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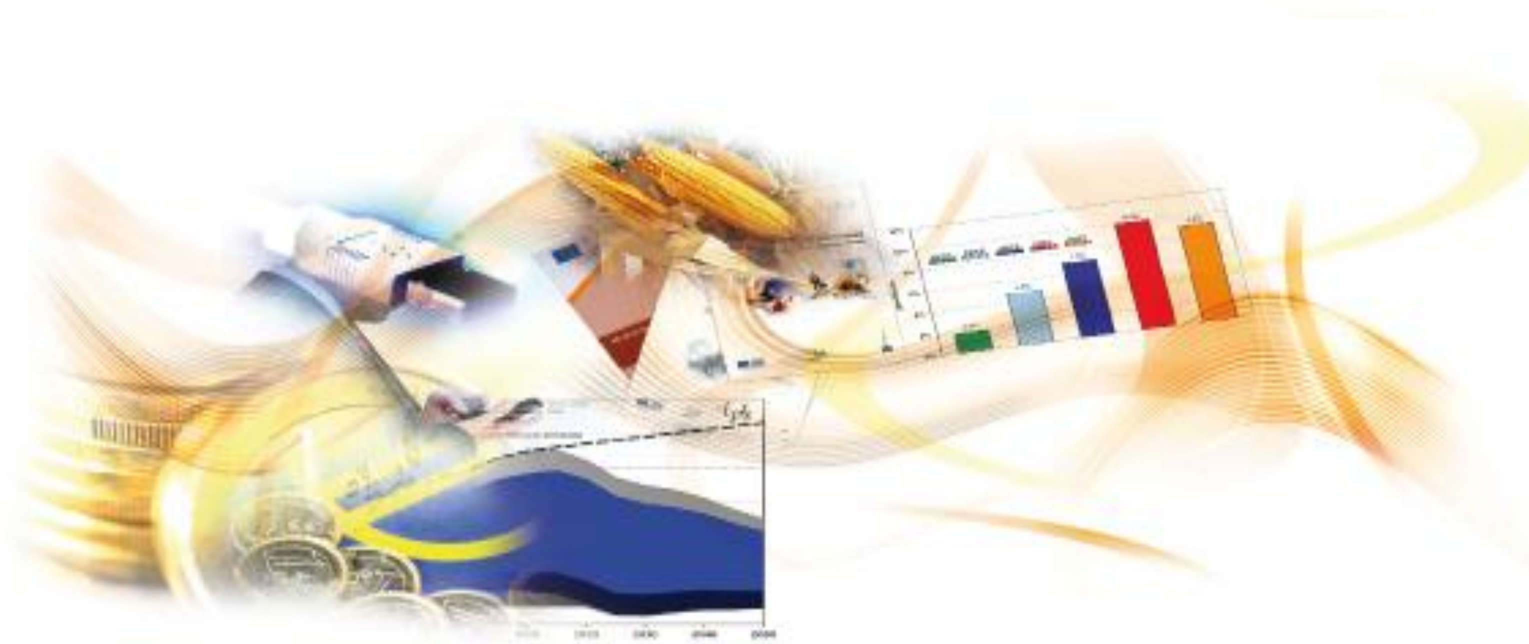

Digital Economy Working Paper 2014/07

Are ICT Displacing Workers? Evidence from Seven European Countries

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2014

Joint Research Centre

European Commission
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This publication is a Working Paper by the Joint Research Centre of the European Commission. It results from the Digital Economy Research Programme at the JRC Institute for Prospective Technological Studies, which carries out economic research on information society and EU Digital Agenda policy issues, with a focus on growth, jobs and innovation in the Single Market. The Digital Economy Research Programme is co-financed by the Directorate General Communications Networks, Content and Technology.

JRC91122

ISSN 1831-9408 (online)

Spain: European Commission, Joint Research Centre, 2014

Abstract
This paper examines whether ICT substitute labour and reduce the demand for labour. We used firm-level comparable data separately for firms in manufacturing, services and ICT-producing sectors from seven European countries. We adopted a common methodology and applied it to a unique dataset provided by the ESSLait Project on Linking Microdata. We controlled for unobservable time-invariant firm-specific effects and we found no evidence of a negative relationship between intensity of ICT use and employment growth. We read this as an indication that ICT use is not reducing employment among ICT using firms.

Abstract:

This paper examines whether ICT substitute labour and reduce the demand for labour. We used firm-level comparable data separately for firms in manufacturing, services and ICT-producing sectors from seven European countries. We adopted a common methodology and applied it to a unique dataset provided by the ESSLait Project on Linking Microdata. We controlled for unobservable time-invariant firm-specific effects and we found no evidence of a negative relationship between intensity of ICT use and employment growth. We read this as an indication that ICT use is not reducing employment among ICT using firms.

JEL codes: J23, J24, O33, L86

Keywords: Labour Demand, Technology Change, ICT.

Non-Technical Summary

The impact of Information and Communication Technologies (ICT) on employment is an intensely controversial subject. On the one hand, ICT adoption and diffusion, across all sectors of society, can create employment opportunities, directly for individuals endowed with skills that complement ICT and indirectly in those sectors and firms that, because of ICT use, are more innovative and/or more productive. On the other hand, the adoption and diffusion of ICT can increase the automation of many tasks and result in the substitution of workers involved in those tasks. This has negative consequences on employment, especially for individuals with low and medium-level skills (Brynjolfsson and McAfee, 2011 and 2014). These negative "substitution" effects of ICT –and more generally of technological progress- on employment have been the focus of recent academic and policy debates, and are summarized and discussed in Sabadash (2013). She concludes that the evidence on the relationship between employment and ICT-driven innovation is mixed. This result, which reflects the ambiguous predictions of theory, is due partly to the different methodological approaches (including different specifications) followed by the empirical literature and partly to the variety of indicators used to measure ICT (some of which are, in fact, general measures of technology or innovation). In fact, there are only a very few studies which analyse the relationship between ICT utilization and employment using direct and precise measures of ICT.[1]

The purpose of this paper is to improve upon the existing literature and identify and estimate the "substitution" effect of ICT utilization on employment growth among ICT-using firms. For this we use firm-level data, separately for manufacturing, and services, from seven European countries during a recent period (2007-2010). Our data come from a unique dataset of harmonised and linked micro data compiled by National Statistical Offices, containing data comparable across countries based on the production statistics linked with the ICT /e-commerce survey. To the best of our knowledge, this is one of the very few studies that examine the relationship between the intensity of ICT use and employment using specific ICT measures, and it is the first one that uses a longitudinal dataset containing comprehensive and representative data from a large number of EU countries.

Holding firm output and capital constant and controlling for time-invariant unobservable firm characteristics, we find a non-significant relationship between employment growth and ICT intensive use across firms. Our estimates mainly capture the "substitution" effects of ICT on employment (i.e. those due to ICT substituting for some types of labour and to ICT increasing

[1] The lack of studies using direct measures of ICT use is due to the fact that only recently have these measures become available, in such a way that they can be linked to firms' performance.

productivity and hence reducing demand for inputs, for constant values of output), and our results indicate that these effects are statistically insignificant.

This finding should not be interpreted as evidence to support the hypothesis that ICT are irrelevant for employment. In fact, we expect that the insignificant constant-output employment effect of ICT intensity coexists with the positive effect of increased firm competitiveness due to improved productivity or output quality. This, however, is not the focus of this paper. In summary, we read our results as an indication that, on average, increased intensity of ICT use has at least a non-negative effect on employment growth at firm level.

At the same time, we are conscious that our average firm-level estimates do not take into consideration the effects due to firms exiting and entering the market or business-stealing effects. Nor do we examine whether intensive ICT use has different effects on different skills groups. We intend to address these issues in further research, by using specifications that allow us to capture separately these different effects of ICT on employment. We will also consider higher levels of aggregation (i.e. with meso and macro level data).

1. Introduction

The impact of Information and Communication Technologies (ICT) on employment is an intensely controversial subject. On the one hand, ICT adoption and diffusion, across all sectors of society, can create employment opportunities directly for individuals endowed with skills that complement ICT and indirectly in those sectors and firms that, because of ICT use, are more innovative and/or more productive and hence more likely to increase employment. On the other hand, the adoption and diffusion of ICT can increase the automation of many tasks and hence induce machine-labour substitution, with negative consequences for employment, especially for individuals with low and medium-level skills (Brynjolfsson and McAfee, 2011 and 2014).

While there are many assessments of the effect of ICT on the composition of employment by skill/education in the literature (among others see Michaels et al., 2014; Firpo et al., 2011), there are only a few studies that examine the relationship between ICT and employment using precise ICT indicators (see Falk, 2001; Bloom et al., 2011). However, there is a large body of literature on the effects of technological and organizational innovations on total employment, which, perhaps not surprisingly, is characterized by mixed and contradictory results. This can be explained partly by the ambiguous predictions of theory and partly by the different methodological approaches followed in the empirical analyses (see Vivarelli 2012, 2007). Moreover, while some studies are based on aggregate country-level data, others use sector-level data (some of them only on manufacturing) and others focus on firm-level data. These studies use different measures of technology (the most frequently used being R&D intensity, product and process innovation and patents), and differ in terms of econometric techniques.[2] Only a few studies use internationally comparable firm-level data (see Evangelista and Vezzani 2011, and Dachs and Peters 2014 for exceptions).

This paper examines the effect on employment of intensive ICT use separately for firms in manufacturing, services, and ICT producing sectors in seven European countries (Finland, France, the Netherlands, Norway, Sweden, Poland, and the United Kingdom) from 2007 to 2010. We estimate the relationship between firms' labour demand and the intensity of their ICT use, conditional on their output and other determinants of labour demand. The data used in this study come from a unique set of harmonised and linked micro data compiled by National Statistical Offices in three consecutive projects on linking micro data on ICT usage. This dataset contains data on firms' ICT usage and on a range of other firms' characteristics comparable across countries,

[2] Including how they account for the possible heterogeneous effects of ICT in different institutional and technological settings and how they control for other factors that might affect labour demand while being correlated with a firm's technology.

based on the production statistics linked with the ICT /e-commerce survey for each country and sector.

To the best of our knowledge, our paper is the first to explicitly estimate the substitution effect of ICT on employment, using longitudinal and firm-level data comparable across countries from official sources that provide detailed and high-quality information on the actual use of ICT within the firm. In addition, it covers a very recent period, which includes the economic crisis.

The paper is organized as follows. Section 2 reviews the related literature. Section 3 describes the empirical specification, while Section 4 describes the data used in our paper. Section 5 discusses the results of the estimation. Section 6 offers conclusions.

2. Related Literature

ICT diffusion is one of the most important technology-related characteristics of the recent experience of developed (and developing) countries. Digitalization is a widespread phenomenon affecting almost every sector and profession: from e-Government to the media, the automotive and the health industries, to name just a few.

A number of authors have stressed the negative impact of ICT on employment (often referred to as 'end-of-work' literature, see Rifkin,1995, and, more recently, Brynjolfsson and McAfee, 2011 and 2014) based on the hypothesis that ICT substitute human activities that are no longer needed.[3] Others, however, have argued that ICT, in light of their positive effects on productivity and innovativeness, can be an important source of job creation. They can increase employment not only in firms/sectors that directly benefit from the productivity increase and from innovation,[4] but also across the whole economy, through the general equilibrium effects of increased consumption and investment.

Given the relevance of the issue and the conflicting perspectives, it is not surprising that the consequences of the ICT revolution for employment are attracting growing attention from policymakers and others. In this paper, we look at this relationship with firm-level data.

At the firm level, increased use of ICT may affect total employment in several ways.[5] First, as tasks are automated, ICT may directly substitute workers assigned to those tasks. Second, by increasing

[3] Due, for instance, to the widespread diffusion of computers, numerically-controlled machines, computerized inventory control, voice recognition and online commerce. On the ability of machines to substitute humans, see also Levy and Murnane (1995).

[4] ICT-driven productivity increases become manifest first in the ICT producing sector and then trickle down to all the sectors that use ICT. As for ICT-driven innovation, its effects are by no means limited to the ICT producing sector.

[5] For a detailed review discussion on the relationship between innovation and employment, see Vivarelli and Pianta (2000).

firm productivity (as documented by a large body of literature, recently reviewed by Van Reenen *et al*., 2010, and Biagi, 2013), ICT enable firms to produce the same level of output with fewer inputs, including less labour. *For a given level of output*, such an increase in firm productivity implies that the (conditional) demand for labour falls. These two possible effects are often referred to in the literature as "substitution" effects. Third, if ICT use increases a firm's productivity, it also leads to a decrease in prices and an increase in demand for the firm's products, which, under certain circumstances,[6] would induce an outward shift of the (unconditional) labour demand. This effect is often referred to in the literature as the "compensation effect". The combined result of the substitution and compensation effects is unclear and needs to be examined empirically.

In addition to these direct effects, ICT diffusion may generate indirect employment effects in firms other than those using ICT, such as their competitors (probably a negative effect due to business stealing) and suppliers (probably a positive effect, due to increased demand), with potential additional general equilibrium macroeconomic effects due to increased consumption and investment.[7]

In this paper, which we regard as a first step in the context of a broader research project on the labour market impacts of ICT, we examine the effect of ICT use on firm-level employment, and this is reflected in our literature review.

To the best of our knowledge, ours is one of the very few studies that examine the effect of ICT on firm employment using specific indicators of ICT use. Falk (2001) looks at the employment effects of ICT and organizational change using data from the 1995 and 1997 waves of the Mannheim Service Innovation (MIP) panel and finds that ICT have a positive indirect effect on employment growth, through organizational change. However, once the latter has been controlled for, the direct effects of ICT tend to be not significant.

In a different context,[8] Bloom *et al.* (2011) estimate a conditional labour demand function where employment growth is regressed, among other variables, on measures of 5 year lagged ICT intensity.[9] Their results indicate that ICT intensity has a positive long-term overall effect on employment growth.

Our paper is closely related to the empirical literature on the effect of technology and innovation - especially process innovation- on total employment. This literature, recently reviewed by Vivarelli

6 See Vivarelli and Pianta (2000) for discussions on the factors that may affect this effect.

7 These would be generated by ICT-induced increases in productivity that raise incentives to invest in human capital and investment.

8 They explore the impact of imports from China on innovation, IT and productivity among 12 European countries.

9 Alternative measures used are the number of personal computers, the use of Enterprise Resource Planning, Databases and Software.

(2012, 2007), is very heterogeneous in terms of measurement of technology and innovation, methodological approaches, country and sector coverage. This, together with the ambiguous predictions of economic theory, is reflected in its mixed findings. However, some regularities emerge, and results tend to differ systematically with the measure of innovation/technology used: product innovation tends to be robustly and positively related to employment and employment growth, whereas for process innovation, the relationship is not robust. For instance, when looking at process innovation and employment or employment growth, some authors[10] find small or insignificant effects, some[11] find positive effects, and some[12] document a negative relationship.

It should also be noted that most of the existing firm-level studies only cover the manufacturing sector. The few studies that also cover the service sector typically do not allow for cross-sector differences in the effects of innovation variables. Important exceptions are Harrison *et al*. (2008), Evangelista and Vezzani (2011), and Dachs and Peters (2014), who estimate different effects for services and manufacturing.

In conclusion, in spite of the tremendous relevance of the questions on the table, we have to conclude that –so far- the literature has not provided a fully satisfying set of answers. More specifically, there is a lack of firm-level empirical evidence on the effect of ICT use on firm employment and the existing empirical evidence on ICT-related innovation/technology measures is mixed.

3. Empirical specification

To estimate the effect of the intensity of ICT use on employment, we adopt a standard log-linear conditional labour demand framework, commonly used in the empirical literature on the determinants of labour demand (Hammermesh, 1993; Van Reenen, 1997; Amiti and Wei, 2006; Hijzen and Swaim, 2007; Falk and Wolfmayr, 2008). We assume that a profit maximizing firm chooses its inputs in order to minimize the production costs, conditional on a given level of output. The production costs are a function of factor prices, output and demand shifters, which include intensity of ICT use in the firm. We consider labour as homogenous[13] and we follow Berman *et al*. (1994) in treating capital as a quasi-fixed input, which is a reasonable assumption in the short-term and avoids possible problems in measuring the user cost of capital.

[10] See Van Reenen (1997), Peters (2004), Hall *et al*. (2008), Harrison *et al*. (2008) for manufacturing firms in Spain; Evangelista and Vezzani (2011), Giuliodori and Stucchi (2012), Dachs and Peters (2014), for service firms.

[11] Blanchflower and Burgess (1998), Smolny (1998), Greenan and Guellec (2000), Lachenmaier and Rottmann (2011).

[12] Dachs and Peters (2014), for manufacturing firms; Harrison *et al*. (2008) for manufacturing firms in Germany.

[13] We do not consider the compositional effects of ICT use.

The relationship between ICT use and employment cannot be identified from the variation in intensity of ICT use and employment across firms since both variables could be correlated with unobserved firm characteristics, such as offshoring/outsourcing (which is greatly facilitated by ICT), the technology used in the firm, and its management and organization characteristics. To avoid an omitted-variable bias we eliminate time-invariant firm-specific characteristics, and we estimate a conditional labour demand in first differences, which takes the following form:

$$\Delta lnE_{ijt} = \delta_w \Delta lnW_{ijt} + \delta_k \Delta lnK_{ijt} + \delta_y \Delta lnY_{ijt} + \delta_{ict} \Delta ICT_{ijt} + \delta_x \Delta X_{ijt} + \alpha_t + \alpha_j + \upsilon_{ijt} \qquad (1)$$

where Δ denotes the difference between year t and year $t-1$.

The indicators for the intensity of ICT use (ICT_{ijt}) are: *i*) the share of broadband internet-enabled workers; *ii*) the share of mobile internet-enabled workers; *iii*) the share of sales due to e-commerce activities[14] in total sales.

Firm-level *employment* (E_{ijt}) is measured by full-time equivalents (FTE) in Finland, Poland and Sweden, while it is measured using head-counts [15] in France, Netherlands, Norway and the United Kingdom, where data on FTE are not available.[16]

Real average wage (W_{ijt}) in firm i in industry j at time t is measured as the real total wage[17] bill in national currency per unit of employment in the firm.

K_{ijt} represents the *real capital stock* (K_{ijt}) and it is included (instead of the cost of capital) because we assume that capital is a quasi-fixed input.[18]

Real output (Y_{ijt}), or turnover, represents firms' sales from all products, goods, materials and services, including price subsidies, consumption tax and excise duties (excluding value added taxes), deflated by industry price indexes. It also includes the purchase value of goods resold, as well as indirect services.

Equation (1) includes controls for several other firm-specific characteristics (X_{ijt}) that may influence its employment dynamics, such as the firm's age and size, whether it is a multinational and its

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[14] Two types of e-commerce are considered: sales through the firm's web-site and through Electronic Data Interchange (EDI).
[15] For a discussion see Airaksinen *et al*. (2013).
[16] Across-country variation in the measurement of employment is likely not to be a major problem here, since each country is analysed separately and –for each country- our measure is consistent through time.
[17] Real wages are equal to nominal wages deflated by the output price index.
[18] Data on the real capital stock are typically not directly available from the Structural Business Statistics and the ESSlait project solution was to estimate them using book value or replacement value of assets or depreciation in monetary terms (see Airaksinen *et al.*, 2013). As a result, real capital is computed differently across countries. However, this is not likely to distort significantly our estimates as long as, for each country, the same method is used consistently across-time. The use of a logarithmic form is also likely to reduce measurement errors. For a discussion see Hagsten and Sabadash (2014).

export status. In fact, a large body of literature on firm employment growth discusses the different growth patterns of small vs. large and young vs. old firms. Similarly, multinationals and exporting firms are more likely to be subject to competitive forces and are therefore more likely to experience higher productivity and, possibly, higher employment.

To capture *firm's age* we use five categories: less than 3 years old, between 3 and 6 years old, between 6 and 9 years old, between 9 and 12 years old, between 12 and 15 years old and older than 15 years. As for *firm's size*, we generate the following classes: less than 10 employees, from 10 to 19 employees, from 20 to 49 employees, from 50 to 199 employees, from 100 to 249 employees, from 250 to 499 employees, and above 500 employees. A firm is considered multinational if it has a foreign subsidiary and/or is part of group with headquarters abroad and is considered *domestic* otherwise. A firm is considered to be an exporter if exports any goods and/or services and a *non-exporter* otherwise.[19]

Additionally, we include sector (a_j) and year (a_t) fixed effects. These are meant to control for unobservable factors that can influence firms' employment, including the prices of intermediate goods or energy. Sector dummies are based on two-digit NACE rev.1.1 classification. In some cases, some two-digit sectors are combined. The reference industry for manufacturing regressions is the combination of sectors 36 and 37 (manufacturing n.e.c. and recycling), while it is sector 73 (research and development) for the service regressions.

We would expect that, other things being equal, a rise in the average wage would increase labour costs and reduce labour demand. We would also expect that, ceteris paribus, K_{ijt} and Y_{ijt} would increase the quantity of labour demanded. As for our main variable (ICT_{ijt}), since we control for firm output and capital,[20] we would expect it to enter with a non-positive coefficient,[21] which would be negative if the job substitution hypothesis put forward by Brynjolfsson and McAfee (2011, 2014) is correct. Moreover, given our specification, we reckon that our estimates of the coefficient on ICT_{ijt} should be considered as lower-bound values for the effect of ICT use on the conditional labour demand.

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[19] Primary data sources for this indicator vary across countries and include Structural Business Statistics, Foreign Trade Statistics and the Statistics on International Trade in Services.

[20] Intensive ICT use might have positive effects on sales and capital and, indirectly, on labour demand. In our specification, these effects will be captured by the coefficients on output and capital.

[21] The coefficient would capture the pure substitution effects of ICT.

4 Data and summary statistics

The unique data used in this paper come from the national and cross-country datasets constructed in three projects funded by Eurostat:[22] *Eurostat ICT Impacts,* ESSnet on Linking of Microdata on ICT Usage (*ESSLimit*) and ESSNet on Linking of Microdata to analyse ICT Impact (*ESSLait*).[23] These projects have developed a research infrastructure and a data repository that enables (restricted) access to the harmonised firm level data from European countries.

Data used in this paper come from two sources: the Production Survey (PS), and the ICT Usage Survey (or E-commerce Survey[24], EC). The Production Survey contains a number of firm-level economic variables. Some of them are collected via the Structural Business Statistics, others come from different sources including the Business Register and Trade Survey. The PS is used as a main data-source for employment (E_{ijt}), real wages (W_{ijt}), real capital (K_{ijt}) and real output (Y_{ijt}), firm's age and size, export intensity, and whether a company is a multinational entity (X_{ijt}). The EC survey is used as a source for the information on ICT usage (ICT_{ijt}).

After linking the PS and EC data for a selection of variables used in our regressions, we obtain linked datasets for seven European countries[25] (Finland, France, the Netherlands, Norway, Sweden, Poland, and the United Kingdom) for the period 2007-2010, covering the manufacturing and service sectors.[26] The matched datasets are unbalanced, due to the considerable numbers of firms that enter and exit the market over time.

All estimations were implemented using the *Distributed Microdata Approach (DMD*) in the Esslait project. This method consists of executing the same estimations from a centrally-managed platform on different harmonised, national firm-level datasets kept at data repositories in different countries.[27] This approach has several advantages. It allows efficient access to data available only locally in different countries. The use of the same code and the harmonisation of the national level datasets ensure that the results are comparable across countries. However, it also has a few limitations. First, as data is kept at National Statistics Offices, data cannot be pooled across countries. Second, executing the estimations from a centrally-managed platform and the requirement to comply with the timeline of the Esslait project imposed certain restrictions on the

22 Eurostat Grant agreements 49102.2005.017-2006.128, 50701.2010.001-2010.578 and 50721.2013.001-2013.082. See also Awano (2012).

23 Eurostat (2008, 2012 and 2013).

24 The EC surveys records information for firms that have 10 employees or more.

25 Which become five when we analyze the effect of broadband intensity due to data limitations.

26 Excluded sectors are: agriculture, fishing, mining and quarrying, electricity, gas and water supply, public administration and defence, compulsory social security, education, health and social work and other community, social and personal service activities.

27 See Bartelsman and Barnes (2001), Bartelsman (2004), and Bartelsman *et al* (2013).

number of specifications and type of empirical methods that could be executed. In the case of this study, these restrictions limited the econometric specifications and the robustness checks.

Employment (joint) coverage in the Business Register, the Production Survey and the E-commerce Survey in 2010 is reported in Table , while firm coverage is described in Table 2. Both firm and employment coverage varies considerably by country, however, employment coverage is higher than firm coverage. When focusing on employment (see Table 1), coverage of the joint Business Register-Production Survey sample is about 50% in the Netherlands and in the UK, while it is close to 100% in the other five countries studied (Finland, France, Poland, Norway and Sweden). Linking the Business Register, the Production Survey and the E-commerce Survey reduces considerably employment coverage. The resulting samples represent between 19.5% and 78% of the total employment captured by the Business Register. Firm coverage by the joint Business Register, Production Survey and E-commerce Survey, is generally much smaller, ranging from 0.3% in France to 18% in Poland (see Table 2). The sample used in the empirical analysis is further reduced by eliminating the firms that did not provide information on all variables of interest.

Table 3 reports descriptive statistics on the main variables of interest: intensity of ICT use (ICT_{ijt}) and firm employment (E_{ijt}). For each indicator, the table reports the country-sector specific means, both at the beginning and at the end of the period studied (2007-2010), including their changes. Between 2007 and 2010, the average intensity of ICT use by firms increased in all countries, in both manufacturing and service (with the exception of France). On average, the largest increases took place in the share of employees using mobile internet, followed by the share of employees with access to broadband (the lowest took place in e-sales). The evolution of the e-sales indicator suggests large differences across countries and sectors: while the share of e-sales in total sales increased significantly in the Netherlands and the UK, this share was small or even negative in other countries. During the same period, average employment by firms decreased in most countries and sectors (however, employment increased considerably in the UK across all service sectors, as it also did in France and Norway).

To explore further the relationship between ICT intensity and employment, we ran exploratory OLS regressions of basic firm conditional labour demand augmented with ICT demand shifters. The results for each measure of ICT use, country and sector are reported in Table 4 and Table 6. For most country and sector combinations, the results show that, keeping output and capital constant, firms that use ICT more intensively tend to have lower employment levels. This suggests that more ICT-intensive firms have higher labour productivity, as they are able to produce the same level of output with fewer employees.

To summarize, there is some descriptive evidence suggesting a negative association between firm employment and ICT use. However, basic OLS regressions like those presented in Table 4 to Table 6 do not control for other relevant firm-specific characteristics, which may lead to spurious correlations, due to omitted variable bias. The econometric analysis in the following section will isolate the effect of ICT on firm employment by including additional controls and eliminating time-invariant firm-specific characteristics.

5. Estimation results

Eq (1) is estimated using OLS[28] separately for manufacturing and services[29] in each country. This allows the parameters of the labour demand equation and the effects of the main variables of interest to differ by country and by macro-sector.

Tables 7 to 9 show the results of the estimation of (1). Results are reported separately for each measure of intensity of ICT use, sector and country. Specifically, Table 7 shows results for the share of employees with access to broadband, Table 8 the share of employees with access to mobile internet, and Table 9 the share of e-sales in total sales. Each table contains two panels. The upper-panel reports the results for firms in the manufacturing sector, while the lower-panel reports the results for firms in the service sector. Each column reports the results for a different country. The number of countries differs across measures of ICT use intensity, as some measures are not available for all countries. The coefficients can be interpreted as short-term elasticities.

The coefficients of the classical determinants of the labour demand (output, capital and wages) are statistically significant and have the expected signs and plausible magnitudes in almost all estimations. The wage coefficient is negative and statistically significant in all countries and sectors. The coefficients on sales and capital are positive and statistically significant in almost all estimations, with the exception of Finland in the case of capital. Overall, the variation in the explanatory variables included explains a large part of the variation of firm employment growth (around 80% in many countries and sectors). The high R squared value indicates that the model has a good fit overall. This is remarkable given that the variables are measured in first differences. The coefficients on the variables capturing multinational and exporting status, age and size categories, and on the sector dummies are mostly insignificant and where they are significant, they do not suggest any clear pattern.

[28] We also estimated a specification which includes ICT lags to allow for delays in adjustment of employment in response to changes in the intensity of ICT use. The results for the lagged intensity of ICT use were very similar to our baseline results.

[29] We also estimated the equation (1) separately for ICT producing sector ELECOM (Electrical machinery and Post and Telecommunications). The results were very similar to the results for the manufacturing and services.

The coefficients on the ICT measures are statistically insignificant in thirty-four out of thirty eight country-sector combinations. In particular, when ICT use is measured as the share of employees with access to broadband, the effect of ICT is always insignificant, though when it is measured as the share of employees with mobile internet access, the coefficient is insignificant for eleven country-sector combinations out of fourteen.[30] Finally, when ICT is measured as the share of e-sales in total sales, the effect of ICT is insignificant in all but one country-sector (service sector in Finland). The consistency of our results across countries and sectors is quite remarkable, given that several variables, including employment, were defined differently in different countries.[31]

Taken these results together suggests the following relationship between ICT and employment at firm level: firms that use ICT more intensively tend to have higher labour productivity and therefore, *ceteribus paribus*, lower employment levels. However, an increase in the intensity of ICT use is not significantly associated to within-firm reductions in employment[32] (i.e. there is no evidence that firms that increase their use of ICT are also experiencing a drop in employment).

In interpreting these results, it is important to consider that the coefficients represent partial effects, as we control for all other variables in the model. Specifically, some of the effects of ICT on employment are captured by the coefficients on sales and capital, which are almost always positive and statistically significant. This leads us to conclude that the insignificant substitution effect of ICT may coexist with a positive effect of ICT on employment that works through improved firm competitiveness and increased sales.

How do these results compare with previous results on this topic? Falk (2001) estimated a system of two equations in which the conditional labour demand included both a measure of ICT intensity and organizational change, where the latter was estimated with ICT use among the regressors. His results show that, once organisational change had been controlled for, ICT had no additional effect on employment growth. However, since ICT use positively affected organizational change, which had a positive and significant effect on employment growth, the implication is that ICT did have a positive effect on the employment growth of German firms in the period 1995-1997. Since Germany is not among the countries for which ESSlait data are available, it has not been possible to test our specification with German data and directly compare our results to those of Falk (the time interval covered is also different). As for Bloom et al. (2011), who found that five-year lagged ICT use had some positive effects on employment growth, it must be said that their study differs

[30] In the remaining cases, the coefficient of ICT use is negative and statistically significant in two country-sectors (manufacturing in Poland and services in UK) and positive and marginally statistically significant in one (manufacturing in Sweden).

[31] Firm-level employment is measured in FTE in Finland, Poland and Sweden and in head-counts in France, Netherlands, Norway and the United Kingdom.

[32] Methodologically, these results highlight the importance of taking into consideration firm unobserved firms' characteristics, which may be correlated with ICT use and with labour demand.

from ours in two important ways. First, while we focus on the substitution effect, they examine the total effect of ICT on employment, which is the sum of the substitution and the compensation effects. Second, while we focus on the short-term,[33] they examine the long-term effect of ICT intensity on employment. It is possible that the insignificant short-term substitution effect of ICT found in this study coexist with the long-term overall positive effects ICT have as a result of improved firm competitiveness.

It must also be noted that our findings are broadly in line with those of several other firm-level studies on the direct (substitution) effects of process innovation on employment. In particular, Evangelista and Vezzani (2011), who distinguish between the direct effect of process innovation on employment and its effect through increased sales, found that the substitution effect of process innovation on employment is statistically insignificant in six European countries (Czech Republic, Spain, France, Italy, Portugal and Slovenia). Several other studies (Van Reenen; 1997, Hall *et al.*, 2008; Giuliodori and Stucchi, 2012) also found that process innovation has insignificant or very small job displacement effects at firm level.

6. Conclusions

In this study, we analyse the relationship between ICT use and employment growth among ICT-using firms. We use firm-level data separately for manufacturing and services from seven European countries during a recent period (2007-2010). Our data come from a unique dataset of harmonised and linked micro data compiled by National Statistical Offices. This contains data comparable across countries based on production statistics linked with the ICT /e-commerce survey on firms' ICT usage for each country and sector and on a range of other firm characteristics. To the best of our knowledge, this is one of the very few studies that examine the relationship between the intensity of ICT use and employment using specific ICT measures, and it is the first one that uses a longitudinal dataset containing comprehensive and representative data from a large number of EU countries.

Holding firm output and capital constant and controlling for time-invariant unobservable firm characteristics, we find a non-significant relationship between employment growth and ICT intensity among ICT-using firms. Since our estimates mainly capture the "substitution" effects of ICT on employment (i.e. those due to ICT substituting for some type of labour and to ICT increasing productivity and hence reducing demand for inputs, for constant values of output), our results indicate that these effects are statistically insignificant.

[33] They study the effect firm initial ICT intensity on employment growth during the following 5 years, while we study the effect of yearly changes in ICT intensity on yearly changes in employment.

This result should not be interpreted as evidence for the hypothesis that ICT are irrelevant for employment. In fact, we expect that the insignificant constant-output employment effect of ICT intensity coexists with the positive effect of increased firm competitiveness -due to improved productivity or output quality- which, however, is not the focus of this paper. In summary, we read our results as an indication that, on average, increased intensity of ICT use has at least a non-negative effect on employment at firm level.

We are conscious that our average firm-level estimates do not take into consideration the effects due to firms exiting or entering the market or business-stealing effects. Nor do we examine whether intensive ICT use has different effects on different skill-groups. We intend to address these issues in further research, by using specifications that allow us to capture separately these different ICT effects on employment, while also considering higher levels of aggregation (i.e. with meso and macro level data).

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Annexes

Tables

Table 1: Coverage through the merging procedure: share of employment captured in the linked dataset

Country	Business Register (BR) (Employment)	BR-PS (% of BR)	BR-PS-EC (% of BR)
Finland	1 113 088	95.6	43.3
France	4 373 323	100.0	78.1
The Netherlands	4 548 025	50.9	19.5
Norway	1 218 653	95.4	41.8
Poland	4 108 381	100.0	55.8
Sweden	1 886 255	100.0	34.1
The United Kingdom	15 422 078	52.0	27.8

Source: adopted from Iancu *et al.* (2013), p.8.

Table 2: Coverage through the merging procedure: share of firms captured in the linked dataset

Country	Business Register (BR) (No. of firms)	BR-PS (% of BR)	BR-PS-EC (% of BR)
Finland	182 009	54.1	1.4
France	23 253	0.8	0.3
The Netherlands	937 362	5.0	0.5
Norway	398 577	44.5	0.8
Poland	56 958	100.0	18.0
Sweden	569 478	100.0	0.5
The United Kingdom	1 366 044	2.6	0.2

Source: adopted from Iancu *et al.* (2013), p.7.

Table 3: Descriptive Statistics

Country	FI			FR			NL			NO			PL			SE			UK		
Year	2007	2010	Δ(%)	2007	2010	Δ(%)	2007	2010	Δ(%)	2007	2010	Δ(%)	2007	2010	Δ(%)	2007	2010	Δ(%)	2007	2010	Δ(%)
<u>Manufacturing</u>																					
Broadpct (%)	46.7	52.5	5.9	44.7	38.8	-5.9	41.1	45.4	4.3	47.2	53.7	6.4	16.4	25.6	9.1	47.0	66.4	19.4	39.9	50.1	10.2
Mobpct (%)	34.6	48.0	13.4	24.3	37.3	13.0	16.4	29.8	13.4	22.6	44.5	21.9	9.6	16.6	7.0	31.1	60.4	29.2	30.1	45.4	15.3
E-sales (%)	9.2	10.8	1.7	15.4	11.5	-3.8	5.8	12.2	6.4	31.7	34.4	2.7	5.2	7.4	2.1	34.9	35.1	0.3	9.3	23.6	14.3
Employment	64.7	62.2	-3.8	160.5	149.2	-7.0	109.0	99.3	-8.8	50.8	47.8	-5.9	93.5	86.8	-7.1	67.2	60.7	-9.8	192.4	259.9	35.1
<u>Services</u>																					
Broadpct (%)	70.0	76.4	6.4	57.3	48.1	-9.2	65.3	66.0	0.6	63.8	70.2	6.4	38.1	47.3	9.2	65.5	65.3	-0.3	50.5	60.3	9.8
Mobpct (%)	48.5	69.3	20.9	27.3	42.4	15.1	32.3	45.7	13.4	29.9	56.2	26.3	22.9	30.9	7.9	44.8	56.5	11.7	42.3	56.4	14.1
E-sales (%)	6.1	7.7	1.6	7.9	6.0	-1.9	6.7	14.0	7.3	28.0	29.0	1.0	3.4	4.8	1.4	25.5	27.6	2.1	7.0	11.4	4.4
Employment	43.9	44.1	0.4	189.1	240.7	27.3	77.4	77.7	0.4	31.6	34.3	8.7	70.6	67.1	-4.8	36.9	36.9	-0.1	404.1	545.7	35.0

Notes: Own calculations based on Esslait (PSSTAT and ECSTAT). Broadpct represents the share of employees with access to broadband in total employees. Mobpct represents the share of employees with access to mobile internet in total employees. E-sales represent the share of sales via computer networks in total sales. For Sweden, the change in E-sales is calculated for 2007-2009. Employment represents average firm employment in a given sector and country. The statistics are based on the PSEC (Production Survey and E-commerce Survey) sample.

Table 4: Effect of ICT use (measured as share of employees with access to broadband) on employment level

Country	FI		FR		NO		SE		UK	
Manufacturing										
lnWage	1.28	***	0.65	***	0.55	*	-0.84	***	0.70	***
	[0.17]		[0.09]		[0.27]		[0.28]		[0.12]	
lnCapital	-1.03	***	-0.83	***	-0.75	***	-0.68	***	-0.75	***
	[0.04]		[0.02]		[0.05]		[0.05]		[0.03]	
lnSales	0.05	***	0.15	***	0.05	***	0.07	***	0.16	***
	[0.01]		[0.01]		[0.01]		[0.01]		[0.01]	
Broadpct	-0.17	***	-0.10	***	-0.26	***	-0.13	***	-0.14	***
	[0.03]		[0.02]		[0.04]		[0.03]		[0.04]	
Obs.	2239		5791		1962		2152		2140	
R-squared	0.84		0.85		0.84		0.90		0.79	
Services										
lnWage	-1.09	***	-0.88	***	-0.96	***	-0.94	***	-0.77	***
	[0.03]		[0.02]		[0.02]		[0.03]		[0.02]	
lnCapital	-0.01	***	0.00		-0.01		0.01		0.03	***
	[0.00]		[0.00]		[0.00]		[0.01]		[0.01]	
lnSales	0.84	***	0.79	***	0.86	***	0.87	***	0.73	***
	[0.01]		[0.01]		[0.01]		[0.01]		[0.01]	
Broadpct	-0.34	***	-0.10	***	-0.37	***	-0.36	***	-0.52	***
	[0.03]		[0.02]		[0.03]		[0.03]		[0.03]	
Obs.	3175		7128		5069		3255		3577	
R-squared	0.87		0.83		0.88		0.90		0.83	

Notes: Pooled OLS estimations. Dependent variable is ln(Employment). All equations include controls for export and multinational status, age categories, sector and year fixed effects. Standard errors are reported in the brackets. *, ** and *** indicate significance at 10%, 5% and 1%, respectively.

Table 5: Effect of ICT (measured as share of employees with mobile internet access) on employment level

Country	FI		FR		NL		NO		PL		SE		UK	
<u>**Manufacturing**</u>														
lnWage	-1.08	***	-0.85	***	-0.95	***	-0.84	***	-0.86	***	-0.72	***	-0.77	***
	[0.04]		[0.02]		[0.03]		[0.05]		[0.04]		[0.05]		[0.03]	
lnCapital	0.05	***	0.15	***	0.13	***	0.05	***	0.08	***	0.07	***	0.16	***
	[0.01]		[0.01]		[0.01]		[0.01]		[0.01]		[0.01]		[0.01]	
lnSales	0.72	***	0.65	***	0.59	***	0.71	***	0.59	***	0.76	***	0.58	***
	[0.01]		[0.01]		[0.01]		[0.01]		[0.02]		[0.01]		[0.01]	
Mobpct	-0.06	*	-0.05	*	-0.04	*	-0.01		-0.13	**	-0.04		-0.06	*
	[0.03]		[0.02]		[0.02]		[0.03]		[0.05]		[0.03]		[0.03]	
Obs.	2239		5791		2919		1962		1340		2150		2140	
R-squared	0.84		0.85		0.77		0.84		0.78		0.90		0.79	
<u>**Services**</u>														
lnWage	-1.15	***	-0.90	***	-0.80	***	-1.01	***	-0.95	***	-0.99	***	-0.81	***
	[0.03]		[0.02]		[0.02]		[0.02]		[0.03]		[0.03]		[0.02]	
lnCapital	-0.01	***	0.00		0.07	***	0.00		0.04	***	0.01		0.04	***
	[0.00]		[0.00]		[0.01]		[0.00]		[0.01]		[0.01]		[0.01]	
lnSales	0.86	***	0.80	***	0.67	***	0.87	***	0.76	***	0.89	***	0.74	***
	[0.01]		[0.01]		[0.01]		[0.01]		[0.02]		[0.01]		[0.01]	
Mobpct	-0.09	***	0.00		0.00		-0.02		-0.20	***	-0.10	***	-0.37	***
	[0.02]		[0.02]		[0.02]		[0.02]		[0.04]		[0.02]		[0.03]	
Obs.	3175		7128		3671		5069		1463		3255		3577	
R-squared	0.86		0.83		0.77		0.87		0.87		0.89		0.83	

Notes: Pooled OLS estimates. Dependent variable is ln(Employment). All equations include controls for export and multinational status, age categories, sector and year fixed effects. Standard errors are reported in the brackets.
*, ** and *** indicate significance at 10%, 5% and 1%, respectively.

Table 6: Effect of ICT use (measured as share of e-sales in total sales) on employment level

Country	FI		FR		NL		NO		PL		SE		UK	
<u>**Manufacturing**</u>														
lnWage	-1.06	***	-0.86	***	-0.96	***	-0.86	***	-0.91	***	-1.00	***	-0.78	***
	[0.04]		[0.02]		[0.03]		[0.07]		[0.04]		[0.08]		[0.03]	
lnCapital	0.05	***	0.15	***	0.13	***	0.06	***	0.08	***	0.06	***	0.16	***
	[0.01]		[0.01]		[0.01]		[0.01]		[0.01]		[0.02]		[0.01]	
lnSales	0.71	***	0.65	***	0.59	***	0.74	***	0.59	***	0.79	***	0.58	***
	[0.01]		[0.01]		[0.01]		[0.02]		[0.02]		[0.02]		[0.01]	
E-sales	0.25	***	0.02		-0.03		-0.04		-0.04		0.00		0.02	
	[0.04]		[0.02]		[0.04]		[0.04]		[0.04]		[0.05]		[0.03]	
Obs.	2220		5791		2919		891		1340		700		2140	
R-squared	0.84		0.85		0.77		0.87		0.78		0.91		0.79	
<u>**Services**</u>														
lnWage	-1.18	***	-0.90	***	-1.00	***	-0.81	***	-1.00	***	-1.12	***	-0.88	***
	[0.03]		[0.02]		[0.03]		[0.02]		[0.03]		[0.05]		[0.02]	
lnCapital	-0.01	***	0.00		0.04	***	0.07	***	0.04	***	0.00		0.04	***
	[0.00]		[0.00]		[0.01]		[0.01]		[0.01]		[0.01]		[0.01]	
lnSales	0.86	***	0.81	***	0.77	***	0.67	***	0.77	***	0.90	***	0.74	***
	[0.01]		[0.01]		[0.02]		[0.01]		[0.02]		[0.02]		[0.01]	
E-sales	-0.14	***	-0.29	***	-0.21	***	-0.16	***	-0.21	***	0.02		-0.23	***
	[0.04]		[0.03]		[0.06]		[0.04]		[0.06]		[0.06]		[0.04]	
Obs.	3150		7128		3670		2464		1468		963		3582	
R-squared	0.86		0.83		0.77		0.87		0.87		0.89		0.82	

Notes: Pooled OLS estimates. Dependent variable is ln(Employment). All equations include controls for export and multinational status, age categories, sector and year fixed effects. Standard errors are reported in the brackets.
*, ** and *** indicate significance at 10%, 5% and 1%, respectively.

Table 7: Effect of changes in ICT use (measured as share of employees with access to broadband) on changes in employment

Country	FI		FR		NO		SE		UK	
Manufacturing										
ΔlnWage	-0.87	***	-0.77	***	-0.44	***	-0.69	***	-0.41	***
	[0.05]		[0.01]		[0.03]		[0.02]		[0.02]	
ΔlnCapital	-0.03	*	0.17	***	0.07	***	0.11	***	0.23	***
	[0.02]		[0.01]		[0.01]		[0.01]		[0.05]	
ΔlnSales	0.83	***	0.32	***	0.35	***	0.43	***	0.37	***
	[0.01]		[0.01]		[0.01]		[0.01]		[0.02]	
ΔBroadpct	0.01		0.00		0.00		0.01		0.04	
	[0.03]		[0.01]		[0.02]		[0.01]		[0.04]	
Obs.	1647		3654		1304		1367		837	
R-squared	0.86		0.61		0.52		0.63		0.44	
Services										
ΔlnWage	-0.84	***	-0.96	***	-0.29	***	-0.76	***	-0.62	***
	[0.04]		[0.01]		[0.01]		[0.02]		[0.01]	
ΔlnCapital	0.01		0.04	***	0.04	***	0.05	***	0.09	***
	[0.01]		[0.01]		[0.00]		[0.01]		[0.02]	
ΔlnSales	0.90	***	0.59	***	0.43	***	0.54	***	0.39	***
	[0.01]		[0.01]		[0.01]		[0.01]		[0.01]	
ΔBroadpct	-0.04		0.00		0.01		0.01		-0.01	
	[0.03]		[0.01]		[0.01]		[0.02]		[0.02]	
Obs.	1786		3900		2809		1773		1810	
R-squared	0.81		0.84		0.43		0.62		0.57	

Notes: OLS in first differences estimates. Dependent variable is Δln(Employment). All equations include controls for export and multinational status, age and size categories, sector and year fixed effects. Standard errors are reported in the brackets. *, ** and *** indicate significance at 10%, 5% and 1%, respectively.

Table 8: Effect of changes in ICT use (measured as share of employees with mobile internet access) on changes in employment

Country	FI		FR		NL		NO		PL		SE		UK	
<u>Manufacturing</u>														
ΔlnWage	-0.87	***	-0.77	***	-0.67	***	-0.44	***	-0.34	***	-0.69	***	-0.41	***
	[0.05]		[0.01]		[0.01]		[0.03]		[0.04]		[0.02]		[0.02]	
ΔlnCapital	-0.03	*	0.17	***	0.05	***	0.07	***	0.01	***	0.11	***	0.23	***
	[0.02]		[0.01]		[0.01]		[0.01]		[0.00]		[0.01]		[0.05]	
ΔlnSales	0.83	***	0.32	***	0.27	***	0.35	***	0.24	***	0.43	***	0.37	***
	[0.01]		[0.01]		[0.01]		[0.01]		[0.01]		[0.01]		[0.02]	
ΔMobpct	0.00		0.01		0.01		0.01		-0.07	***	0.02	*	-0.01	
	[0.02]		[0.01]		[0.01]		[0.01]		[0.03]		[0.01]		[0.03]	
Obs.	1647		3654		1349		1304		1184		1367		837	
R-squared	0.86		0.61		0.70		0.52		0.34		0.63		0.44	
<u>Services</u>														
ΔlnWage	-0.85	***	-0.96	***	-0.84	***	-0.29	***	-0.26	***	-0.76	***	-0.62	***
	[0.04]		[0.01]		[0.01]		[0.01]		[0.04]		[0.02]		[0.01]	
ΔlnCapital	0.01		0.04	***	0.06	***	0.04	***	0.01	*	0.05	***	0.09	***
	[0.01]		[0.01]		[0.01]		[0.00]		[0.00]		[0.01]		[0.02]	
ΔlnSales	0.90	***	0.59	***	0.33	***	0.43	***	0.10	***	0.54	***	0.39	***
	[0.01]		[0.01]		[0.02]		[0.01]		[0.01]		[0.01]		[0.01]	
ΔMobpct	0.01		0.00		0.01		-0.01		0.01		0.01		-0.04	**
	[0.02]		[0.01]		[0.01]		[0.01]		[0.02]		[0.01]		[0.02]	
Obs.	1786		3900		1503		2809		1073		1773		1810	
R-squared	0.81		0.84		0.77		0.43		0.20		0.62		0.57	

Notes: OLS in first differences estimates. Dependent variable is Δln(Employment). All equations contain controls for export and multinational status, age and size categories, sector and year fixed effects. Standard errors are reported in the brackets.
*, ** and *** indicate significance at 10%, 5% and 1%, respectively.

Table 9: Effect of changes in ICT use (measured as share of e-sales in total sales) on changes in employment

Country	FI	FR	NL	NO	PL	SE	UK
Manufacturing							
ΔlnWage	-0.87 ***	-0.77 ***	-0.68 ***	-0.49 ***	-0.34 ***	-0.83 ***	-0.41 ***
	[0.05]	[0.01]	[0.01]	[0.06]	[0.05]	[0.03]	[0.02]
ΔlnCapital	-0.03 *	0.17 ***	0.05 ***	0.06 ***	0.01 ***	0.05 **	0.23 ***
	[0.02]	[0.01]	[0.01]	[0.01]	[0.00]	[0.02]	[0.05]
ΔlnSales	0.84 ***	0.32 ***	0.28 ***	0.60 ***	0.24 ***	0.44 ***	0.37 ***
	[0.01]	[0.01]	[0.01]	[0.02]	[0.01]	[0.03]	[0.02]
ΔE-sales	0.04	0.01	-0.01	0.00	0.00	0.02	-0.02
	[0.04]	[0.01]	[0.01]	[0.02]	[0.02]	[0.04]	[0.03]
Obs.	1570	3655	1724	418	1184	352	837
R-squared	0.86	0.61	0.69	0.76	0.34	0.81	0.44
Services							
ΔlnWage	-0.81 ***	-0.96 ***	-0.83 ***	-0.39 ***	-0.26 ***	-0.54 ***	-0.62 ***
	[0.04]	[0.01]	[0.01]	[0.03]	[0.04]	[0.04]	[0.01]
ΔlnCapital	0.01	0.04 ***	0.05 ***	0.03 ***	0.01 *	0.02	0.09 ***
	[0.01]	[0.01]	[0.01]	[0.01]	[0.00]	[0.02]	[0.02]
ΔlnSales	0.90 ***	0.59 ***	0.37 ***	0.40 ***	0.10 ***	0.36 ***	0.39 ***
	[0.01]	[0.01]	[0.02]	[0.02]	[0.01]	[0.03]	[0.01]
ΔE-sales	0.09 *	0.00	0.01	0.00	0.02	0.04	-0.04
	[0.04]	[0.01]	[0.02]	[0.01]	[0.04]	[0.04]	[0.03]
Obs.	1696	3900	1961	1000	1073	421	1810
R-squared	0.81	0.84	0.74	0.42	0.20	0.49	0.57

Notes: OLS in first differences estimates. Dependent variable is Δln(Employment). All equations contain controls for export and multinational status, age and size categories, sector and year fixed effects. Standard errors are reported in the brackets.
*, ** and *** indicate significance at 10%, 5% and 1%, respectively.

European Commission
Joint Research Centre – Institute for Prospective Technological Studies

Title: Are ICT Displacing Workers? Evidence from Seven European Countries

Authors: Smaranda Pantea, Federico Biagi and Anna Sabadash

Spain: European Commission, Joint Research Centre

2014 – 26 pp. – 21.0 x 29.7 cm

EUR – Scientific and Technical Research series – ISSN 1831-9408 (online)

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