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ICT and occupation-based measures of organisational change: Firm and employee outcomes[*]

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Abstract

To examine the productivity, employment and wage effects of ICT, we apply novel occupation-based measures of organisational change within firms. With these measures, we directly address the complementarities between ICT and organisational changes. Our results support the view that organisational change complements ICT investments in a productivity-enhancing manner. In particular, the ICT-driven productivity gains are associated with the destruction of routine and non-interactive tasks in an organisation. Furthermore, using longitudinal aspects of our linked employer-employee data, we find that whereas ICT does not affect the probability of an employee becoming unemployed, it has a positive impact on the wage growth of retained employees.

JEL classification: J24, J31, L23, M51
Keywords: ICT, innovation, organisational change, restructuring, productivity, performance, wages

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Abstract

To examine the productivity, employment and wage effects of ICT, we apply novel occupation-based measures of organisational change within firms. With these measures, we directly address the complementarities between ICT and organisational changes. Our results support the view that organisational change complements ICT investments in a productivity-enhancing manner. In particular, the ICT-driven productivity gains are associated with the destruction of routine and non-interactive tasks in an organisation. Furthermore, using longitudinal aspects of our linked employer-employee data, we find that whereas ICT does not affect the probability of an employee becoming unemployed, it has a positive impact on the wage growth of retained employees.

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1. Introduction

Although productivity growth shows declining trends in the United States and several other developed countries (e.g. Gordon 2010), information and communications technology (ICT) investments are still a driver of productivity growth. Arguably, as productivity growth is slowing, there is now an even more urgent need to understand the mechanisms through which ICT increases productivity than around the turn of the century when ICT-driven acceleration of productivity growth became a widely accepted fact (Oliner and Sichel 2002). Addressing questions that are relevant to policy, such as complementarities and spillover effects, requires the use of comprehensive, firm-level data, which has become increasingly popular (e.g. Brynjolfsson and Hitt 1995, Brynjolfsson and Hitt 2000, Black and Lynch 2001, Bresnahan et al. 2002, Brynjolfsson et al. 2002). Furthermore, firm-level analyses allow one to address a portion of the statistical challenges that are encountered in the identification of productivity effects (e.g. Draca et al. 2007).

For the most part, firm-level studies show a positive relationship between ICT and productivity (Brynjolfsson and Hitt 1995, Black and Lynch 2001, Bloom et al. 2012). These studies have also explored the important issue of potential interactions between ICT and organisational capital (Brynjolfsson et al. 2002). In these studies, it is repeatedly stressed that ICT alone is insufficient; successful adaptation of ICT requires the firm to fundamentally reorganise its operations to use the new technology. In other words, to maximise the value of ICT investments, complementary changes to work organisations have to be implemented (Brynjolfsson and Hitt 2000, Bresnahan et al. 2002). Surprisingly, only few studies have linked occupation-level flow measures to ICT investments. This shortcoming is unfortunate because occupational restructuring is an important part of changes in the task contents. The strong connection between task content and ICT investments has been under thorough consideration in the labour market literature since the seminal work by Autor et al. (2003).

Their research shows how ICT-dominated technological changes have decreased the demand for routine and non-interactive tasks and, consequently, how these changes have increased the demand for non-routine and interactive tasks. This strand of the literature provides a useful framework that explains how and why ICT fundamentally reshapes the compositions of jobs. Furthermore, occupational restructuring is the crux of the organisational change that has been argued to play a decisive complementary role in the productivity effects of ICT.

In this paper, we attempt to fill this gap in the empirical literature by applying occupation-based measures of organisational change to examine the effects of ICT on multiple firms and employee outcomes. We use comprehensive measures of organisational restructuring that have a logical connection to the leading theoretical frameworks that are used to understand the impacts of ICT and, in addition, are closely related to the empirical research regarding job and worker flows.

This extension of the previous research is particularly important because much of the previous literature has relied on simple measures of organisational change that fail to capture the intensity of organisational innovations in firms. Only the first few steps have been taken with regard to conducting research in this area. The main exceptions are the studies by Bauer and Bender (2004) and Askenazy and Moreno-Galbis (2007). However, both of these studies use a narrower set of occupation-based indicators with somewhat less comprehensive data. Furthermore, organisational innovations are not necessarily linked to occupational restructuring, which is an essential component of the changes in job content and the division of work in firms.

With this motivation, we examine ICT and occupational restructuring at three levels. Firstly, we study how ICT investments are related to a comprehensive set of measures of occupational restructuring. Our measures are firm-level counterparts to the standard industry-level indicators of job and worker flows (see Davis and Haltiwanger 1990, Davis et al. 1996), but in our work, a job is defined based on occupation within each firm (see also Bauer and Bender 2004, Askenazy and Moreno-Galbis 2007). In using this notion of a job, we highlight the ICT-driven patterns of occupational restructuring. Our measures also capture the changes in job content in terms of the shares of interactive and non-routine tasks in the firm, which are computed based on the two-digit occupation groups (according to the ISCO88 classification) of the employees. Disentangling the patterns of occupational restructuring is necessary to understand how companies adjust their work organisations to realise the full potential of costly ICT investments for competitiveness and growth. For employees and their well-being, how these changes occur in firms is highly relevant.

Secondly, we analyse the effects of ICT investments on a firm's performance. Specifically, we identify the impact of ICT on a firm's productivity, and we particularly examine the complementarities between ICT investments and occupational restructuring within firms. Such complementarities are increasingly gaining attention in the literature, due to the importance of assessing *how* companies actually create organisational conditions that make ICT investments *profitable*.

Thirdly, we change our perspective from that of the firm to that of the individual, and we examine the subsequent careers of employees and the wage effects of ICT-induced mobility on them. This employee perspective, which has been largely neglected in the literature, provides important additional insight on the nature of ICT-related occupational restructuring and how the gains from ICT investments are distributed between firms and employees in economy. We consider which firms and individuals achieve the greatest gains from investments in ICT and related organisational changes.

By investigating the topics outlined above, our analysis adds to the understanding of how jobs and tasks are reorganised within firms when new ICT is introduced. Our research also provides new insights on the specific organisational practices that are required for the successful adoption of ICT. Additionally, it addresses the largely neglected point of view of a firm's employees. Assembling these pieces of missing evidence is necessary to assess whether ICT investments and complementary organisational changes make business performance and the quality of work life coincide.

The remainder of the paper is organised as follows: the following section outlines our conceptual framework, which is used to understand the impacts of ICT on both firm and employee outcomes. Section 3 introduces both the linked data and our new measures to capture the organisational changes related to the adoption of ICT. Section 4 reports the results. Section 5 provides concluding remarks.

2. Conceptual framework

This section lays out the conceptual framework underlying our empirical analysis. Firstly, we consider how and through which channels ICT may affect occupational structures. Next, we consider how ICT and occupational restructuring may affect productivity. Finally, we consider the implications of these changes for workers.

ICT can affect the composition of tasks and thus occupations in firms in various ways. The prominent framework that was put forward by Autor et al. (2003) is based on the insight that computers are substitutes for tasks that are narrow and follow rules-based logic because such tasks can be programmed (routine tasks) and computers complement tasks that require problem solving and complex communication (non-routine tasks).

A direct prediction of this theory is that ICT investments decrease the demand for routine tasks and increase the demand for non-routine tasks. Consequently, one would expect the demand for knowledge workers (i.e., managers, professionals, technicians and associate professionals, and clerks) to increase. These changes would correspond to the changes in job content. Thus, this framework implies that ICT investments should simultaneously increase the creation and destruction of jobs. For example, consider a case where some clerical jobs are rendered unnecessary and hence are destroyed by the introduction of new ICT. While the unnecessary clerical jobs will be eliminated, this job destruction may be accompanied by a simultaneous increase of new jobs that involve, for instance, programming. However, this framework does not give any insight regarding where the new jobs are created (i.e., regarding whether they are created in the same firm or in other firms) or what happens to the employees whose jobs are replaced by ICT.

If ICT is to change the operations of a firm, there will be job destruction, as certain jobs will be replaced by ICT. This destruction may lead to an outflow of the employees from the firm (external separation) or changing occupations, i.e., occupational mobility, within the firm (internal separation). If ICT creates new jobs (i.e., if it increases filled vacancies in some occupations) in the firm, it will lead to increased hiring either outside of the firm (external hiring) or inside of the firm (internal hiring). However, because the firm may outsource ICT services, it is equally probable that ICT will not lead to increased replacement hiring. In this case, the new jobs are created in another firm. The previous considerations show how ICT may affect the occupational composition within a firm. ICT may have further effects if it increases productivity and thus leads to increased hiring as the firm increases its market share and expands its workforce.

As argued by Bresnahan et al. (2002), productivity gains from ICT depend heavily on both complementary organisational changes and the introduction of new products and services to the marketplace. On the other hand, the framework of Autor et al. (2003) shows that an increase in the share of non-routine tasks is one of the key organisational changes that should go hand in hand with ICT investments. To sum, these two insights imply that firms that simultaneously invest in ICT and increase the share of non-routine workers should achieve the highest return on their labour and non-ICT capital.

So far we have discussed the patterns of occupational restructuring in firms and how they may be related to ICT investments, organisational changes and productivity growth. Obviously, these changes also have implications for employees. In the framework of Autor et al. (2003), ICT reshapes occupational structures. The effects of ICT on employees depend heavily on both their skills and the nature of the occupational restructuring. Destruction of jobs in the firm's occupations following investments in ICT may have drastic consequences for employees who have had a considerable amount of narrow occupation-specific human capital that is also firm-specific. Furthermore, in imperfectly competitive labour markets, job losses may have negative long-term consequences. Conversely, ICT may also help employees to move to better jobs either within the same firm or through separation to another employer. Naturally, this possibility depends on the transferability of human capital across different occupations and firms. ICT may affect the earnings of workers if it increases productivity and if labour markets are imperfectly competitive. This effect may even depend on the interaction between ICT investments and occupational restructuring if, as suggested by the framework of Autor et al. (2003), the productivity effects of ICT depend on complementary (and simultaneous) changes in task composition (which would be reflected in occupational restructuring).

3. Data

We merge several data sources. Firstly, we use the *Finnish Longitudinal Employer-Employee Data* (FLEED) compiled by Statistics Finland. FLEED is constructed by the use of comprehensive administrative records that cover nearly all of the members of the labour force, as well as all private-sector firms (including their establishments). This large, representative collection of data on the Finnish labour market forms the backbone of our empirical analysis. Apart from being representative, another great advantage of FLEED is that, as it is compiled from register-based administrative records, it contains practically no reporting errors, and non-response bias is almost non-existent. FLEED currently covers the years 1990-2006, but for our research purposes, it is sufficient to restrict the sample to the period 2000-2005. FLEED contains ample information on each individual such as age, education, occupation, family background, and income. Importantly, FLEED also allows us to trace both employees and employers over time; hence, it is possible to identify firm-specific worker flows (within-firm mobility, hires and separations) and occupational restructuring.

Our second data source is the *Community Innovation Survey* (CIS) conducted by Statistics Finland.[1] This survey provides information on firms' innovation activities, including binary variables on the forms of the organisational changes conducted in the firm. We use the CIS data from the year 2004. The third dataset that we use is Statistics Finland's *Structural Business Statistics Data* (SBS), which

[1] See http://tilastokeskus.fi/til/inn/index_en.html (accessed 9 May, 2012).

is closely related to Financial Statement Statistics Data. This dataset covers the period 1994-2007. From this data, we obtain information on both ICT investments and productivity.[2]

Each of the three data sources (FLEED, CIS and SBS) includes unique identification codes for firms. Therefore, linking them is a straightforward operation that results in a unique dataset that is well-suited for undertaking the research outlined above. The quality of the linking is excellent, which allows us to avoid the problems associated with errors in record linkages (Ridder and Moffitt 2007). The fact that our linked data are representative is important because the effects of ICT may be heterogeneous across firms or industries, and those firms and industries that have attracted researchers' attention in the past may be those where positive ICT effects can be anticipated, which makes it difficult to generalise from these results to the population as a whole.

3.1. Measures

The richness of our linked data allows novel ways of measuring some of the most important factors of productivity and economic growth, i.e., ICT adoption and organisational change. In our empirical analyses, ICT adoption is measured based on ICT investments per value added. The relevant data were obtained from the *Structural Business Statistics Data*.

A more challenging issue is how to measure organisational change in a way that captures both its intensity (or pervasiveness) and its pattern (or job/task content). Our approach is based on a set of the indicators of occupational restructuring that are measured by job flows at the level of firms, as proposed by Maliranta (2009, 2012) and recently applied by Böckerman and Maliranta (2012) in

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[2] For a more detailed description of Structural Business Statistics Data and Financial Statements Statistics Data, see http://tilastokeskus.fi/keruu/yrti/index_en.html (accessed 9 May, 2012).

the context of analysing the connection between outsourcing and employee well-being (see also Bauer and Bender 2004, Askenazy and Moreno Galbis 2007).

We define a job as the match between a worker and an occupation in a firm. Thus, a firm is a collection of different jobs with different occupations. Consequently, occupational restructuring is a result of job creation and destruction at the occupation-level within firms. Various aspects of intra-firm occupational restructuring are gauged by applying the standard measures of job and worker flows, but these measures are applied at the level of firms instead of at the level of a sector or an industry, as is typical in the literature (Davis and Haltiwanger 1999, Burgess et al. 2000). To measure job creation and destruction in this context, we identify the number of workers in different occupations in the firm using the ISCO-88 classification of occupations at the one-digit level.[3] The groups are as follows:

1. Managers
2. Professionals
3. Technicians and associate professionals
4. Clerks
5. Service and care workers and shop and market sales workers
6. Craft and related trade workers
7. Plant and machine operators and assemblers
8. Elementary occupations.

Job creation (*JC*) in firm *i* is the sum of the positive employment changes in all of the occupations (j=1, …, 8) between years *t* and *t*-1, $JC_{it} = \sum_{j=1}^{j=8} \Delta L_{ijt}^{+}$, where Δ denotes the difference operator and the superscript "+" indicates that $L_{ijt} > L_{ij,t-1}$. Job destruction (*JD*) is defined analogously: $JD_{it} = \sum_{j=1}^{j=8} \left| \Delta L_{ijt}^{-} \right|$, where the superscript "-" indicates that $L_{ijt} < L_{ij,t-1}$. The net employment change

[3] Skilled agricultural and fishery workers are excluded from the analysis because we focus solely on the non-farm business sector.

in firm i is $NET_{it} = \sum_{j=1}^{j=8} L_{ijt} - \sum_{j=1}^{j=8} L_{ij,t-1}$. Therefore, a firm may simultaneously experience job creation and destruction. According to the literature on job flows, a suitable indicator of such actions is excess job reallocation (*EJR*): $EJR_{it} = JC_{it} + JD_{it} - NET_{it}$.

The measures of worker flows provide a useful extension to the analysis of occupational restructuring. It holds that $NET_{it} = JC_{it} - JD_{it} = H_{it} - S_{it}$, where H (hired) denotes the number of employees who were hired for their current occupation in year t, and S (separated) indicates the number of employees who left their occupation in year t. The hired employees consist of two groups: internally hired (*IH*) employees, who worked for the same firm (but in a different occupation) in year t-1, and externally hired (*EH*) employees, who did not work for the same firm in year t-1. Analogously, the separations can be divided into internally separated (*IS*) and externally separated (*ES*) employees. Thus, $NET_{it} = JC_{it} - JD_{it} = H_{it} - S_{it} = IH_{it} + EH_{it} - IS_{it} - ES_{it}$. By definition, $IH_{it} = IS_{it}$. To measure the amount of "excessive" worker turnover in a firm, we use the churning flow measure: $CF_{it} = H_{it} + S_{it} - \left(JC_{it} + JD_{it}\right)$.

Following the convention in the literature on job and worker flows, all flow measures are converted into rates by dividing them by the average employment of the firm in years t and t-1 (*AL*): $AL_{it} = \left(\sum_{j=1}^{j=8} L_{ijt} + \sum_{j=1}^{j=8} L_{ij,t-1} \Big/ 2\right) = \left(L_{it} + L_{i,t-1}\right)\Big/ 2$.[4] In the empirical analysis, we do not use annual changes (i.e., changes between years t-1 and t); instead, we use a five-year window (i.e., changes between 2000 and 2005). This choice is dictated by the structure and content of our data.

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[4] A useful implication of using the average employment as a denominator is that the growth rates are symmetric around zero (Davis and Haltiwanger 1999).

Furthermore, longer differences are useful for capturing gradual, time-consuming mechanisms, such as those examined in this study, especially when the data potentially contain short-run “noise” (Griliches and Hausman 1986).

In addition to the measures of job and worker flow rates, we also apply indicators that gauge the shares of interactive and non-routine tasks in the firms. By measuring the changes in these indicators between 2000 and 2005, we can explore the interesting characteristics of occupational restructuring at a more detailed level. This opportunity exists because the indicators of the shares of interactive and non-routine tasks are defined with the ISCO-88 classification of the occupations at the two-digit level following Becker et al. (2009).[5] Inasmuch as non-routine tasks involve non-repetitive work methods and creative problem solving, they cannot be programmed as simple rules. Interactive tasks require personal interaction with co-workers or third parties.

A more straightforward measure of occupational restructuring consists of the change in the share of knowledge workers between two points in time. In the empirical analysis, ‘knowledge workers’ comprise a broad category, including the first four occupational groups (i.e., managers, professionals, technicians and associate professionals, and clerks) because, in most workplaces, technicians and associate professionals, as well as clerks, work in close co-operation with professionals.[6]

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[5] Nilsson Hakkala et al. (2009) use the same classification of occupations and the same information on the skill content of tasks.

[6] Hopp et al. (2009) consider specific aspects of white-collar tasks at the individual, team and organization levels.

Therefore, in the empirical specifications, we use the following eleven measures of occupational restructuring: 1) the job destruction rate, 2) the worker separation rate, 3) the external worker separation rate, 4) the internal worker separation rate, which is equal to the internal worker hiring rate, 5) the excess job reallocation rate, 6) the churning flow rate, 7) the change in the share of interactive tasks, 8) the change in the share of non-routine tasks, 9) the job creation rate, 10) the worker hiring rate, and 11) the change in the share of knowledge workers.

4. Results

4.1. ICT and occupational restructuring

We start by examining the relationship between ICT investments and occupational restructuring, and we use job and worker flows at the level of firms and occupations. Clearly, there is a need to empirically disentangle the main features of ICT-induced occupational restructuring. For this purpose, Table 1 reports the estimates that capture the empirical relationship between ICT investments and various job and worker flow measures, which have already been described in detail. ICT investments are measured over the period 2001-2004 and the measures of occupation restructuring cover the period 2000-2005. Because we are particularly interested in the role of firms' investments in ICT from the perspective of how productively labour input is being used in the entire economy, the estimates are obtained with employment-weighted regressions. An additional advantage of employment-weighted regressions is that they put much greater emphasis on larger firms; for these firms, the measures of occupational restructuring (and other measures) are more reliable.

The firm-level OLS regressions take the following form:

$$RESTRUCTURING_{jk} = \beta X_j + \delta ICT_j + \varepsilon_{jk}, \quad k = 1,...,13, \qquad (1)$$

where $RESTRUCTURING_{jk}$ represents the measure *k* of occupational restructuring for firm *j.* As dependent variables, we use 13[7] different measures of occupational restructuring, as described earlier. X_j represents the industry effects (there are 55 industries).

In addition to our 13 measures of occupation restructuring, which were obtained from FLEED, we have constructed an overall measure of ongoing organisational change with principal component analysis, based on the Community Innovation Survey (CIS) of Statistics in Finland. The Innovation survey contains a large number of 0/1-indicators for organisational change, each capturing somewhat different aspects of this multi-dimensional latent phenomenon.[8] Because this survey information most likely contains considerable measurement error, in contrast to comprehensive register-based measures of occupational restructuring, we have summarised the survey information content with principal component analysis, and we used the single summary measure as one of the dependent variables in the regressions.

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[7] Note that the change in the share of knowledge workers has been measured both in absolute terms and relative terms. Furthermore, for the sake of comparison, we have included an additional, more traditional measure of organisational change that is constructed by means of principal component analysis.

[8] Organisational innovations are measured by i) new management practices, ii) major changes in the organisation of work and iii) significant changes in the relations with other firms or institutions (e.g., outsourcing). Marketing innovations are measured by i) significant change in the design or packaging of products or services and ii) new or significantly changed sales or distribution methods.

The estimates reported in Table 1 reveal a consistent pattern. The results for the entire private sector show that ICT investments significantly increase both job destruction and worker separation (Columns 1-2). Importantly, our empirical evidence indicates that ICT investments especially increase external worker separation (Column 3). However, the opposite effect on internal worker separation (i.e., internal hiring) prevails. The latter result implies that ICT investments tend to dampen any ongoing restructuring within an organisation. In particular, these investments decrease the vertical mobility of employees between different layers in firms. ICT investments also have a negative effect on the rate of excess job reallocation and the churning flow. Thus, there is less simultaneous turnover, as measured by job and worker flows, in firms that have invested heavily in ICT over the period 2001-2004.

Table 1 here

Furthermore, our findings reveal that ICT investments have a strong statistical relationship with changes of the shares of interactive and non-routine tasks in firms (Columns 7-8), as suggested by the recent literature. These patterns are consistent with the insight that ICT increases the demand for occupations that involve intensively interactive tasks that require personal interaction with co-workers or third parties. Additionally, the demand for occupations that include many non-routine tasks also increases with ICT. To sum, ICT investments do seem to change the content of work in a firm in an anticipated manner when the content of occupations is defined using the ISCO-88 classification of the occupations at the two-digit level following Becker et al. (2009).

Additionally, ICT investments considerably increase the share of workers who are engaged in knowledge work (Columns 11-12). These effects are in accordance with the earlier theoretical discussion because ICT investments and knowledge work are strongly complementary inputs in the production process. These estimation results also clearly reveal that the job flow measures that we introduced into this particular strand of the literature are capable of capturing the relevant changes in the occupational structure of firms that are induced by ICT.

The impact of ICT investments on the ‘creative’ side of occupational restructuring is, for the most part, mixed. The estimate for job creation in a firm is not even close to being statistically significant (Column 9). In contrast, the effect of ICT investments on worker hiring is negative and statistically significant (Column 10). Because ICT investments increase the share of knowledge work considerably, the latter observation implies that there is a net reduction in the share of the workforce that is engaged in non-knowledge work as a consequence of ICT investments. This pattern is exactly what ICT is supposed to induce in firms. Taken together, we find that the effects of ICT mostly occur through job destruction and worker separation in firms’ occupations. For this reason, it is particularly important to evaluate systematically the effects of ICT on the subsequent labour market outcomes of the employees and hence on their well-being.

The result in the last column of Table 1 reveals that the typical summary measure of organisational change, which is taken from CIS, is not connected to ICT investments. One interpretation of this finding is that in terms of both reliability and validity, firm-level surveys with vaguely defined variables that represent multi-dimensional organisational changes are inferior to occupation-based measures of organisational change, which are computed by means of register-based information from linked employer-employee data. This observation is particularly important because the earlier literature has almost exclusively used various firm-level surveys to account for organisational change.

To evaluate further the sensitivity of these baseline results, we have also estimated separate specifications for the manufacturing sector only and for the set of small firms that have fewer than 250 employees. We briefly discuss these results, which are reported in Appendix (Table A1). The main difference in the results that are estimated separately for the manufacturing sector is that ICT investments also decrease job creation at the level of occupations within firms. Otherwise, the results are very similar. Even the quantitative magnitude of the estimates is almost identical to the results that were obtained for the entire private sector.

These additional results also reveal that the relationships between ICT investments and occupational restructuring are generally much stronger in large firms. This pattern prevails both in the entire private sector and in the manufacturing sector. One potential explanation for this phenomenon is that job flows are measured with better precision for large firms, and therefore there is a better noise-to-signal ratio for these firms. However, it is interesting that in the results that are estimated exclusively for the small firms in the entire private sector, there is evidence that ICT investments have increased net employment because they have increased the rate of job creation without having any significant negative effects on job destruction (i.e., job creation minus job destruction is positive). Therefore, we obtain some evidence that the 'creative' side of the process prevails among small businesses.

4.2. ICT and firm productivity

Next, to shed light on the effects of ICT investments on firms, we estimate a set of production-function specifications in which the dependent variable is the logarithm of the firm's value-added (Y). The right-hand side variables include the capital stock (K), which is measured by the book value of the tangible capital, and labour input (*L*), which is measured by the number of employed persons in full-time equivalent units.

These firm-level OLS regressions take the following form:

$$LogY_j = \delta \ln\left(K_j\right) + \eta \ln\left(L_j\right) + \beta \boldsymbol{X}_j + \lambda ICT_j + \gamma OC_j + \kappa ICT_j \times OC_j + \varepsilon_j \quad (2)$$

Using FLEED, we control for the vector of the average employee's characteristics (***X***) at the firm level (i.e., the average age and the average years of education of employees), following, e.g., Ilmakunnas et al. (2004). The main explanatory variable of interest is the one that captures the ICT investments that were made over the period 2001-2004. Furthermore, we are particularly interested in exploring the interaction effects between ICT investments and the actual content of occupations (*OC*) because these effects should be related to a firm's performance, as explained earlier in our conceptual framework. All specifications are estimated both with and without a full set of industry effects. As expected, controlling for heterogeneity among industries is important for the estimation results. We estimate these models for both the level of value added in 2005 and the change in value added over the period 2000-2005. By their construction, the latter models account for the firm-specific effects, as well. Again, the baseline estimations are performed with employment-weighted regressions.

We find that in the specifications that use cross-sectional variation to explain the level of value added in 2005, the estimate for the labour input ranges from 0.877 to 1.007, and the estimate for the capital stock varies from 0.074 to 0.121, depending on the exact specification of the model (Table 2). Both of these effects are statistically significant in different model specifications. The estimate for the ICT investments varies from -0.108 to 0.134.[9] Furthermore, the interaction term between non-routine work and ICT investments has a statistically significant positive effect on the value added in 2005 in the manufacturing sector (Columns 4-6 of Table 2). This effect is much smaller and statistically insignificant in the entire private sector.

Table 2 here

As expected, all effects are generally much weaker as we explain the changes in added value over the period 2000-2005 (Table 3). Evidently, time-invariant, firm-specific effects are important determinants of a firm's performance. However, it is worth noting that we still obtain clear evidence that the interaction term between non-routine work and ICT investments has a significant positive effect on the changes in value added. This time the effect can be found not only in the manufacturing sector (Columns 4-6 of Table 3) but also in the entire business sector (Columns 1-3 of Table 3). On the other hand, the interaction term between interactive work and ICT investments shows negative effects in many cases.

Table 3 here

4.3. ICT and employee mobility

To complete the analysis, we explore the effects of ICT investments over the period 2001-2004 on the changes in the subsequent labour market outcomes (i.e., the unemployment and wages) of the

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[9] The coefficients on labour, capital and ICT are larger when the fixed industry effects are not included in the models. These results are available upon request.

employees. This approach allows us to evaluate the effects of ICT on employees' mobility and incomes and, eventually, their well-being. To accomplish this goal, we use the Employment Statistics maintained by Statistics Finland, which recorded each employee's labour market status during the last week of 2005. Because we use comprehensive register data, we are able to measure the exact labour market status of each employee with a minimal amount of measurement error. With this data, we can systematically map all of the relevant labour market outcomes, as opposed to a few specific statuses.

These individual-level regressions take the following form:

$$Outcome_{ij} = \beta \boldsymbol{X}_{ij} + \delta ICT_j + \varepsilon_{ij}\,, \qquad (3)$$

where *Outcome* represents the measure of labour market status in 2005 for employee *i* who was employed in firm *j* in 2000. $\boldsymbol{X}_j$ represents the vector of individual-level control variables. These factors include the 'usual suspects', such as education and occupational groups, that are important determinants of the changes in labour market outcomes, according to previous studies. Because these models are estimated at the individual level and cover all of the employees that worked in firm *j* in 2000, the sample size that is used in the estimations is much larger than in the earlier specifications. The increased sample sizes give us substantial statistical power. The standard errors for the estimates take clustering at the firm level into account.

Table 4 documents the estimates, and the dependent variable is whether a person was unemployed in the last week of 2005. As expected, separation, and especially external worker separation, has a positive impact on the unemployment probability of an employee. Furthermore, we find that job creation in the firm decreases the probability of unemployment. However, ICT does not seem to play any independent role here. Both the main effect of ICT and its interaction effects are statistically insignificant and economically small.

Table 4 here

To close the discussion of the effects of ICT on subsequent employee outcomes, we examine the effects of ICT investments on the growth of logarithm of monthly wages. Table 5 shows that job destruction and worker separation negatively affect the wage growth of stayers (people who stay in the same occupation and at the same firm), which can be interpreted as evidence regarding the wage flexibility within firms. Similarly, with respect to job creation, we find a positive effect. Interestingly, the interaction between job destruction and worker separation with ICT is positive, which implies that ICT investments mitigate the negative wage effects of job destruction and worker separation. However, when the effect of job destruction is controlled for, ICT does not show an independent effect on wage growth (Columns 9 of Table 5). Thus, there is a clear asymmetry between the roles of job destruction and creation.

Table 5 here

The last important finding from Table 5 is that when the firm simultaneously invests in ICT, increases in interactive and non-routine tasks in the firm increase the wage growth of stayers. Generally, other measures of occupational restructuring are not related to wage growth. The results for job switchers (those who have changed their occupations but who stayed in the same firm) in Table 6 are similar, but the organisational restructuring has a somewhat larger effect on the wage growth of the occupation switchers. All in all, our results show that ICT and associated organisational restructuring affects mainly those employees who stay with the same employer. Furthermore, the effects primarily take place through job destruction and worker separation at the level of occupations within firms.

Table 6 here

5. Conclusions

This paper explores the effects of ICT on multiple firm and employee outcomes. We contribute to the existing knowledge with a set of occupation-based indicators of job and worker flows that capture the relevant aspects of organisational changes in firms; these indicators include both the intensity (or depth) of these changes and the actual job content (i.e., the shares of interactive and routine occupations) in a firm. These measures are obtained using comprehensive, linked employer-employee data. By applying these measures in the analysis, we can build a bridge between two important but distinct strands of the existing literature that have examined the productivity, employment and wage effects of ICT on a firm's employees.

Surprisingly, the existing literature has rarely linked the task-related flow measures to ICT investments, even though a close connection between ICT and the changes in the task composition of firms has received thorough consideration in the labour market literature since the seminal work by Autor et al. (2003). Furthermore, occupational restructuring (an important reflection of the changes in task composition) is clearly the crux of the organisational change that has been argued to play a decisive complementary role in the positive productivity effects of ICT at least since the work by Brynjolfsson and Hitt (2000). Furthermore, we address the largely neglected point of view of employees in our empirical analysis, which is necessary for assessing whether ICT investments and complementary organisational changes make business performance and the quality of work life coincide.

The occupation-based job and worker flow measures that we apply in the study of the effects of ICT are firm-level counterparts to the standard industry-level indicators of job and worker flows, but in this paper, a job is defined based on the occupation within each firm. These measures turn out to be exceptionally revealing because they are capable of capturing both the intensity and the task content of the ICT-induced organisational changes. Most of the earlier studies on this topic have used survey information that contains considerable measurement error in contrast to the comprehensive, register-based measures of occupational restructuring that we apply in this paper for the first time to account for the productivity, employment and wage effects of ICT.

With these novel measures, and using linked employer-employee data, we document that ICT investments significantly increase both job destruction and worker separation. Importantly, our empirical evidence reveals that ICT investments especially increase external worker separation. Additionally, we find evidence that organisational change complements ICT investments in a productivity-enhancing manner. These ICT-driven productivity gains are associated with the destruction of routine and non-interactive tasks in the organisation. Furthermore, we examine the effects of ICT on multiple employee outcomes. Although job destruction and creation affect the probability of becoming unemployed, ICT does not play a role here. Concerning wage growth, we find that ICT and associated organisational restructuring affects the wage growth of employees who stay at the same firm. Wages are principally affected by job destruction, but ICT moderates this effect.

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Table 1
ICT and occupation-based organisational change.

	Job destruction	Separation	External job separation	Internal job separation	Excess job reallocation	Worker churning	The change in the share of interactive jobs	The change in the share of non-routine jobs	Job creation	Hiring	The change in the share of knowledge workers	The relative change in the share of knowledge workers	Organizational changes
ICT investments	0.034***	0.027***	0.031***	-0.005***	-0.004***	-0.014***	0.001***	0.004***	-0.003	-0.010***	0.010***	0.025***	0.104
	[0.003]	[0.002]	[0.002]	[0.000]	[0.001]	[0.002]	[0.000]	[0.000]	[0.003]	[0.003]	[0.001]	[0.002]	[0.088]
Observations	2928	2928	2928	2928	2928	2928	2589	2589	2928	2928	2591	2585	1029
R-squared	0.17	0.152	0.165	0.215	0.185	0.157	0.129	0.115	0.203	0.216	0.119	0.127	0.365

Notes: the measures of task-based organizational change are for 2000-2005 and ICT investments are measured as averages over 2001-2004 (in thousands). The additional variables in the regressions are 55 industry dummies. In the last column, organizational changes are measured using information from the Community Innovation Survey. The variable is the first principal component score, and the variables used in the analysis are 1) changes in strategy, 2) changes in management policies, 3) changes in organization, 4) changes in external relations, 5) changes in marketing, 6) aestethic changes in products or services. The robust standard errors are in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table 2
ICT, occupation-based organisational structure and productivity, OLS 2005.

	All			Manufacturing			<250 employees			Manufacturing <250 employees		
Log employment	0.939***	0.934***	0.877***	1.007***	1.007***	1.007***	0.918***	0.922***	0.895***	0.910***	0.918***	0.909***
	[0.033]	[0.033]	[0.024]	[0.048]	[0.048]	[0.038]	[0.039]	[0.039]	[0.027]	[0.055]	[0.054]	[0.040]
Log capital	0.093***	0.095***	0.121***	0.081**	0.081**	0.074***	0.107***	0.109***	0.120***	0.110***	0.110***	0.101***
	[0.022]	[0.022]	[0.015]	[0.033]	[0.033]	[0.025]	[0.022]	[0.023]	[0.019]	[0.034]	[0.035]	[0.025]
Average age	0.001	-0.002	-0.005	-0.004	-0.004	-0.007	0.002	-0.001	0.007	-0.002	-0.004	-0.004
	[0.007]	[0.007]	[0.006]	[0.010]	[0.010]	[0.007]	[0.007]	[0.007]	[0.005]	[0.010]	[0.010]	[0.006]
Average years of education	0.120***			0.011			0.082**			0.085		
	[0.042]			[0.063]			[0.041]			[0.063]		
Log ICT investments	-0.087*	-0.108**	-0.054	-0.03	-0.03	-0.066	0.023	0.021	0.032	0.134**	0.11	0.110**
	[0.051]	[0.051]	[0.038]	[0.056]	[0.056]	[0.054]	[0.037]	[0.038]	[0.049]	[0.064]	[0.068]	[0.043]
Non-routine	-0.018	-0.006	0.004	-0.055*	-0.055*	-0.029	-0.002	0.006	0.005	0.043	0.046	0.050***
	[0.022]	[0.021]	[0.013]	[0.029]	[0.029]	[0.025]	[0.025]	[0.025]	[0.012]	[0.031]	[0.033]	[0.019]
Interactive	-0.003	-0.019	-0.009	0.056	0.055	0.032	-0.001	-0.007	0.008	-0.022	-0.028	-0.033*
	[0.032]	[0.031]	[0.021]	[0.039]	[0.039]	[0.034]	[0.031]	[0.031]	[0.023]	[0.028]	[0.029]	[0.018]
Change in strategy (2002-2004)	0.337	0.287		0.342	0.344		0.697*	0.718*		0.315	0.341	
	[0.394]	[0.404]		[0.351]	[0.351]		[0.401]	[0.400]		[0.335]	[0.346]	
Change in management policies (2002-2004)	-0.35	-0.269		-0.386	-0.381		-0.606	-0.567		-0.104	-0.103	
	[0.461]	[0.467]		[0.384]	[0.381]		[0.447]	[0.449]		[0.355]	[0.363]	
Change in organization (2002-2004)	0.539	0.545		0.829**	0.830**		0.389	0.33		-0.136	-0.12	
	[0.349]	[0.353]		[0.357]	[0.357]		[0.430]	[0.431]		[0.314]	[0.323]	
ICT*Non-routine	0.002	0.002	0.001	0.006**	0.006**	0.004*	0	0	0	-0.004	-0.004	-0.005**
	[0.002]	[0.002]	[0.001]	[0.003]	[0.003]	[0.002]	[0.003]	[0.003]	[0.001]	[0.003]	[0.003]	[0.002]
ICT*Interactive	0.001	0.002	0.001	-0.006	-0.006	-0.004	0	0	-0.001	0.002	0.003	0.003*
	[0.003]	[0.003]	[0.002]	[0.004]	[0.004]	[0.003]	[0.003]	[0.003]	[0.002]	[0.003]	[0.003]	[0.002]
ICT*Change in strategy	-0.031	-0.027		-0.035	-0.035		-0.074*	-0.077*		-0.037	-0.04	
	[0.036]	[0.037]		[0.032]	[0.032]		[0.040]	[0.039]		[0.034]	[0.035]	
ICT*Change in management policies	0.025	0.018		0.033	0.032		0.054	0.051		-0.002	-0.002	
	[0.041]	[0.042]		[0.033]	[0.033]		[0.044]	[0.044]		[0.036]	[0.037]	
ICT*Change in organization	-0.052	-0.051		-0.080**	-0.080**		-0.035	-0.029		0.02	0.019	
	[0.032]	[0.032]		[0.032]	[0.032]		[0.043]	[0.043]		[0.033]	[0.033]	
Observations	763	763	2060	482	482	923	607	607	1775	377	377	780
R-squared	1	1	1	1	1	1	0.999	0.999	0.999	0.999	0.999	0.999

Notes: Table reports coefficients and standard errors from OLS regressions. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Additional variables are

Table 3
ICT, occupation-based organisational structure and productivity: Difference 2005-2000.

	All			Manufacturing			<250 employees			Manufacturing <250		
Log employment	0.810***	0.811***	0.820***	1.305***	1.352***	1.118***	0.903***	0.819***	0.900***	0.966***	0.921***	0.904***
	[0.134]	[0.137]	[0.114]	[0.182]	[0.206]	[0.186]	[0.099]	[0.099]	[0.108]	[0.094]	[0.091]	[0.079]
Log capital	0.021	0.02	0.089*	-0.164	-0.181	-0.035	0.087**	0.099**	0.091**	0.144***	0.162***	0.086**
	[0.097]	[0.098]	[0.048]	[0.143]	[0.150]	[0.109]	[0.043]	[0.047]	[0.041]	[0.045]	[0.046]	[0.041]
Average age	0.014	0.014	0.024	0.008	0.003	0.043	0.007	0.017	0.024***	0.019	0.028*	0.022***
	[0.045]	[0.043]	[0.026]	[0.042]	[0.040]	[0.040]	[0.012]	[0.012]	[0.007]	[0.016]	[0.014]	[0.008]
Average years of education	-0.003			-0.188			0.237***			0.174*		
	[0.173]			[0.224]			[0.075]			[0.091]		
Log ICT investments	-0.011	-0.011	-0.047*	0.004	0.008	-0.043	0.004	0.001	-0.022	0.024	0.022	0.007
	[0.024]	[0.024]	[0.025]	[0.030]	[0.033]	[0.045]	[0.024]	[0.027]	[0.017]	[0.034]	[0.036]	[0.023]
Non-routine	1.03	1.025	0.705	7.213***	6.691***	3.141*	-0.906	-0.327	-0.349	-0.271	0.317	0.458
	[1.581]	[1.429]	[0.770]	[2.703]	[2.246]	[1.901]	[0.865]	[0.909]	[0.807]	[0.875]	[0.919]	[0.816]
Interactive	-3.421*	-3.419*	-2.683***	-8.794***	-8.695***	-5.633***	-0.441	-1.036	0.35	-0.254	-0.525	-1.065
	[1.797]	[1.750]	[0.971]	[2.592]	[2.532]	[1.995]	[1.217]	[1.283]	[1.075]	[1.190]	[1.270]	[0.979]
Change in strategy	-0.068	-0.068		-0.177*	-0.188*		0.1	0.1		0.167**	0.153*	
	[0.087]	[0.087]		[0.101]	[0.104]		[0.076]	[0.078]		[0.082]	[0.084]	
Change in management policies	0.025	0.025		0.111	0.133		0.065	0.095		0.041	0.054	
	[0.119]	[0.122]		[0.135]	[0.148]		[0.074]	[0.077]		[0.087]	[0.090]	
Change in organization	0.12	0.119		0.269***	0.218**		-0.043	0.021		-0.114**	-0.077	
	[0.075]	[0.078]		[0.095]	[0.086]		[0.055]	[0.057]		[0.052]	[0.051]	
ICT*Non-routine	1.326*	1.329*	1.227*	1.670*	1.744*	1.660*	0.349	0.269	1.245**	0.961	0.965	0.563
	[0.792]	[0.779]	[0.638]	[0.959]	[0.932]	[0.945]	[0.483]	[0.477]	[0.620]	[0.649]	[0.667]	[0.580]
ICT*Interactive	-1.848*	-1.851*	-1.318*	-2.872**	-2.895**	-2.168*	-0.592	-0.463	-1.046	-1.341	-1.334	-0.483
	[0.991]	[0.982]	[0.769]	[1.214]	[1.199]	[1.108]	[0.712]	[0.726]	[0.786]	[0.927]	[0.964]	[0.641]
ICT*Change in strategy	0.082	0.082		-0.03	-0.008		0.048	0.035		0.014	0.003	
	[0.076]	[0.076]		[0.073]	[0.065]		[0.045]	[0.042]		[0.053]	[0.052]	
ICT*Change in management poli	-0.117	-0.117		-0.101	-0.115		0.049	0.065		0.034	0.035	
	[0.078]	[0.077]		[0.079]	[0.079]		[0.045]	[0.043]		[0.053]	[0.053]	
ICT*Change in organization	-0.026	-0.026		0	-0.01		-0.067*	-0.058*		-0.038	-0.025	
	[0.040]	[0.041]		[0.047]	[0.050]		[0.035]	[0.035]		[0.039]	[0.041]	
Observations	241	241	527	159	159	253	172	172	413	113	113	194
R-squared	0.451	0.451	0.408	0.586	0.58	0.477	0.726	0.706	0.549	0.803	0.795	0.676

Notes: Table reports coefficients and standard errors from OLS regressions. Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1. Additional variables are 55 industry dummies.

Table 4
ICT, occupation-based organisational change and unemployment.

	Job destruction	Separation	External job separation	Internal job separation	Excess job reallocation	Worker churning	The change in the share of interactive jobs	The change in the share of non-routine jobs	Job creation	Hiring	The change in the share of knowledge workers	The relative change in the share of knowledge workers
Main effect	0.01	0.012*	0.011*	-0.027	-0.01	0.01	0.023	2.10E-02	-0.014**	-0.01	0.02	0.01
	[0.005]	[0.007]	[0.006]	[0.017]	[0.008]	[0.007]	[0.039]	[0.028]	[0.007]	[0.007]	[0.019]	[0.009]
Interaction with ICT	-0.008	-0.011	-0.011	0.019	0.018	0.001	-0.044	-0.022	0.002	0.001	-0.025	-0.015
	[0.007]	[0.008]	[0.008]	[0.021]	[0.022]	[0.006]	[0.035]	[0.021]	[0.006]	[0.005]	[0.028]	[0.018]
ICT	0.000	0.005	0.003	-0.004	-0.004	-0.002	0.000	0.000	-0.002	-0.002	-0.001	-0.002
	[0.002]	[0.005]	[0.003]	[0.003]	[0.004]	[0.006]	[0.001]	[0.002]	[0.003]	[0.005]	[0.001]	[0.001]
Observations	81882	81882	81882	81882	81882	81882	80375	80375	81882	81882	80375	80375
R-squared	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022	0.022

Table 5
ICT, occupation-based organisational change and wage growth: Stayers.

	Job destruction	Separation	External job separation	Internal job separation	Excess job reallocation	Worker churning	The change in the share of interactive jobs	The change in the share of non-routine jobs	Job creation	Hiring	The change in the share of knowledge workers	The relative change in the share of knowledge workers
Main effect	-0.068***	-0.058**	-0.082***	0.042	0.011	0.024	-0.047	-0.05	0.043**	0.048**	-0.111**	-0.024
	[0.026]	[0.029]	[0.030]	[0.047]	[0.021]	[0.021]	[0.086]	[0.069]	[0.020]	[0.019]	[0.045]	[0.017]
Interaction with ICT	0.245***	0.201***	0.281***	-0.032	0.049	0.006	0.459*	0.326*	0.04	0.043	-1.257**	0.304***
	[0.047]	[0.056]	[0.051]	[0.167]	[0.102]	[0.061]	[0.242]	[0.194]	[0.029]	[0.033]	[0.596]	[0.110]
ICT	-0.015	-0.080***	-0.068***	0.014	0.001	0.003	0.017*	0.014	-0.006	-0.023	0.052***	0.040***
	[0.013]	[0.028]	[0.018]	[0.035]	[0.021]	[0.046]	[0.010]	[0.010]	[0.016]	[0.026]	[0.015]	[0.014]
Observations	30839	30839	30839	30839	30839	30839	30838	30838	30839	30839	30838	30838
R-squared	0.057	0.057	0.057	0.056	0.056	0.056	0.056	0.056	0.057	0.057	0.057	0.057

The table reports coefficients and standard errors from the individual-level OLS regressions. The table considers individuals who are employed in the years 2000 and 2005 and have stayed in the same task and firm. The dependent variable the is log of the monthly wage. The measures of task-based organizational change are for 2000-2005. The ICT and organizational change variables are for the firm where the person was employed in 2000. Standard errors account for clustering at the firm level. *** p<0.01, ** p<0.05, * p<0.1. The additional variables are education dummies (9 classes), occupational dummies (8 classes), age, firm size and industry dummies (52 classes).

Table 6
ICT, occupation-based organisational change and wage growth: Occupation switchers.

	Job destruction	Separation	External job separation	Internal job separation	Excess job reallocation	Worker churning	The change in the share of interactive jobs	The change in the share of non-routine jobs	Job creation	Hiring	The change in the share of knowledge workers	The relative change in the share of knowledge workers
Main effect	-0.125***	-0.103***	-0.080***	-0.104**	-0.059***	0.066**	0.243**	0.072	0.035	0.062***	-0.022	0.001
	[0.022]	[0.024]	[0.023]	[0.048]	[0.021]	[0.026]	[0.104]	[0.081]	[0.022]	[0.022]	[0.042]	[0.020]
Interaction with ICT	0.247***	0.057	0.031	0.043	0.144**	-0.071	-0.192	-0.122	0.025	0.004	-1.102**	0.059
	[0.057]	[0.049]	[0.056]	[0.089]	[0.065]	[0.048]	[0.190]	[0.109]	[0.028]	[0.019]	[0.491]	[0.087]
ICT	-0.018**	-0.026	-0.006	-0.001	-0.020	0.072	0.012	0.014	-0.009	-0.001	0.011	0.008
	[0.007]	[0.029]	[0.023]	[0.014]	[0.013]	[0.050]	[0.010]	[0.012]	[0.015]	[0.019]	[0.009]	[0.007]
Observations	15116	15116	15116	15116	15116	15116	15115	15115	15116	15116	15115	15115
R-squared	0.061	0.059	0.059	0.058	0.059	0.058	0.058	0.058	0.058	0.059	0.058	0.058

The table reports coefficients and standard errors from individual level OLS regressions. The table considers individuals who are employed in the years 2000 and 2005, but have changed tasks during the period. The dependent variable is the log of the monthly wage. The measures of task-based organizational change are for 2000-2005. The ICT and organizational change variables are for the firm where the person was employed in 2000. Standard errors account for clustering at the firm level. *** p<0.01, ** p<0.05, * p<0.1. The additional variables are education dummies (9 classes), occupational dummies (8 classes), age, firm size and industry dummies (52 classes).

Appendix

Table A1: ICT and occupation-based organizational change

	Job destruction	Separation	External job separation	Internal job separation	Excess job reallocation	Worker churning	The change in the share of interactive jobs	The change in the share of non-routine jobs	job creation	Hiring	The change in the share of knowledge workers	The relative change in the share of knowledge workers	Organizational changes
Manufacturing													
ICT investments	0.034***	0.027***	0.032***	-0.005***	-0.005***	-0.014***	0.001***	0.004***	-0.005*	-0.012***	0.010***	0.026***	0.152
	[0.002]	[0.002]	[0.002]	[0.000]	[0.001]	[0.002]	[0.000]	[0.000]	[0.003]	[0.002]	[0.001]	[0.002]	[0.136]
Observations	1323	1323	1323	1323	1323	1323	1193	1193	1323	1323	1193	1193	679
R-squared	0.212	0.196	0.205	0.182	0.207	0.151	0.102	0.104	0.242	0.249	0.135	0.134	0.27
Small firms (<250)													
	Job destruction	Separation	External job separation	Internal job separation	Excess job reallocation	Worker churning	The change in the share of interactive jobs	The change in the share of non-routine jobs	job creation	Hiring	The change in the share of knowledge workers	The relative change in the share of knowledge workers	Organizational changes
ICT investments	-0.005	-0.002	0	-0.002	0.001	0.006	0.003***	0.005***	0.033*	0.036**	0	-0.003	0.035**
	[0.005]	[0.006]	[0.006]	[0.002]	[0.005]	[0.008]	[0.001]	[0.002]	[0.019]	[0.017]	[0.002]	[0.003]	[0.016]
Observations	2613	2613	2613	2613	2613	2613	2300	2300	2613	2613	2302	2296	854
R-squared	0.083	0.069	0.091	0.073	0.051	0.083	0.082	0.071	0.059	0.078	0.054	0.053	0.11
Small Manufacturing													
	Job destruction	Separation	External job separation	Internal job separation	Excess job reallocation	Worker churning	The change in the share of interactive jobs	The change in the share of non-routine jobs	job creation	Hiring	The change in the share of knowledge workers	The relative change in the share of knowledge workers	Organizational changes
ICT investments	-0.009	0.018	0.018	0	-0.023	0.055	0.012*	0.016	0.158**	0.186***	0.008	0.001	0.057
	[0.029]	[0.046]	[0.034]	[0.018]	[0.019]	[0.062]	[0.007]	[0.011]	[0.080]	[0.054]	[0.012]	[0.021]	[0.076]
Observations	1160	1160	1160	1160	1160	1160	1040	1040	1160	1160	1040	1040	558
R-squared	0.051	0.042	0.044	0.056	0.059	0.029	0.062	0.035	0.037	0.048	0.029	0.022	0.112

Notes: the measures of task-based organizational change are for 2000-2005 and ICT investments are measured as average over 2001-2004 (in thousands). Additional variables in the regressions are 55 industry dummies. In the last column organizational changes are measured using information from the Community Innovation Survey. The variable is the first principal component score and the variables used in the analysis are 1) changes in strategy, 2) changes in management policies, 3) changes in organization, 4) changes in external relations, 5) changes