference to the results from SMEs is that the share of employees working mainly at the PC does not raise productivity significantly, whereas the share of high-skilled employees does. This result might reflect that the majority of large firms has reached their optimal level

[24] See Section 4 for this argument.

Table 8: Productivity Regressions of IT and Work Organization for Large Firms

	All Industries, Dependent Variable: log(Value Added)								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
IT - Index(ERP+CRM+SCM)		0.121^{***}	0.114^{***}	0.117^{***}	0.002	-0.007	-0.011	-0.010	0.108^{***}
		(0.025)	(0.025)	(0.026)	(0.057)	(0.057)	(0.056)	(0.056)	(0.026)
Self-responsible Business Unit (BU)				0.059	0.063	0.052	0.051	0.057	0.046
				(0.054)	(0.054)	(0.053)	(0.053)	(0.053)	(0.053)
Team Work (TW)				-0.012	-0.007	-0.013	-0.012	-0.010	-0.018
				(0.058)	(0.058)	(0.057)	(0.056)	(0.056)	(0.057)
Performance Pay (PP)				-0.072	-0.051	-0.041	-0.047	-0.046	-0.071
				(0.068)	(0.071)	(0.071)	(0.072)	(0.073)	(0.070)
IT * BU					0.099^{**}	0.098^{**}	0.091^{*}	0.092^{*}	
					(0.049)	(0.049)	(0.048)	(0.048)	
IT * TW					-0.004	-0.004	0.002	0.006	
					(0.054)	(0.054)	(0.053)	(0.053)	
IT * PP					0.065	0.070	0.070	0.068	
					(0.056)	(0.056)	(0.055)	(0.055)	
log(Employment)	0.847^{***}	0.840^{***}	0.846^{***}	0.847^{***}	0.841^{***}	0.838^{***}	0.823^{***}	0.818^{***}	0.828^{***}
	(0.042)	(0.041)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)	(0.040)
log(Capital Stock)	0.159^{***}	0.145^{***}	0.143^{***}	0.143^{***}	0.143^{***}	0.145^{***}	0.145^{***}	0.147^{***}	0.145^{***}
	(0.025)	(0.024)	(0.025)	(0.025)	(0.025)	(0.024)	(0.024)	(0.024)	(0.024)
% Emp. Working with PC			0.292^{**}	0.282^{**}	0.282^{**}	0.181	0.168		0.169
			(0.121)	(0.120)	(0.119)	(0.120)	(0.119)		(0.120)
% High-Skilled Emp.						0.494^{***}	0.505^{***}	0.584^{***}	0.501^{***}
						(0.182)	(0.183)	(0.179)	(0.184)
Exporting							0.105	0.106	0.107
							(0.081)	(0.081)	(0.082)
Works Council							0.161	0.166	0.167
							(0.107)	(0.108)	(0.109)
Change in Management							0.011	0.014	0.012
							(0.046)	(0.046)	(0.046)
Constant	9.006^{***}	9.309^{***}	9.204^{***}	9.236^{***}	9.231^{***}	9.212^{***}	9.060^{***}	9.100^{***}	9.063^{***}
	(0.338)	(0.337)	(0.342)	(0.346)	(0.345)	(0.341)	(0.349)	(0.347)	(0.350)
Control Variables	yes	yes	yes	yes	yes	yes	yes	yes	yes
Number of Observations	763	763	763	763	763	763	763	763	763
Number of Firms	595	595	595	595	595	595	595	595	595
Adjusted R^2	0.6836	0.6942	0.6973	0.6970	0.6984	0.7020	0.7035	0.7029	0.7023

Significance levels: $*$: 10% $**$: 5% $***$: 1%. Control variables include industry dummy variables based on two-digit classification interacted with a full set of year fixed effects, a dummy variable for location equal to one if the firm is in one new German Bundesland (member state), i.e. formerly East Germany, and a dummy variable if the firm belongs to a multi-plant group. Robust standard errors clustered at the firm level in parentheses.

of PC-based employees so that differences in this share do not explain productivity differences in contrast to different levels of skilled human capital employed by the firm.

The findings support prior evidence on complementarity between IT and decentralization which has been found for rather large firms. The comparison of the results between smaller and larger firms is compatible with the results in Tambe and Hitt (2012). They argue that large firms derive larger productivity returns from IT than firms of smaller size, which is consistent with advantages in economies of scale for larger firms. Moreover, the results from the productivity analysis in this paper support their argument that large firms may have advantages in benefitting from IT-related complements, such as decentralization. Nevertheless, the results can only be interpreted as reflecting robust correlations and should not be viewed as causal. It might be that the positive interaction term between IT and decentralization reflects the impact of an unobservable factor that is correlated with both IT and decentralization, which is the true relevant factor for improved productivity.

6 Conclusion

The goal of this paper has been to increase the knowledge about the relationship between IT and decentralized work organization and their productivity contributions in SMEs. I provide empirical evidence from correlation analyses between IT and decentralized work organization and from productivity analyses of these two factors. Given that SMEs play an important role for employment and the creation of economic value in Germany, examining which factors contribute to productivity for firms of this size is relevant for policymakers to understand determinants of the economy's productivity performance. Moreover, I compare the findings to those for larger firms to analyze similarities and differences.

My results show different productivity contributions from combining IT and decentralization for SMEs and for large firms. For SMEs, the combination of IT and decentralized work is not related to higher productivity. Contrarily, the results for large firms support prior evidence of complementarity between IT and decentralization.

Given that there is few evidence on complementarity between IT and decentralization for SMEs, my results cast doubt on whether productivity-enhancing interaction effects from IT and decentralized work practices have ever been present for smaller firms. In small firms, coordination issues between different subunits and the optimal use of information are probably on average easier to handle than in large firms, regardless of their decentralization degree. Thus, small firms might on average have lower demand for formal decentralization as they might benefit less from it. Alternatively, they might be less adept than large firms to employ IT and accompany it with complementary investments. These could be explanations why for SMEs the results do not show that the productivity of IT depends positively on decentralized work organization like for large firms. The comparison of results across firm size suggests that findings on IT returns from larger firms cannot necessarily be generalized to smaller firms.

There are some limitations of the data used in this paper. Most importantly, I could only include a small number of work organization practices, which capture only a small part of a firm's work organization. More empirical evidence on IT returns and the role of IT-related intangibles in SMEs, such as work reorganization or training, would be helpful to better understand the impact of IT in smaller firms and to see whether there are differences between small and large firms as it is found in this paper and by recent research (e.g. Tambe and Hitt (2012)). Moreover, my findings raise questions about possible reasons for different levels of IT intensity and work organization. Are there financial barriers preventing firms from investing more in IT? Or do firms lack internal IT knowledge to implement advanced IT solutions? In light of an ongoing digitization of economic processes, using information as an input to the value creation process and to gain competitive advantage will remain important for firm success. A better understanding why firms of similar size use different IT levels and work organization structures and which barriers of adoption they face could help policymakers designing supportive policy measures, for instance, by providing access to facilitated funding or special IT training sessions for SMEs.

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A Appendix

A.1 Data from the Federal Statistical Office of Germany

I use information from the German National Accounts from 2012 ("Volkswirtschaftliche Gesamtrechnung 2012" Fachserie 18, Reihe 1.4) provided by the Federal Statistical Office of Germany to construct a measure for real value added from total sales that are available in the ICT survey and to deflate gross investment. For real value added, I create a correction factor equal to the ratio of price-adjusted value added over the nominal total production value in Euro by two-digit industry (WZ 2008 industry values) and year. The year 2005 serves as the base year for the deflation of the nominal values. This correction factor $CFVA$ provides a measure for the yearly j average share of real value added in the nominal total production value at the two-digit industry level j:

$$\text{CFVA}_{jt} = \frac{\text{price-adjusted value added}_{jt}}{\text{nominal total production value}_{jt}}$$

Then, I multiply firms' total sales, where i indicates each firm, with this correction factor to obtain an approximation for the firms' real value added in the respective year:

$$\text{deflated value added}_{it} = \text{nominal sales}_{it} * \text{CFVA}_{jt}$$

To obtain deflated gross investment, I create a correction factor $CFINV$ in a similar way.

$$\text{CFINV}_{jt} = \frac{\text{price-adjusted gross investment}_{jt}}{\text{nominal gross investment}_{jt}}$$

$$\text{deflated gross investment}_{it} = \text{nominal gross investment}_{it} * \text{CFINV}_{jt}$$

If firms reported zero investment, I replace gross investment with the 10th percentile of gross investment per employee in the corresponding industry multiplied by the firm's number of employees. For some industries also the 10th percentile of gross investment is zero so that in this case I use the 15th percentile value.