Wirtschaftswissenschaftliches Zentrum (WWZ) der Universität Basel

March 2011

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WWZ Discussion Paper 2011/04
(D-135)

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A publication of the Center of Business and Economics (WWZ), University of Basel.

This publication and the research project presented within it have been financially supported by the Förderverein of the WWZ (Center of Economics Sciences of the University of Basel).

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- Preliminary Version: March 2011 -

Abstract

Since several decades, information and communication technologies (ICT) as well as new organizational designs change the working life in firms. Using nationally representative Swiss firm-level panel data, the present paper analyzes the relationship between these developments and examines, whether ICT is associated with centralization or decentralization tendencies. The results suggest a positive impact of ICT on the degree of delegation. Furthermore, the diffusion of ICT use within the workforce and the intensity of ICT investments are essential for the decentralization effect of ICT. Thus, reduced agency costs owing to ICT use result in decentralized decision-making authorities in Swiss firms. The results are robust to potential endogeneity biases like reversed causality and unobserved firm characteristics.

JEL Classification: L22 - L23 - O32 - O33
Key Words: ICT - Decision-Making Authority - Decentralization - Mundlak‘s Approach

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1 Introduction

In the last years, working life has undergone tremendous changes. These changes are promoted largely by (1) the introduction of information and communication technologies (ICT) and (2) new organizational designs. By now, ICT has become an essential part of working life. Applications like email, internet, digital assistants or computer based production technologies are self-evident for most employees. In the last decades, huge investments in ICT in Switzerland as well as worldwide can be observed (Arvanitis (2005)). According to the sample of the present paper, in 2008 98,9% of all interviewed Swiss firms report that they use computers; in average 19% of their whole gross investments are invested in ICT. These innovations have revolutionized the way how work is done and partly influence productivity[1].

In addition to the appearance of ICT, a trend concerning the organizational architecture of firms has also profound effects on work life: Different authors ascertain a restructuring from Tayloristic to so-called Holistic work organization. Clearly and narrowly-defined decision-making authorities and centralization are replaced by multitasking and decentralization (Milgrom and Roberts (1990), Lindbeck and Snower (2000)). This "new firm model" (Arvanitis (2005)) is characterized by an increased use of team work and job rotation, a decrease of the number of managerial levels and more direct participation in decision-making (Lindbeck and Snower (2000)). In 2008 69% of all asked Swiss firms declare that they use continuing teams, which handle task areas corporately or discuss topics. After all, 19% declare to use programs for job rotation. The consequential decentralized responsibility necessitates continuous learning and development from employees and requires better skills[2].

The simultaneous development of ICT use and organizational change suggests the question, whether there exists a relationship between both evolutions. The approaches to investigate a relationship between ICT and the allocation of decision rights are numerous. In this context several authors argue that ICT supports centralization (e.g., Leavitt and Whisler (1958), Bolton and Dewatripont (1994)), others argue that ICT promotes decentralization (e.g., Radner (1993), Wyner and Malone (1996)). Basically, the use of ICT

[1]Studies which analyze productivity effects of ICT are for example of Black and Lynch (2001), Brynjolfsson and Hitt (2000), Brynjolfsson and Hitt (2003), Hempell (2005) or Zammuto and O'Connor (1992).

[2]The skill-biased organizational change is examined for example in the studies of Beckmann (2004), Bresnahan, Brynjolfsson and Hitt (2002), Caroli and Van Reenen (2001) or Caroli, Greenan and Guellec (2001).

lowers on the one hand *decision information costs*, which favors centralization, but enables on the other hand decentralization by decreasing *agency costs*. The resulting allocation of decision-making authority depends on the question, which effect outbalances when using ICT.

The present study analyzes whether ICT is associated with centralization or decentralization tendencies in firms. For the analysis, two surveys from the KOF Swiss Economic Institute (KOF) from the ETH Zurich are used. They are a nationally representative sample for the Swiss private business sector. From these waves a panel dataset with two periods including firms with at least 20 employees is built.

Contrary to several previous studies, the data allow to explicitely separate between centralization and decentralization tendencies. Former studies often focus on the general relationship of ICT with organizational structure (e.g., Heintze and Bretschneider (2000)). In addition, a large scale representative data set including all firm sizes and business sectors is used for the present study in contrast to several papers which are constrained to specific industries or firms (e.g., Greenan (2003) and Pinsonneault and Kraemer (1997)). Finally, the ICT variables used in this study picture diverse ICT characteristics and therefore offer a broader view of ICT use in firms. This allows to differentiate between single effects of diverse ICT characteristics.

When examining the impact of ICT on the allocation of decision rights, there are especially two sources for potential estimation biases: First, the firms organizational structure may be an enabler for the use of ICT. For example, a decentralized allocation of decision rights may help to exploit the advantages of emailing because employees may communicate directly. This could increase the share of employees who use emailing. In order to avoid this problem of reversed causality, the ICT variables are lagged. They come from the survey which was conducted three years before. Second, unobservable firm characteristics, which are not captured by the controls, but which are correlated with the allocation of decision-making authority and ICT, may lead to estimation biases. For example, a type of managers may have a preference to try innovations and therefore introduces ICT and decentralizes the decision-making authorities. To the best of the author's knowledge, in the relevant literature reversed causality and unobserved firm characteristics are until now only considered in the studies of Acemoglu et al. (2007) and Bloom et al. (2009).

Therefore the methodological procedure of this paper is as follows: In a first step, a pooled cross sectional OLS model is estimated. Using the panel structure of the data, in the next step random and fixed effects models are used. Since these estimation models are not always unproblematic, Mundlak's (1978) approach is additionally applied as a compromise.

The paper proceeds in the following way: In the second chapter the theoretical background is presented. Afterwards different empirical studies concerning the research question are shown in Chapter 3. Chapter 4 introduces the data, variables and descriptive statistics of the econometric analyses, followed by a description of the econometric approaches-applied in this paper. The results of these models are presented in detail in the following subsection. The paper is finished by a conclusion in Section 5.

2 Theoretical Considerations

2.1 ICT and the Allocation of Decision-Making Authorities

From a theoretical perspective it is argued on the one hand, that there is a causal relationship between ICT and organizational architecture. On the other hand, a relationhsip between these aspects is disputed. According to the first approach, it is assumed that the use of ICT leads to a change in organizational architecture (e.g., Huber (1990)). This view was firstly argued in organizational research like contingency theory or work of the Aston group[3]. According to this so-called "technological determinism" (Greenan (2003)) or "technological imperative" (George and King (1991)) both a fostering of centralization and decentralization is possible. The argumentation why the causality goes in this direction is mainly based on the fact that indeed the prices for ICT have fallen dramatically in the past decades (Brynjolfsson and Hitt (1998), Brynjolfsson and Hitt (2000)). However, there is no evidence for a similar fall in the price for organizational changes (Hempell and Zwick (2008)). Consequently, the decline in the price for ICT resulted in a simultaneous

[3]According to contingency theory, the optimal allocation of decision rights - or in general organizational design - is contingent on internal and external determinants. Supporters from the contingency theory (e.g., Blau et al. (1976), Marsh and Mannari (1981), Woodward (1981)) and the Aston group (e.g., Child and Mansfield (1972), Hickson, Pugh and Pheysey (1969)) argue for a causal relationship from technology to organizational structure. In contrast to maintainers of contingency theory, the Aston group found a stronger relationship of size than of technology with the organizational structure.

development of ICT use and reorganization (Bresnahan, Brynjolfsson and Hitt (2002)). Aligned with an increasing use of ICT, costs for coordination, communication and information processing have fallen intensely (Brynjolfsson and Hitt (2000), Malone (1997)). Thus, ICT is seen as an enabler for the introduction of advanced organizational structure and practices (Malone (1997), Pinsonneault and Kraemer (1997)).

Second, some authors argue that there is no inherent relationship at all between ICT and organizational change. Thus, both developed simultaneously due to the influence of other factors like the internal and external economic structure of a firm (e.g., a challenging environment) or the nature of the task environment (Brynjolfsson and Hitt (1998), Delehanty (1967), George and King (1991), Myers (1966), Robey (1977)). Also, instead of a single reaction to ICT, a range of management effects could appear and other factors determine the relationship eventually (Attewell and Rule (1984)).

2.2 Centralization versus Decentralization Tendencies

In this section the focus lies on the expected impact of ICT on organizational design. More precisely, it is examined whether ICT is more likely to foster centralization or decentralization. ICT influences the components of internal coordination costs in firms. Internal coordination costs accrue due to self-interested preferences of the principal and the agent (Jensen and Meckling (1976), Alchian and Demsetz (1972)). These costs contain agency costs, like monitoring costs, bonding costs and residual costs. Furthermore, they consist of decision information costs like information processing costs (for communication and documentation) and opportunity costs resulting from poor information (Gurbaxani and Whang (1991)). ICT reduce both decision information and agency costs.

On the one hand, ICT decreases decision information costs and thus fosters centralization. This centralization effect occurs in different ways (e.g., Leavitt and Whisler (1958), Bolton and Dewatripont (1994)): Firstly, the intense reduction of information and communication costs leads to a transformation of specific into general information (Jensen and Meckling (1992)). As a result, it is possible for the principal to monitor managers and to coordinate activities made by peripheral teams (Colombo and Delmastro (2004)) at low costs. He can examine work results from lower level managers via expert systems as well as give orders using ICT. Less inefficiencies in the communication process and lower information costs are therefore expected to lead to a more centralized allocation of tasks and decision making (Radner (1993)). Furthermore, because a larger amount of information is more simply and faster available, the top management is less dependent on middle-managers and reduces its number. As a consequence, ICT makes centralization easier and the allocation of decision rights is centralized in the top management (Leavitt and Whisler (1958)). These arguments can be combined as the *decision information costs effect*.

On the other hand, ICT also decreases agency costs and therefore makes decentralization more beneficial. Different relations may lead to this effect (e.g., Radner (1993), Wyner and Malone (1996)): Firstly, employees and lower level managers gain access to information which were reserved to the principal so far. This enables the employees to make decisions independently. It also motivates them to show more initiative and higher effort. Secondly, the principal has the ability to monitor the agent indirectly via computer (Hubbard (2000)). Thus, he can delegate decisions but is anyway able to control the agent and to intervene potentially in critical situations. Lastly, ICT reduces also the costs for lateral communication between agents. This allows them to work in teams. Thus, ICT lowers communication and transaction costs (Brynjolfsson and Hitt (2000)) and therefore allows the use of more multitasking and decentralization (Lindbeck and Snower (2000)). ICT helps to introduce flexibility in firms (Lucas and Baroudi (1994)). These lines of arguments can be integrated as the *agency costs effect* of ICT on the allocation of decision-making authority.

Thus, the use of ICT leads both to a reduction of decision information and agency costs. The resulting allocation of decision-making authority depends on the role of local information as well as on the cost structure of the individual firm. If local information is highly important, a principal will delegate decisions to the agent instead of communicating, as long as the incentive problem is small (Baker, Gibbs and Holmstrom (1994), Brynjolfsson and Hitt (2003), Dessein (2002), Hart and Moore (2005)). Hereby, finally a trade-off arises, which is known as the dilemma of organizational theory (e.g., Aghion and Tirole (1997), Melumad, Mookherjee and Reichelstein (1992), Mookherjee (2006)). According to the cost structure of the individual firm, the degree of delegation should be located, where the sum of agency and decision information costs is minimized (Gurbaxani and Whang (1991)). To put it another way, if through ICT the relevant information increase quality and speed of top management decisions, centralization results. On the contrary, decision rights get more decentralized when ICT improves the opportunity to supervise employees and reduces agency costs (Gurbaxani and Whang (1991)).

Combining different lines of argumentation two hypotheses can be derived. According to the first hypothesis the *decision information costs effect* outweighs the *agency costs effect* when ICT is used, which results in centralized decision-making authority. Here we would expect a negative impact of ICT on the allocation of decision-making authority. In contrast, corresponding to the second hypothesis, ICT leads to more delegation and decentralization when the *agency costs effect* outweighs the *decision information costs effect*.

Since the theoretical predictions on the relationship between ICT and the allocation of decision rights are not unambigious, the objective of the present paper is to examine empirically whether ICT is associated with centralization or decentralization tendencies in firms. The following section contains the related empirical literature on this issue.

3 Related Literature

Empirical investigations related to the research question can be separated in three areas. Studies from the first area generally look at the relationship between ICT and organizational structure. The type of structure is not taken into account. Empirical investigations from the second area, which is the largest one, explicitely focus on whether ICT is related to centralization or decentralization tendencies. Finally, the third area contains studies which look seperately on the effects of different kinds of ICT on centralization or decentralization.

Studies from the first area analyze generally whether there exists a relationship between ICT and the firm organization. This research question was at first examined using correlations (e.g., Pfeffer and Leblebici (1977)) and case studies. Foster and Flynn (1984) adopt the perspective that information technology effects organizational roles and tasks in the case of General Motors. The technology-structure relationship is also observed in a study from Carter (1984) who analyzes the effects of computerization on the structure of newspaper organizations. The impact depends on the used task, where organizational size serves as a moderator variable. Burnes (1988) uses case studies of nine engineering companies for his analysis and concludes, that CNC[4] machine tools do not determine job design.

[4]CNC: Computer numerically controlled

After examining the relationship of ICT and organizational design primarily with case studies, first regression results are achieved. Kelley (1990) finds that technology is only one of a number of determinants of job design. The author carries out a multivariate regression analysis using a national survey of 506 production managers. Heintze and Bretschneider (2000) find in their examination of public agencies using two-stage least square regressions only little impact of IT on an agency's structure.

Empirical literature from the second area relates to studies, which explicitely distinguish between centralization or decentralization tendencies associated with ICT. In this range, several studies are focused on specific industries. Wijnberg, van den Ende and de Wit (2002) implement two case studies in the financial sector to analyze the impact of new IT on the involvement of employees and find mixed results.

Three further studies concentrate on manufacturing. In a Danish case study AMT[5] is seen as an enabler of group-based work organization, but a number of other factors also influence organizational changes (Sun and Gertsen (1995)). Gupta, Chen and Chiang (1997) observe a positive interaction of AMT with decentralization. The interaction of formalization and mechanistic structures is negatively related to AMT. Greenan (2003) conducts an exploration of the relationship between technological and organizational change with correlations. She uses the survey on organizational changes in the manufacturing industry (Changement Organisationnel) conducted in 1993 by SESSI and INSEE, which is representative of 1824 firms with more than 50 employees in manufacturing.[6] Variables related to technological change concern the use of computer-aided systems like CAPC, CADM, CASC or CAMM, networked and non-networked NCMT as well as robots.[7] For the organizational change information about decentralization, integration, increased technical expertise, off-line groups, autonomous work groups and delayering is used. The findings show on the whole positive correlations between different types of technological change and reorganizations.

Several other studies include different sectors in its analysis. Hitt and Brynjolfsson (1997) use data from several sources: Data about IT and technology use are from the Computer Intelligence Corporation Installation database telephone surveys. Human Resource

[5]AMT: Advanced manufacturing technology

[6]SESSI: the statistical agency of the French ministry of industry, INSEE: the French national statistical agency

[7]CADM: computer-aided design and manufacture, CAPC: computer-aided production control, CASC: computer-aided stock control, CAMM: computer-aided maintenance management, NCMT: numerically controlled machine tools

practices are obtained from an own telephone survey including 273 firms. Lastly, the Compustat data delivers additional firm information. The four measures for IT are the total capital stock of IT, the total central processing power in millions of instructions per second, the number of PCs, the number of local area network nodes and a five point measure of computerization of the workplace gained from the HR survey. Furthermore, the authors distinguish between structural and individual decentralization. The first measure of decentralization is expressed by self-managing teams, employee involvement groups and broad jobs. The second one, individual decentralization, relates to the pace and the method of work. Additionally, composite variables of those measures are built. Controlling for production worker occupation and firm size, conditional Spearman rank order correlations between organizational change and IT measures are calculated. The authors find significant correlations, which are consistent across industries and variation measures. In the case firms invest in ICT, they use also a system of decentralized authority and connected practices.

In a further study the authors expand their analysis in both data and methods (Brynjolfsson and Hitt (1998)). Additionally to the previous project, information about firm performance (panel data from Compustat), investments in training, education, incentives and promotion criteria (obtained from an own survey) are gathered. Most analyses are made using a sample size of 379 firms. Beyond their previous study, the authors estimate demand equations for IT because they assume organizational change as exogenous determinant of IT. Interpreting the coefficients as demand elasticities, the authors find that decentralized firms have a higher demand for IT and increase their demand for IT at a faster rate than centralized firms.

Caroli and Van Reenen (2001) are primarily interested in skill-biased organizational change in British and French establishments. But also the impact of ICT on organizational change is considered. Data about British firms come from the pooled British Workplace Industrial Relations Surveys from 1984 and 1990. Additional information about earnings, education and occupation are gained from the General Household survey. The French data is built of four different data sources[8]. For Britain, the dependent variable is a dummy for whether the establishment has introduced organizational change over the past three years, for France whether the plant had introduced delayering between 1989 and 1992. The main explaining variables are a dummy for whether the plant has introduced new plant

[8] Relations Professionnelles et Négociations d'Entreprise (RESPONSE) for organizational methods like delayering, ESE for the employment structure, Enquête Emploi for population information and Bilans Industriels et Commerciaux for firm-level data like capital stock or value added

machinery or equipment that includes new micro-electronic technology over the previous three years (Britain) and the proportion of workers using new technologies (France). The authors carry out a probit maximum likelihood regression with 1674 respectively 1014 observations. They find that in Britain technical change is strongly correlated with organizational change, in contrast to France. But here high-tech firms rather change their organizational structure.

In a study conducted by Acemoglu et al. (2007) three datasets from British and French establishments are used for probit maximum likelihood estimations. Measures for decentralization are organization into profit centres, decentralization of investment decisions and delayering. In order to account for reversed causality, the exogenous variables are lagged. The authors find that firms closer to the technological frontier are more decentralized. Insofar as in the present study the ICT variables are also lagged, the proceeding is similar to the study of Acemoglu et al. (2007).

Finally, the third kind of studies does not only observe centralization or decentralization tendencies, but also examines whether the effect varies with the kind of ICT. Pinsonneault and Kraemer (1997) use hierarchical regressions to analyze data from 155 city governments. The dependent variable is the number of middle managers divided by the total number of managers; the independent variables are four indices of the extent of automation concerning control, coordination, efficiency, and access. Computing decision authority serves as a moderator; organization size is a control variable. According to the authors, in centralized organizations IT is associated with a lower ratio of middle managers, in decentralized with a higher one. The results also indicate that different types of IT exert various influences on the ratio of middle managers. IT focused on coordination is associated with a lower number of middle managers whereas IT used as a monitoring device involves a higher ratio. The effect of IT, which aims at gaining efficiency, is not clear and depends on the role middle managers play in the organization. By and large, the authors interpret their results as a support for the reinforcement politics perspective, where the influences of IT are contingent upon the structural arrangements of the organization and the congruence between these structures.

Bloom et al. (2009) use in their working paper data from the Center for Economic Performance Management and Organization Survey and the Harte-Hanks ICT panel, complemented by external data sources. Estimating OLS and probit maximum likelihood models, they find that information and communication technologies exercise different effects on firm organization. While information technologies lower information costs and therefore enable delegation, a lower degree of communication costs fosters centralization. As proxies for better information technology, they use Enterprise Resource Planning for plant managers and CAD/CAM for production workers. The use of data networks stands for decreasing communication costs. The authors take into account potential endogeneity: In an extending equation, a country-level network price variable is regressed on plant manager autonomy. The coefficient shows the expected positive sign. Insofar as Bloom et al. (2009) distinguish between different forms of ICT, the present investigation is related to their paper. However, they divide ICT in information and communication technologies. In contrast, the present paper looks at different characteristics of ICT.

To sum, the results concerning the relationship between ICT and organizational change are in general quite mixed. Note that several of the above mentioned studies are restricted to specific industries or firms. This restrains to draw general conclusions. Also much empirical work analyzes the research question using correlations or OLS regressions. Reversed causality or unobserved firm characteristics as sources for potential estimation biases are predominantly not considered.

The innovation of the present paper can therefore be summarized as follows: First, the paper jointly analyzes the research questions of the above demonstrated areas. It examines whether there exists a relationship between ICT and organizational change at all. It also proofs, whether ICT is associated with centralization or decentralization tendencies in firms. Additionally, the single effects of different ICT measures are observed. Second, the nationally representative data used in this paper contain information about diverse industries in contrast to several previous studies, which focused on one industry or firm. This allows a wider perspective on the use of ICT. Finally, in contrast to most previous studies, the potential sources of estimation biases reversed causality and unobserved firm characteristics are taken into account in the present paper.

4 Empirical Investigation

4.1 Data, Variables and Descriptive Statistics

For the empirical investigation panel data from the KOF Swiss Economic Institute (KOF) from the ETH Zurich are used. The KOF conducts regularly nationally representative surveys for the privated business sector containing comprehensive questions about firm characteristics. The sample of the KOF is based on the business census and is broken down according to sectors and size categories specific to each sector. For the present analysis, the waves 2005 and 2008 from the survey "Innovation Activities, Information Technologies and Work Organization" offer questions which are particularly well appropriate for the adaptation of the research question. Questions concerning the ICT use of firms can additionally be used from the wave 2000 of the survey "Organizational Change and the Adoption of Information and Communication Technologies". The surveys offer especially for ICT a more versatile data base than comparable surveys in other countries. The analysis is restricted to firms with at least 20 employees because only they are asked questions concerning the allocation of decision rights.

The dependent variable refers to the allocation of decision rights at work. Seven questions relate to the allocation of competences within the firm defined on a five-point Likert scale. They cover different areas of the distribution of competences between supervisor and associate. One question is for example "Who decides on the pace of work?". Response categories range from "associate alone" to "supervisor alone". All questions concerning competence distribution may be found in Table A1 in the Appendix. They are used to build the index variable *delegation* by transforming the response categories to 0 to 4, adding up the responses and dividing by 28, by what the variable is normed between 0 and 1. A firm with a value of *delegation* closer to one therefore has a more decentralized allocation of decision-making authority and vice versa.

A wide range of questions is related to the application of ICT. Different ICT variables are used in order to gain a comprehensive picture of the ICT use in each firm. The first variable is built in the following way: Firms are asked whether or not they use a digital assistant (organizer, PDA, etc.), laptop, internet, local area network, EDI, intranet, extranet or website. These binary variables are added up to build the variable *ict*, which reflects the diversity of ICT use. In three further questions the share of employees who use computers, internet and intranet is asked. There are six different response categories which begin with 0% and move up in steps of 20% until a share of 100% is reached. The responses of these three questions are again added up in order to get the variable *ictshare*, which serves as an indicator for the diffusion of the use of computers, internet and intranet. Finally, investments in ICT per capita (Acemoglu et al. (2007)) are calculated by the following equation (1):

$$ictpc = (invest * ictinvest)/L, \tag{1}$$

where overall investments (*invest*) are multiplied with the share of ICT investments as part of the overall investments (*ictinvest*) in the last three years and divided by the number of employees working in the firm (L). This variable serves as an indicator for the intensity of ICT investments. Unfortunately, it cannot be lagged due to lack of data in 2000.

The information of these single variables is combined to get two comprehensive ICT measures which cover various characteristics of ICT use. Therefore, the variable *stdict* is built by standardizing the sum of the standardized single ICT variables (Bresnahan, Brynjolfsson and Hitt (2002)):

$$stdict = std(std(ict) + std(ictshare) + std(ictpc)). \tag{2}$$

In order to get a further exogenous variable, the share of employees which uses computers is applied instead of the combination of computer, internet and intranet use. The variable *stdictcompu* is then composed again through standardizing the sum of the standardized components *ict*, *compushare* and *ictpc*, as shown in equation (3):

$$stdictcompu = std(std(ict) + std(compushare) + std(ictpc)). \tag{3}$$

The resulting variables *stdict* and *stdictcompu* cover different aspects and offer therefore a comprehensive picture of the diversity, diffusion and intensity of ICT use in each firm.

A bunch of control variables accounts for observed heterogeneity between the firms. The log of sales of the firm in Switzerland (lnY) and the log of gross investments (lnK) are explanatory variables (Brynjolfsson and Hitt (1998), Caroli and Van Reenen (2001)). According to the existing literature, larger firms tend towards more decentralization (e.g., Caroli and Van Reenen (2001), Colombo and Delmastro (2004)). Therefore also the log of the number of employees including apprentices (lnL) is inserted in all equations. Furthermore, younger firms are expected to rather have a decentralized work organization (Acemoglu et al. 2007). That is why the founding year (*fyear*) is another variable. A dummy variable which takes the value 1 for firms which have a foreign (non domestic) owner and 0, otherwise (*foreign*) is inserted to catch the potential effect of a more complex production process (Acemoglu et al. (2007)). More competitive environments are expected to bring forward decentralized structures (e.g., Acemoglu et al. (2007), Ichniowski and Shaw (1995), OECD (1999), Osterman (1994)). That is why the share of exports as a percentage of sales (*exportshare*) is a further control variable.

Because advanced work organization is often associated with a well educated work force (e.g., Bloom et al. (2009), Hempell and Zwick (2008)), the share of graduates and employees with a degree higher than apprenticeship as a percentage of the whole employment (*highedu*) is integrated. According to Brown, Geddes and Heywood (2007), complementary HR practices like formal training and incentive pay increase the likelihood of having employee-involvement schemes[9]. This can be integrated since the surveys contain information about the importance of different forms of transition to flexible working hours like part-time employment, temporary employment or flexible annual working time. The questions are answered on a five-point Likert scale ranging from no (1) to a very high importance (5) and are converted to dummy variables which take the value 1 if the importance is 4 or 5, 0 otherwise (*parttime01*, *temp01*, *flextime01*).

Additionally, the mode of incentive systems, in particular the use of performance indicators for the determination of wages, is assumed to be related to more decentralized decision making (Gittleman, Horrigan and Joyce (1998), Osterman (1994)). Therefore, the importance of individual performance, team performance and firm performance for the determination of the amount of wages is captured in dummy variables. The variables are again asked on a five-point Likert scale. They take the value 1 if the firms assign a high or very high importance by choosing the response category 4 or 5, and 0 otherwise (*indwage01*, *teamwage01*, *firmwage01*). Also the percentage of employees who participated in internal or external training (*training*) is a further variable (Gittleman, Horrigan and Joyce (1998), Osterman (1994)). Finally, dummy variables for six regions (*reg1*-*reg6*), six sectors (*sec1*-*sec6*) and a time dummy (*t05*) are inserted in the equations. Table 1 displays descriptive statistics for the presented variables.

[Table 1 about here]

4.2 Econometric Modeling

As a starting point, a pooled cross sectional OLS regression with cluster robust standard errors is estimated. Two of the variables, which are used to build the *stdict* variable, are

[9] These are in their definition for example autonomous groups, quality circles, joint consultative committees and task forces.

lagged (*t-1*) from the surveys 2000 respectively 2005, whereby the problem of reversed causality is dispelled:

$$delegation_{it} = \beta_0 + \beta_1 stdict_{it-1} + \beta_2 X_{it} + \epsilon_{it}, \tag{4}$$

where $delegation_{it}$ is the dependent variable for the allocation of decision rights, the variable $stdict_{it-1}$ indicates the use of ICT and X_{it} is a vector of the control variables for firm i at time t to account for observed firm heterogeneity. ϵ_{it} is the error term, which is assumed to be normally distributed with zero mean and finite variance. In order to gain efficient and unbiased estimates, the explaining variables must be strictly exogenous and independent across observations (Greene (2008)).

The panel structure of the data allows to estimate models that account for unobserved firm characteristics. The estimation model can therefore be written as

$$delegation_{it} = \beta_0 + \beta_1 stdict_{it-1} + \beta_2 X_{it} + u_{i.} + \epsilon_{it}. \tag{5}$$

Panel estimation with random effects uses both between and within variation, but demands - in order to be unbiased and efficient - that the firm heterogeneity u_i is uncorrelated with the regressors. This assumption is unlikely to be fulfilled: If, for example, certain types of managers tend to apply a more diverse and intensive use of ICT than other managers and if the same type of managers likes to decentralize decision-making authority to subordinate hierarchical levels, then the ICT variable is no longer exogenous to the model, potentially leading to biased results. Therefore, the results could be under- or overestimated.

As an alternative a fixed effects model can be estimated. This model enables to decrease the heterogeneity bias and imposes a less strong condition to gain unbiased and efficient results: The explanatory variables are allowed to be correlated with the time-invariant part of the error term u_i but have to be uncorrelated with the idiosyncratic error term ϵ_{it}. So, they are permitted to be correlated with the unobserved firm specific effects. However, the fixed effects model requires sufficient level variation within firms in order to gain reliable results. In the present case, there are several control variables which either do not change their size or change only little over time, like the founding year (*fyear*) or whether the firm is foreign-controlled (*foreign*). When the within variation is too small, the results of the fixed effects model might be less efficient because only information within and not between the group of firms is used. Additionally, due to the elimination of fixed effects which are not time-variant, only coefficients of the time-variant variable can be estimated in this model (Greene (2008)).

Thus, both random and fixed effects models may lead to unreliable results in the present case. To overcome the above mentioned shortcomings, the Mundlak's approach (Mundlak (1978)) as extension of the random effects model is used aiming at decreasing the heterogeneity bias. Here it is assumed that included means over the time explain the correlation between the panel error terms and the explanatory variables (Greene (2008)):

$$delegation_{it} = \beta_0 + \beta_1 stdict_{it-1} + \beta_2 X_{it} + \beta_3 \overline{Y}_{i.} + u_{i.} + \epsilon_{it}. \tag{6}$$

$\overline{Y}_{i.}$ reflects the averaged time-varying explaining variables for a given firm i. This approach is used to overcome the respective shortcomings of both random and fixed effects models.

4.3 Results

4.3.1 Combined ICT Variables

The central results of the estimated models using the combined ICT variables may be found in Table 2 (the complete regression outputs with all control variables are displayed in Tables A2 and A3 in the Appendix). As shown in columns C1 and C5, where the results of the pooled OLS model are displayed, both ICT variables *stdict* and *stdictcompu* have a positive sign and are significant at the 1% level. The sizes of the coefficients are 0.021 for *stdict* and 0.022 for *stdictcompu*. With an F-value of 9.00 and 9.03 and using 1068 observations the whole models are significant at the 1%-level.

[Table 2 about here]

In the next step a random effects model is estimated, which imposes relatively strong restrictions. Here, no correlation between error term and regressors is allowed in order to gain consistent and efficient results. As can be seen in columns C2 and C6, the size of the coefficients slightly decreases to 0.019 and 0.020. Again *stdict* as well as *stdictcompu* have a significant positive impact at a significance level of 1%. According to the Wald Test, both models are significant at the 1%-level. Note that these results could be biased if the omitted heterogeneity is correlated with the regressors.

In the fixed effects model, the unobserved firm characteristics are allowed to be correlated with the time-invariant part of the error term. Now the results are completely changing and both ICT variables are loosing its significance (see columns C3 and C7). Compared to the previous estimations, the R^2's are declining clearly to 0.0052 and 0.0058. Indeed the complete models are significant, but with very low F-values of 2.11. A reason for this result could be the much higher between variation compared to the within variation of the variables. For example, the number of employees (L) has a between variation of 1598.32, but a within variation of only 226.20. Another example is the variable *exportshare*, which has a between variation of 33.58 but a within variation of only 4.77. Therefore, the fixed effects estimates could suffer from efficiency loss. It seems that the within variation in the data is too small to explain the degree of delegation using the fixed effects model. These indicators point that the fixed effects estimation is not the appropriate method to analyze the impact of ICT on the allocation of decision-making authority in this paper.

Using post estimation tests the appropriateness of both models can be analyzed. The Breusch and Pagan Lagrangian multiplier test for random effects rejects the null hypothesis of no correlation of the firm-specific effects with the coefficients with Prob$>chi^2 = 0.000$ in models with both variables. However, the Hausman test's null hypothesis that the random effects estimator is consistent, is scarcely not rejected with Prob$>chi^2$ of 0.1725 and 0.1449. The hypothesis, that the coefficients of random and fixed effects models are the same, can therefore not be rejected. Thus, these test statistics do not give a convincing recommendation for a preferred model.

Due to the characteristics of the data and the related shortcomings of the random and fixed effects approach, therefore in a last step, the Mundlak‘s approach as extension of the random effects model is applied. As most striking result the ICT variables *stdict* and *stdictcompu* in C4 and C8 are significant positive on the 1%-level. The size of the coefficient remains the same compared to the random effects model with 0.019 and 0.020. This is a slightly decrease in contrast to the pooled OLS model (0.021 and 0.022). Of the mean variables *lny* exhibits a significant positive and *indwage01* exhibits a significant negative impact. The Wald test shows that both models are significant on the 1%-level. Also, the whole model gains a slightly better explanation of the between, within and overall variation than the random effects model: The R^2s show that between (0.2267 and 0.2285) and overall (0.2002 and 0.2020) variation is slightly and within (0.0436 and 0.0422) variation is clearly better explained by the Mundlak‘s model compared to the original random effects model ($R^2_{between}$: 0.2163 and 0.2181, $R^2_{overall}$: 0.1892 and 0.1911, R^2_{within}: 0.0068 and 0.0065). To sum up, the ICT variables *stdict* and *stdictcompu* show a highly significant positive impact on the degree of delegation using OLS, random effects and the Mundlak's approach.

4.3.2 Combinations of Single ICT Variables

In order to gain further insights about the impact of ICT on the allocation of decision-making authorities, the effects of the single components of the combined ICT variables are analyzed separately, in pairs and in a threesome. The empirical investigation follows the principle of the standardized ICT variables in the previous section: After estimating pooled OLS, random and fixed effects models in a last step the Mundlak's approach is applied. To avoid confusion, only the coefficients of interest with its standard errors are presented in Table 3. The complete regression results can be found in Table A4 in the Appendix.

[Table 3 about here]

In short, the share of workers who use computers, internet and intranet (*ictshare*), the share of workers who use computers (*compushare*) and the investments in ICT per capita (*ictpc*) show consistent and significant positive impact on the *delegation* variable in all equations. The number of ICT (*ict*) used in the firm has significant positive impact when included alone and simultaneously with *ictpc*. Following the Wald test, the null hypothesis that the models offer no explanation, is rejected on the 1%-level.

These are the results in detail: When included separately, *ict*, *ictshare*, *compushare* and *ictpc* have a positive and significant impact on decentralization. Included in pairs, the size of the coefficients of *ictshare* and *ictpc* remains about the same (0.006 and $6.13*10^{-10}$). The size of *compushare* decreases slightly when included with *ictpc* (0.017) and *ict* (0.016). *ict* exhibits only significant positive impact at the 5%-level when included with *ictpc*. It can be seen, that the explanatory power increases slightly when the variables are included together.

When all three variables are inserted simultaneously, *ictshare*, *compushare* and *ictpc* are significant positive at the 1% significance level. The size of *ictshare* remains with 0.006 the same, whereas that of *compushare* decreases very slightly respectively remains the same with 0.016. Also the sizes of *ictpc* are about the same with $6.82*10^{-8}$ and $6.17*10^{-10}$.

Obviously, *ictshare*, *compushare* and *ictpc* are the driving forces in explaining the positive impact of ICT on delegation.

All in all, the results confirm the second hypothesis, where the *agency costs effect* outweighs the *decision information costs effect* of ICT which leads to decentralized decision-making authorities. According to the results, not the variety of ICT, but the diffusion of ICT within the workforce and the intensity of ICT investments are the central determinants of decentralization (*ictshare*, *compushare*, *ictpc*). The variety of ICT use (expressed by *ict*) shows only in some regressions significant positive impact. As one possible explanation for this result, the use of advanced ICT (which would lead to a high value of the *ict* variable for the firm) are maybe only used from a small fraction of the employees and therefore has no impact on the overall allocation of decision-making authorities in the firm. In contrast, it seems likely that a wide diffusion of ICT within the workforce also leads to a general decentralization of decision rights.

5 Conclusion

In the present paper the relationship between ICT and the allocation of decision rights is examined using two waves of nationally representative Swiss firm-level panel data. Particularly, it is analyzed whether ICT is associated with centralization or decentralization tendencies. Therefore pooled cross sectional, random and fixed effects models are estimated. In the present case, although accounting for unobserved firm heterogeneity, these techniques will potentially not lead to consistent and efficient results. As a compromise therefore an estimation approach according to Mundlak (1978) is applied additionally. A further potential estimation bias caused by reversed causality is also taken into account using lagged ICT variables. Hence, the results are robust to potential endogeneity biases like reversed causality and unobserved firm characteristics.

The empirical results show a clear association of ICT with decentralization tendencies. They can be summarized in the following way. First, the use of ICT is generally related with decentralized decision-making authorities. This confirms the hypothesis where the *effect of lower agency costs* seems to outweigh the *effect of decreased decision information costs* of ICT and hence fosters decentralization.

Second, indeed also all single ICT variables show a positive impact on decentralization. However, the effects of various ICT characteristics differ from each other. The variables for the share of employees which use ICT and the share of investments in ICT per capita have the highest fraction to explain the promotion of decentralization. The number of used ICT shows only some positive impact on decentralization. Thus, first and foremost the diffusion of ICT within the workforce and the intensity of ICT investments and not the variety of ICT are essential for the decentralization effect of ICT.

Third, the results do not change significantly using OLS and random effects models and the Mundlak's approach. In the present case, unobserved heterogeneity of Swiss firms apparently does not lead to drastically deviating results compared to the basic OLS regression.

The conclusion of the present paper therefore is, that lower ageny costs due to the use of ICT result in decentralized decision-making authorities in Swiss firms. It confirms the results of several previous studies which found a relationship between ICT and organizational structure. However, it contradicts studies which found evidence for a centralization effect of ICT. Beyond that, it provides further insights: Firms that let a high share of their employees participate in ICT use and invest intensively in ICT, give their employees also more decision-making power. Contrary, the use of advanced ICT is not essential for decentralized decision-making authorities. Since the development of ICT still goes on, also the organizational structure will probably be adjusted. Recent trends in ICT like social networks and instant messenger programms may as well have influence on the allocation of decision-making authorities in firms in the future.

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Table 1: Descriptive Statistics of the Variables

Variable	Mean	Std.Dev.	Min	Max
delegation	0.34	0.14	0.00	0.79
stdict	-0.02	1.01	-2.24	15.70
stdictcompu	-0.02	1.02	-2.36	16.38
ict	5.76	1.70	0	8
ictshare	6.42	4.01	0	15
compushare	2.81	1.48	0	5
ictpc	5169.305	87742.82	0	2863300
sales	145,000,000	929,000,000	372,000	19,200,000,000
L	226	571	20	8630
invest	4,235,627	17,100,000	10	372,000,000
fyear	1942	41	1657	2005
foreign	0.16	0.37	0	1
exportshare	25.24	34.58	0.00	100.00
highedu	19.80	17.60	0.00	100.00
parttime01	0.24	0.43	0	1
temp01	0.21	0.41	0	1
flextime01	0.27	0.45	0	1
indwage01	0.87	0.33	0	1
teamwage01	0.28	0.45	0	1
firmwage01	0.48	0.50	0	1
training	29.73	28.78	0.00	100.00

Calculations are restricted to firms which do not provide item non-response for the subsequent regression analysis of C4 and C5. The sample size is $N = 1068$.
Sources: KOF Innovation Panel (waves 2005 and 2008) and the survey "Organizational Change and the Adoption of Information and Communication Technologies" (2000), own calculations.

Table 2: Regression Results for Combined ICT Variables

Dependent Variable: delegation					
Estimation Method:	**OLS**	**RE**	**FE**	**Mundlak**	
	C1	C2	C3	C4	
stdict	0.021***	0.019***	0.000	0.019***	
	(0.005)	(0.005)	(0.008)	(0.005)	
	C5	C6	C7		C8
stdictcompu	0.022***	0.020***	0.001		0.020***
	(0.006)	(0.005)	(0.008)		(0.005)
$\overline{lnY}$				0.042***	0.042***
				(0.012)	(0.012)
$\overline{lnK}$				0.006	0.006
				(0.007)	(0.007)
$\overline{lnL}$				-0.038	-0.039
				(0.036)	(0.035)
$\overline{exportshare}$				-0.001	-0.001
				(0.001)	(0.001)
$\overline{highedu}$				0.000	0.000
				(0.001)	(0.001)
$\overline{parttime01}$				0.003	0.002
				(0.021)	(0.021)
$\overline{temp01}$				0.015	0.015
				(0.022)	(0.022)
$\overline{flextime01}$				-0.030	-0.030
				(0.019)	(0.019)
$\overline{indwage01}$				-0.058**	-0.058*
				(0.030)	(0.030)
$\overline{teamwage01}$				0.033	0.034
				(0.021)	(0.021)
$\overline{firmwage01}$				-0.020	-0.019
				(0.017)	(0.017)
$\overline{training}$				0.000	0.000
				(0.000)	(0.000)
stdict					
F test/Wald test	9.00***	261.24***	2.11***	296.57***	
R^2	0.1900	0.1892	0.0052	0.2002	
N	1068	1068	1068	1068	
stdictcompu					
F test/Wald test	9.03***	261.39***	2.11***		294.43***
R^2	0.1918	0.1911	0.0058		0.2020
N	1068	1068	1068		1068

Legend: Coefficient (standard error)

***/**/* indicates significance at the 1/5/10%-level

The standard errors are robust and clusterd by firms.

Sources: KOF Innovation Panel (waves 2005 and 2008) and the survey "Organizational Change and the Adoption of Information and Communication Technologies" (2000), own calculations.

Table 3: Mundlak's Regression Results for Combinations of Single ICT Variables

Dependent Variable: delegation
Estimation Method: Mundlak's Approach

	Single Variables				**Combinations of Single Variables**					**All Variables**	
	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19
ict	0.005**				0.002	0.003	0.005**			0.002	0.003
	(0.003)				(0.003)	(0.003)	(0.003)			(0.003)	(0.003)
ictshare		0.006***			0.006***			0.006***		0.006***	
		(0.001)			(0.001)			(0.001)		(0.001)	
compushare			0.018***			0.016***			0.017***		0.016***
			(0.003)			(0.003)			(0.003)		(0.003)
ictpc				$5.42*10^{-8}$***			$6.13*10^{-8}$***	$6.73*10^{-8}$***	$5.83*10^{-8}$***	$6.82*10^{-8}$***	$6.17*10^{-8}$***
				(0.000)			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Wald test	275.38***	301.15***	302.29***	434.85***	299.71***	298.57***	329.50***	366.64***	356.50***	367.31***	354.62***
R^2	0.1803	0.2014	0.2060	0.1704	0.1977	0.2022	0.1897	0.2090	0.2136	0.2069	0.2102
N	1157	1201	1201	2095	1152	1152	1073	1114	1114	1068	1068

Legend: Coefficient
(standard error)

***/**/* indicates significance at the 1/5/10%-level

All columns are estimated using the Mundlak's approach. The standard errors are robust and clusterd by firms.

Sources: KOF Innovation Panel (waves 2005 and 2008) and the survey "Organizational Change and the Adoption of Information and Communication Technologies , own calculations.

Appendix

A 1: Description of the Variables

Variable	Description
Allocation of Decision-Making Authorities	
Allocation of decision rights (*delegation*)	Index variable composed of seven questions concering the allocation of decision rights in the firm: - Who determines the pace of work? - Who determines the order of tasks to be performed? - Who distributes the work on employees? - Who determines the modality of the conducting of the work? - Who is responsible in case of production difficulties or problems with the creation of services? - Who is routinely responsible for customer contact? - Who is in contact with customers in case of problems or complaints?
Information and Communciation Technologies	
ICT (*ict*)	Variable indicating the number of information and communication technologies applied in a firm (digital assitent, laptop, internet, local area network, EDI, intranet, extranet, website) in 2000/2005
Share of ICT usage (*ictshare*)	Variable indicating the share of employees who use computers, internet and intranet by adding up the diffusion of use of these technolgies 2000/2005
Share of computer usage (*compushare*)	Variable indicating the share of employees who use computers 2000/2005
ICT investments per capita (*ictpc*)	Variable indicating investments in ICT per capita 2005/2008
stdict (*stdict*)	Variable indicating the diversity, diffusion and intensity of ICT use in a firm, $stdict = \text{std}(\text{std}(ict) + \text{std}(ictshare) + \text{std}(ictpc))$
stdictcompu (*stdictcompu*)	Variable indicating the diversity, diffusion and intensity of ICT use in a firm, $stdictcompu = \text{std}(\text{std}(ict) + \text{std}(compushare) + \text{std}(ictpc))$
Firm Characteristics	
Log sales (*lnY*)	Natural logarithm of a firm's sales in 2004/2007
Log capital (*lnK*)	Natural logarithm of a firm's gross investments in 2004/2007
Log labor (*lnL*)	Natural logarithm of a firm's number of employees in 2004/2007
Founding year (*fyear*)	Founding year of a firm
Foreign-controlled (*foreign*)	Dummy variable indicating whether or not a firm is foreign-controlled
Highly educated employees (*highedu*)	Share of employees who have an education higher than apprenticeship or are graduates
Parttime employment (*parttime01*)	Dummy variable indicating whether or not parttime employment is important for a firm
Temporary employment (*temp01*)	Dummy variable indicating whether or not temporary employment is important for a firm
Flexible employment (*flextime01*)	Dummy variable indicating whether or not flexible employment is important for a firm
Importance of individual performance for wage (*indwage01*)	Dummy variable indicating whether or not individual performance is important for the determination of wages
Importance of team performance for wage (*teamwage01*)	Dummy variable indicating whether or not team performance is important for the determination of wages
Importance of firm performance for wage (*firmwage01*)	Dummy variable indicating whether or not firm performance is important for the determination of wages
Training (*training*)	Share of employees who participated in 2004/2007 in internal or external training
Regional dummies (*reg1-reg7*)	Seven dummies indicating the regional affiliation of the firm
Sector dummies (*sec1-sec7*)	Seven dummies indicating the sector affiliation of the firm
Time dummy (*t05*)	Dummy variable indicating the year 2005

Sources: KOF Innovation Panel (waves 2005 and 2008) and the survey "Organizational Change and the Adoption of Information and Communication Technologies" (2000), own calculations.

A 2: Complete Regression Results for *stdict*

Dependent Variable: delegation				
Estimation	C1	C2	C3	C4
Method:	**OLS**	**RE**	**FE**	**Mundlak**
stdict	0.021***	0.019***	0.000	0.019***
	(0.005)	(0.005)	(0.008)	(0.005)
lnY	0.010*	0.009*	-0.032***	-0.028***
	(0.005)	(0.005)	(0.010)	(0.011)
lnK	-0.003	-0.003	-0.005	-0.007
	(0.003)	(0.003)	(0.008)	(0.006)
lnL	0.006	0.007	0.040	0.037
	(0.007)	(0.007)	(0.043)	(0.034)
fyear	0.000	0.000	-0.001	0.000
	(0.000)	(0.000)	(0.001)	(0.000)
foreign	0.010	0.010	-0.010	0.008
	(0.012)	(0.012)	(0.024)	(0.012)
exportshare	0.000	0.000	0.001	0.001
	(0.000)	(0.000)	(0.001)	(0.001)
highedu	0.001***	0.001***	0.001	0.001***
	(0.000)	(0.000)	(0.001)	(0.001)
parttime01	0.011	0.010	0.015	0.007
	(0.009)	(0.009)	(0.020)	(0.017)
temp01	-0.021**	-0.020**	-0.039**	-0.029*
	(0.010)	(0.009)	(0.019)	(0.018)
flextime01	0.004	0.008	0.023	0.029*
	(0.009)	(0.009)	(0.017)	(0.016)
indwage01	-0.010	-0.009	0.030	0.032
	(0.013)	(0.013)	(0.037)	(0.026)
teamwage01	-0.011	-0.009	-0.012	-0.031*
	(0.009)	(0.009)	(0.023)	(0.018)
firmwage01	-0.002	-0.001	0.009	0.013
	(0.008)	(0.008)	(0.018)	(0.015)
training	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
reg1	0.033	0.030		0.026
	(0.028)	(0.028)		(0.028)
reg2	0.047*	0.046*		0.046*
	(0.025)	(0.024)		(0.024)
reg3	0.083***	0.084***		0.083***
	(0.025)	(0.025)		(0.025)
reg4	0.073***	0.072***		0.071***
	(0.025)	(0.025)		(0.025)
reg5	0.075***	0.076***		0.075***
	(0.026)	(0.025)		(0.025)
reg6	0.093***	0.093***		0.090***
	(0.026)	(0.026)		(0.026)

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Dependent Variable: delegation				
Estimation Method:	C1 **OLS**	C2 **RE**	C3 **FE**	C4 **Mundlak**
sec1	-0.014	-0.017		-0.018
	(0.018)	(0.017)		(0.018)
sec2	-0.027	-0.033		-0.035*
	(0.020)	(0.020)		(0.021)
sec3	0.039*	0.037*		0.034
	(0.022)	(0.022)		(0.023)
sec4	0.046	0.041*		0.035
	(0.025)	(0.025)		(0.026)
sec5	0.030	0.033		0.025
	(0.024)	(0.024)		(0.024)
sec6	-0.027	-0.030		-0.028
	(0.022)	(0.022)		(0.023)
t05	0.008	0.010	0.018	-0.009
	(0.007)	(0.007)	(0.012)	(0.008)
$\overline{lnY}$				0.042***
				(0.012)
$\overline{lnK}$				0.006
				(0.007)
$\overline{lnL}$				-0.038
				(0.036)
$\overline{exportshare}$				-0.001
				(0.001)
$\overline{highedu}$				0.000
				(0.001)
$\overline{parttime01}$				0.003
				(0.021)
$\overline{temp01}$				0.015
				(0.022)
$\overline{flextime01}$				-0.030
				(0.019)
$\overline{indwage01}$				-0.058*
				(0.030)
$\overline{teamwage01}$				0.033
				(0.021)
$\overline{firmwage01}$				-0.020
				(0.017)
$\overline{training}$				0.000
				(0.000)
cons	0.162	0.163	2.174**	0.165
	(0.212)	(0.208)	(1.055)	(0.211)
F test/Wald test	9.00***	261.24***	2.11***	2896.57***
R^2	0.1900	0.1892	0.0052	0.2002
N	1068	1068	1068	1068

Legend — Coefficient (standard error)

***/**/* indicates significance at the 1/5/10%-level
The standard errors are robust and clusterd by firms.
Sources: KOF Innovation Panel (waves 2005 and 2008) and the survey "Organizational Change and the Adoption of Information and Communication Technologies" (2000), own calculations.

A 3: Complete Regression Results for *stdictcompu*

Dependent variable: delegation				
Estimation	C5	C6	C7	C8
Method:	**OLS**	**RE**	**FE**	**Mundlak**
stdictcompu	0.022***	0.020***	0.001	0.020***
	(0.006)	(0.005)	(0.008)	(0.005)
lnY	0.009*	0.009	-0.032***	-0.028***
	(0.005)	(0.005)	(0.010)	(0.011)
lnK	-0.004	-0.003	-0.005	-0.007
	(0.003)	(0.003)	(0.008)	(0.006)
lnL	0.008	0.008	0.041	0.039
	(0.007)	(0.007)	(0.043)	(0.034)
fyear	0.000	0.000	-0.001	0.000
	(0.000)	(0.000)	(0.001)	(0.000)
foreign	0.010	0.010	-0.010	0.008
	(0.012)	(0.012)	(0.024)	(0.012)
exportshare	0.000	0.000	0.001	0.001
	(0.000)	(0.000)	(0.001)	(0.001)
highedu	0.001***	0.001***	0.001	0.001***
	(0.000)	(0.000)	(0.001)	(0.001)
parttime01	0.010	0.010	0.015	0.007
	(0.009)	(0.009)	(0.020)	(0.017)
temp01	-0.021**	-0.020**	-0.039**	-0.030*
	(0.010)	(0.009)	(0.019)	(0.018)
flextime01	0.004	0.008	0.024	0.029*
	(0.009)	(0.009)	(0.017)	(0.016)
indwage01	-0.009	-0.009	0.030	0.032
	(0.013)	(0.013)	(0.037)	(0.026)
teamwage01	-0.010	-0.008	-0.012	-0.031*
	(0.009)	(0.009)	(0.023)	(0.018)
firmwage01	-0.001	-0.001	0.009	0.013
	(0.008)	(0.008)	(0.018)	(0.015)
training	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
reg1	0.033	0.030		0.026
	(0.028)	(0.028)		(0.028)
reg2	0.048*	0.046*		0.047*
	(0.024)	(0.024)		(0.024)
reg3	0.085***	0.085***		0.085***
	(0.025)	(0.025)		(0.025)
reg4	0.074***	0.074***		0.072***
	(0.025)	(0.025)		(0.025)
reg5	0.076***	0.076***		0.076***
	(0.025)	(0.025)		(0.025)
reg6	0.094***	0.094***		0.091***
	(0.026)	(0.026)		(0.026)

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Dependent Variable: delegation				
Estimation	C5	C6	C7	C8
Method:	**OLS**	**RE**	**FE**	**Mundlak**
sec1	-0.015	-0.018		-0.018
	(0.017)	(0.017)		(0.018)
sec2	-0.027	-0.033*		-0.035*
	(0.020)	(0.020)		(0.020)
sec3	0.037*	0.035		0.032
	(0.022)	(0.022)		(0.023)
sec4	0.047*	0.042*		0.037
	(0.025)	(0.025)		(0.026)
sec5	0.026	0.030		0.022
	(0.024)	(0.024)		(0.025)
sec6	-0.029	-0.032		-0.029
	(0.022)	(0.022)		(0.023)
t05	0.008	-0.010	0.018	-0.009
	(0.007)	(0.007)	(0.012)	(0.008)
$\overline{lnY}$				0.042***
				(0.012)
$\overline{lnK}$				0.006
				(0.007)
$\overline{lnL}$				-0.039
				(0.035)
$\overline{exportshare}$				0.000
				(0.001)
$\overline{highedu}$				0.000
				(0.001)
$\overline{parttime01}$				0.002
				(0.021)
$\overline{temp01}$				0.015
				(0.022)
$\overline{flextime01}$				-0.030
				(0.019)
$\overline{indwage01}$				-0.058*
				(0.030)
$\overline{teamwage01}$				0.034
				(0.021)
$\overline{firmwage01}$				-0.019
				(0.017)
$\overline{training}$				0.000
				(0.000)
cons	0.174	0.187	2.175**	0.177
	(0.211)	(0.207)	(1.048)	(0.211)
F test/Wald test	9.03***	261.39***	2.11***	294.43***
R^2	0.1918	0.1911	0.0058	0.2020
N	1068	1068	1068	1068
Legend	Coefficient (standard error)			

***/**/* indicates significance at the 1/5/10%-level
The standard errors are robust and clusterd by firms.
Sources: KOF Innovation Panel (waves 2005 and 2008) and the survey "Organizational Change and the Adoption of Information and Communication Technologies" (2000), own calculations.

A 4: Complete Mundlak's Regression Results for Combinations of Single ICT Variables

Dependent Variable: delegation
Estimation Method: Mundlak's Approach

	Single Variables				Combinations of Single Variables					All Variables	
	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19
ict	0.005**				0.002	0.003	0.005**			0.002	0.003
	(0.003)				(0.003)	(0.003)	(0.003)			(0.003)	(0.003)
ictshare		0.006***			0.006***			0.006***		0.006***	
		(0.001)			(0.001)			(0.001)		(0.001)	
compushare			0.018***			0.016***			0.017***		0.016***
			(0.003)			(0.003)			(0.003)		(0.003)
ictpc				$5.42*10^{-8}$***			$6.13*10^{-8}$***	$6.73*10^{-8}$***	$5.83*10^{-8}$***	$6.82*10^{-8}$***	$6.17*10^{-8}$***
				(0.000)			(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
lnY	-0.022**	-0.022**	-0.025**	-0.037***	-0.022**	-0.024**	-0.030***	-0.031***	-0.034	-0.031***	-0.034***
	(0.010)	(0.011)	(0.012)	(0.010)	(0.011)	(0.012)	(0.011)	(0.010)	(0.011)	(0.010)	(0.011)
lnK	-0.005	-0.006	-0.006	-0.006	-0.005	-0.004	-0.004	-0.006	-0.005	-0.004	-0.003
	(0.006)	(0.006)	(0.006)	(0.005)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
lnL	0.031	0.037	0.042	-0.049**	0.028	0.034	0.033	0.041	0.046	0.036	0.041
	(0.008)	(0.032)	(0.031)	(0.025)	(0.032)	(0.032)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)
fyear	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
foreign	0.011	0.007	0.006	0.013	0.008	0.007	0.010	0.005	0.004	0.007	0.006
	(0.011)	(0.011)	(0.011)	(0.008)	(0.011)	(0.011)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
exportshare	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001
	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
highedu	0.001	0.001	0.001	0.001**	0.001	0.001	0.001**	0.001**	0.001**	0.001**	0.001**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
parttime01	0.006	0.007	0.008	-0.002	0.006	0.008	0.007	0.007	0.007	0.007	0.007
	(0.016)	(0.015)	(0.015)	(0.012)	(0.016)	(0.016)	(0.017)	(0.016)	(0.016)	(0.017)	(0.017)
temp01	-0.020	-0.019	-0.018	-0.003	-0.020	-0.020	-0.030*	-0.026	-0.026	-0.030*	-0.030*
	(0.017)	(0.016)	(0.016)	(0.016)	(0.017)	(0.017)	(0.018)	(0.017)	(0.017)	(0.018)	(0.018)
flextime01	0.024	0.027*	0.027*	0.000	0.024	0.024	0.028*	0.028*	0.028*	0.028*	0.027*
	(0.016)	(0.015)	(0.015)	(0.012)	(0.016)	(0.016)	(0.015)	(0.015)	(0.015)	(0.016)	(0.016)
indwage01	0.023	0.025	0.025	0.029	0.026	0.027	0.029	0.030	0.031	0.032	0.033
	(0.025)	(0.023)	(0.023)	(0.018)	(0.025)	(0.025)	(0.026)	(0.024)	(0.024)	(0.026)	(0.026)
teamwage01	-0.028	-0.025	-0.023	-0.024	-0.027	-0.026	-0.032*	-0.027	-0.026	-0.031*	-0.030*
	(0.017)	(0.016)	(0.016)	(0.013)	(0.017)	(0.017)	(0.018)	(0.017)	(0.017)	(0.018)	(0.018)
firmwage01	0.013	0.015	0.013	0.014	0.012	0.010	0.014	0.017	0.014	0.013	0.011
	(0.014)	(0.014)	(0.014)	(0.011)	(0.014)	(0.015)	(0.015)	(0.014)	(0.014)	(0.015)	(0.015)
training	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

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	Single Variables				Combinations of Single Variables					All Variables	
	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19
reg1	0.017	0.005	0.005	0.001	0.011	0.011	0.029	0.017	0.018	0.023	0.025
	(0.026)	(0.026)	(0.026)	(0.022)	(0.026)	(0.026)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
reg2	0.036	0.034	0.036	0.050**	0.032	0.033	0.048*	0.047*	0.049**	0.046*	0.047**
	(0.022)	(0.022)	(0.022)	(0.021)	(0.022)	(0.022)	(0.025)	(0.024)	(0.024)	(0.024)	(0.024)
reg3	0.069***	0.068***	0.071***	0.066***	0.067***	0.068***	0.083***	0.083***	0.087***	0.081***	0.084***
	(0.023)	(0.023)	(0.023)	(0.021)	(0.023)	(0.023)	(0.025)	(0.025)	(0.025)	(0.025)	(0.024)
reg4	0.057	0.054**	0.056**	0.060***	0.053**	0.055**	0.072***	0.070***	0.073***	0.069***	0.071***
	(0.023)	(0.023)	(0.023)	(0.021)	(0.023)	(0.023)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)
reg5	0.061***	0.056**	0.058***	0.065***	0.059***	0.059***	0.077***	0.073***	0.075***	0.076***	0.077***
	(0.023)	(0.022)	(0.022)	(0.021)	(0.022)	(0.022)	(0.025)	(0.025)	(0.024)	(0.025)	(0.024)
reg6	0.073***	0.073**	0.076***	0.088***	0.072***	0.074***	0.089***	0.093***	0.096***	0.090***	-0.092***
	(0.024)	(0.024)	(0.024)	(0.021)	(0.024)	(0.024)	(0.026)	(0.026)	(0.025)	(0.026)	(0.025)
sec1	-0.018	-0.025	-0.027	0.010	-0.022	-0.025	-0.015	-0.023	-0.025	-0.020	-0.022
	(0.018)	(0.017)	(0.017)	(0.016)	(0.018)	(0.017)	(0.019)	(0.018)	(0.018)	(0.018)	(0.018)
sec2	-0.037*	-0.037*	-0.038*	-0.007	-0.035*	-0.036*	-0.037*	-0.039*	-0.040**	-0.035*	-0.035*
	(0.020)	(0.020)	(0.020)	(0.019)	(0.020)	(0.020)	(0.021)	(0.020)	(0.020)	(0.020)	(0.020)
sec3	0.032	0.017	0.010	0.055***	0.023	0.016	0.037	0.021	0.015	0.028	0.023
	(0.023)	(0.022)	(0.022)	(0.019)	(0.022)	(0.022)	(0.023)	(0.023)	(0.022)	(0.023)	(0.023)
sec4	0.024	0.022	0.025	0.073***	0.020	0.022	0.037	0.030	0.030	0.032	0.034
	(0.025)	(0.025)	(0.025)	(0.021)	(0.025)	(0.025)	(0.026)	(0.025)	(0.025)	(0.025)	(0.025)
sec5	0.032	0.003	-0.006	0.042**	0.009	0.001	0.038	0.007	-0.002	0.014	0.007
	(0.024)	(0.024)	(0.024)	(0.020)	(0.024)	(0.024)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)
sec6	-0.014	-0.039*	-0.043*	0.010	-0.035	-0.039*	-0.015	-0.042*	-0.044**	-0.037	-0.039*
	(0.022)	(0.022)	(0.022)	(0.019)	(0.022)	(0.022)	(0.023)	(0.023)	(0.022)	(0.023)	(0.022)
t05	0.012	0.019**	0.013**	0.010	0.018**	0.014*	-0.012	0.018**	0.013	-0.018**	-0.013*
	(0.007)	(0.007)	(0.007)	(0.005)	(0.008)	(0.007)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)

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	Single Variables				Combinations of Single Variables					All Variables	
	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19
$\overline{lnY}$	0.040***	0.037**	0.039***	0.062***	0.036***	0.037***	0.047***	0.045***	0.048***	0.044***	0.046***
	(0.012)	(0.012)	(0.014)	(0.011)	(0.013)	(0.014)	(0.012)	(0.011)	(0.012)	(0.012)	(0.012)
$\overline{lnK}$	0.006	0.008	0.007	0.005	0.006	0.005	0.004	0.006	0.005	0.004	0.003
	(0.007)	(0.007)	(0.007)	(0.006)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
$\overline{lnL}$	-0.034	-0.040	-0.043	-0.062**	-0.030	-0.033	-0.039	-0.043	-0.046	-0.037	-0.039
	(0.033)	(0.033)	(0.033)	(0.026)	(0.033)	(0.033)	(0.036)	(0.035)	(0.035)	(0.036)	(0.035)
$\overline{exportshare}$	0.000	0.000	0.000	0.000	0.000	0.000	-0.001	-0.001	-0.001	-0.001	-0.001
	(0.001)	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$\overline{highedu}$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$\overline{parttime01}$	0.012	0.014	0.010	0.017	0.011	0.007	0.004	0.006	0.003	0.004	0.001
	(0.020)	(0.019)	(0.019)	(0.015)	(0.020)	(0.020)	(0.021)	(0.020)	(0.020)	(0.021)	(0.021)
$\overline{temp01}$	0.001	-0.002	-0.002	-0.004	0.000	0.000	0.016	0.011	0.011	0.016	0.016
	(0.021)	(0.020)	(0.020)	(0.018)	(0.021)	(0.021)	(0.022)	(0.021)	(0.021)	(0.022)	(0.022)
$\overline{flextime01}$	-0.027	-0.030	-0.029	-0.010	-0.027	-0.025	-0.030	-0.030	-0.027	-0.029	-0.027
	(0.018)	(0.018)	(0.018)	(0.014)	(0.018)	(0.018)	(0.019)	(0.018)	(0.018)	(0.019)	(0.019)
$\overline{indwage01}$	-0.050*	-0.052*	-0.051*	-0.062***	-0.053*	-0.053*	-0.054*	-0.058**	-0.057**	-0.059**	-0.059**
	(0.028)	(0.027)	(0.027)	(0.021)	(0.028)	(0.028)	(0.030)	(0.028)	(0.028)	(0.030)	(0.029)
$\overline{teamwage01}$	0.029	0.025	0.024	0.025*	0.030	0.029	0.034	0.026	0.026	0.034	0.033
	(0.020)	(0.016)	(0.019)	(0.015)	(0.020)	(0.020)	(0.021)	(0.020)	(0.020)	(0.021)	(0.021)
$\overline{firmwage01}$	-0.024	-0.025	-0.022	-0.015	-0.022	-0.020	-0.021	-0.022	-0.019	-0.019	-0.017
	(0.017)	(0.016)	(0.016)	(0.013)	(0.017)	(0.017)	(0.017)	(0.016)	(0.016)	(0.017)	(0.017)
$\overline{training}$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
cons	0.050	0.045	0.061	0.013	0.079	0.074	0.080	0.086	0.096	0.109	0.111
	(0.201)	(0.198)	(0.197)	(0.131)	(0.200)	(0.200)	(0.212)	(0.209)	(0.207)	(0.211)	(0.211)
Wald test	275.38***	301.15***	302.29***	434.85***	299.71***	298.57***	329.50***	366.64***	356.50***	367.31***	354.62***
R^2	0.1803	0.2014	0.2060	0.1704	0.1977	0.2022	0.1897	0.2090	0.2136	0.2069	0.2102
N	1157	1201	1201	2095	1152	1152	1073	1114	1114	1068	1068

Legend: Coefficient (standard error)

***/**/* indicates significance at the 1/5/10%-level

All columns are estimated using the Mundlak's approach. The standard errors are robust and clusterd by firms.

Sources: KOF Innovation Panel (waves 2005 and 2008) and the survey "Organizational Change and the Adoption of Information and Communication Technologies" (2000), own calculations.