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The Impact of ICT and E-Commerce on Employment in Europe

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Abstract
This study presents new empirical evidence regarding the impact of ICT/e-commerce activities on labour demand. The data is based on new and unique data for 10 European countries for the period 2002-2010. A key feature of the empirical analysis is the use of several types of advanced ICT activities, such as enterprise resource planning (ERP) systems, mobile internet access, and e-commerce practices. The main result of the study is that the increase in ICT/e-commerce activities over time has not led to a decline in jobs. This holds true for both manufacturing and service industries, as well as for SMEs and large firms. For ERP systems and websites, there is some evidence of positive effects. These findings do not support the hypothesis that ICT utilization is leading to labour substitution overall. In fact, ICT activities appear to be rather neutral to employment. The results are robust not only to the model specification, but also the estimation method applied.

Keywords: labour demand, information and communication technologies, e-commerce activities.

JEL, O33, J23.

1. Introduction

While the debate on the employment effects of technological change is almost as old as the study of economics itself, it has taken on an "ICT flavour" in the last 20 years. In particular, economists began in the early 1990s to explore the "skill-biased technological change" hypothesis (see Berman, Bound and Machin, 1998). They then moved on to the "polarizing" effects of ICT, recognizing that the latter influences the demand for labour through its impact on tasks and job composition (see Autor, 2013). More recently, the issue of the impacts of ICT on total employment have become a major source of debate among both academics and policy makers. The study by Frey and Osborne (2013) find that the ICT revolution is putting about 47% of current US jobs at risk due to the ability of machines to substitute humans in routine tasks. Applying Osborne and Frey's methodology to the EU, Bruegel (2014) finds that the share of jobs at risk of substitution is even higher in Europe (Bowles, 2014). On the other hand, Brynjolfsson and McAfee argue forcefully in two recent books (2012, 2014) that the ICT revolution is having profound impacts on the labour market and we (humans) are currently experiencing a race against the (ICT-driven) machine – one we could possibly lose.

Inspired by these recent contributions and the ubiquitous presence of ICT in the workplace, this paper attempts to verify whether there is evidence of firms' (increased) use of ICT applications leading to lower employment. Estimating the impact of ICT on labour demand is not an easy task. While previous studies typically use variables such as ICT capital and ICT investments (which actually capture **ICT infrastructures**), it has become clear in recent years that such variables – though interesting in the context of macro models – can hardly capture the variety and richness of ICT applications that have emerged in the last 10-15 years. Research has hence moved towards studying the impacts of more complex and sophisticated forms of ICT and internet applications, which can be interpreted as measures of **ICT usage**. In particular, the focus has shifted to complex ICT applications (including in e-commerce) that govern relationships with customers, distributors, and more generally, elements within firms' ecosystems (such as ERP systems).

One problem with this line of research is that reliable data on firms' ICT application usage is very difficult to find. In fact, there exist only a scant number of studies that examine the relationship between ICT usage and employment (or employment growth). Based on aggregate data for 27 EU countries, Evangelista, Guerrieri, and Meliciani (2014) find that digitalization is associated with an increase in manufacturing employment, while Koellinger (2008) analyzes data for some 7,000 European firms in determining that the use of e-commerce technologies is associated with a decline in employment. Atasoy, Banker, and Pavlou (2016) study the link between employment and a wide range of ICT applications for Turkey. In distinguishing between firm-wide applications (ERP, etc.) and specific dedicated ICT applications (such as webpages), they find a positive relationship between ICT use and employment, with larger positive impacts for firm-wide ICT applications than for more specific ICT applications.

Other studies investigate the link between employment and broadband access or use based on data at the municipality/county level (Crandall et al., 2007; Kolko, 2012; Atasoy, 2013). Using county-level data for the US for the period 1999-2007, Atasoy (2013) finds that broadband access is significantly and positively associated with an increase in the employment rate (similar results are produced by Kolko, 2012), while Jayakar and Park (2011) conclude that counties with better broadband availability have lower unemployment rates (ceteris paribus). In contrast, De Stefano, Kneller, and Timmis (2014) find that broadband does not affect employment growth using firm-level data for the UK. One drawback of these studies is that broadband access and/or broadband use are measured at the municipality/county/postcode level without distinguishing between households and firms.

This study contributes to the wider research stream by empirically exploring the relationship between different ICT/e-commerce activities and labour demand using representative and internationally comparable data for 10 European countries. Unlike previous studies that mainly rely on cross-sectional methods, this study uses both a specification in first-differences and dynamic panel data methods to investigate the impacts of ICT. In particular, we consider different types of ICT capacities, ranging from websites and broadband internet access to ERP and other complex systems. Special emphasis is placed on the magnitude of the relationships at hand. The data consists of unique panel data for several EU countries (the so-called Micro Moments Database; see Bartelsman, Hagsten, and Polder, 2017). The dimensions emphasized here are industry affiliation (measured as broad industry groups) combined with firm size and the two-digit industry-level data set. Previous studies based on this data set shows that different types of information and communication technologies are positively related to skill intensity (Falk and Biagi, 2016). However, this evidence is based on industry-level data for seven EU countries.

The empirical model is estimated using both robust regression methods based on long differences and dynamic panel data methods while accounting for group effects (by industry-firm size pairs for each country). Estimates are provided for the period before the economic and financial crises started.

The paper is structured as follows: section two presents the theoretical background and empirical model. In section three, we describe the data, while section four contains our main empirical results. Section five provides a discussion of the results and section six concludes.

2. Theoretical background and empirical model

Different measures of ICT usage capture different underlying processes, which can have different impacts on employment. The percentage of workers with access to broadband or a mobile phone, for example, can be interpreted as measures of ICT infrastructures that enable different ICT applications at the firm level. Basu (2016) suggests that the usage of these labor-saving information and communication technologies increased in recent years. Furthermore, ICT usage and digital connectivity in particular make it easier to outsource work to distant places in emerging market economies (Basu, 2016). Thus, digital connectivity can have a direct and indirect negative effect on labour demand through labour saving and the labour shifting technologies.

Others types of ICT capture ERP and customer relationship management (CRM) systems, which are enablers of product,[1] process, and organizational innovations (Koellinger, 2008; Higón, 2012). Such advances reduce transaction costs while improving a firm's information flows both internally and with suppliers/customers, possibly leading to higher labour productivity.[2] For a given level of output, this implies a labour-saving effect, which is likely higher in scale-intensive manufacturing and service industries (Evangelista et al., 2014). The negative effect is likely to be more pronounced in industries where ICT tends to take on routine, labour-intensive tasks, such as in service sectors characterized by a high share of workers that carry out repetitive activities (Evangelista et al., 2014). Overall, the displacement or substitution effect can be found for process innovations in general (see Vivarelli, 2014).

To the extent that ERP and CRM applications make a firm more competitive in its relevant market, however, they can boost its output and employment (this is the compensation effect). This is likely to be the case for CRM, which is meant to support marketing and sales and boost demand.

Other measures of internet applications related to website development or to the relevance of e-sales capture internal and external behavioural and organizational aspects, each of which have both substitution and compensation effects. For example, e-commerce activities may replace traditional distribution channels while potentially creating new sales channels and

[1] Some ERP systems include CRM functions.
[2] These innovations may also directly substitute for labour to the extent that tasks performed by an ERP system were previously handled by workers.

markets. Indicators of activities related to e-sales are well suited to capturing a firm's effort in using ICT to develop and strengthen the market for its products, with positive compensation effects on employment. Finally, e-procurement activities may lead to lower material input costs, thereby increasing productivity and possibly resulting in new jobs.

Overall, different ICT applications can have positive or negative effects on employment, with the possible impacts likely differing considerably by the type of ICT application and the industry at hand (e.g. between ICT using and ICT producing industries). The answer ultimately has to be provided on an empirical basis. The empirical model adopted in this study is derived from a CES cost function with two production factors, namely labour and capital (Hamermesh, 1996). The main assumption is perfect competition in both the goods and factor markets, i.e. labour prices are exogenous. Capital is assumed to be quasi-fixed. The optimal labour demand equation can be derived from the following first order condition:

$$L = v^{a} B^{1-\sigma} Y^{(1-\sigma+\sigma v)} \alpha WP^{-\sigma},$$

where v, σ and α are parameters, *L* denotes employment, *Y* the valued added in constant prices, *WP* the real wage rate, and *B* the level of technology. We assume that the production technology is characterized by neutral technological change at rate λ, where $B = B_o e^{-\lambda t}$. Following Van Reenen (1997), we assume that output can be approximated by the capital stock. Taking logs on both sides of the labour demand equation and adding an error term produces a log-linear static labour demand function in which employment is a function of real wages, capital in constant prices, and technological change:

$$\ln L_{icst} = \beta_{ics} + \beta_1 K_{icst} + \beta_2 \ln WP_{icst} + \beta_3 \lambda + \varepsilon_{icst}, \qquad [1]$$

where *i, c, s,* and *t* denote the industry, country, size class, and year, respectively. *L* denotes employment, *K* real capital stock, *WP* real wages, and λ the rate of technological change. Further, □□□□ is the fixed (group) effect and □ is the error term with mean zero and assumed i.i.d. The rate of technological change cannot be observed directly. In general, technological change is driven by technological innovations and diffusion of new technologies. Different ICT applications represent important components and facilitators of technological innovations. In order to account for these effects, the standard labour demand equation is augmented by a set of ICT indicators. Taking the long difference specification and adding a set of dummy variables leads to the following short-run labour demand function:

$$\Delta \ln L_{icst} = \alpha_0 + \tilde{\beta}_1 \Delta \ln K_{icst} + \tilde{\beta}_2 \ln \Delta WP_{icst} + \Delta ICT_{icst}\theta + \kappa DC + \delta DSEC + \mu DSIZE + \vartheta DYR + u_{icst}, \qquad [2]$$

where $\Delta \ln \square_{\square} = \left(\ln \square_{\square} - \ln \square_{\square,\square-2}\right)$ for *X*=*L*, *WP*, and *K*. Δ refers to the average annual change in the variables within several two-year periods (2002-2004, 2004-2006, and 2006-2008).[3] The new error term is defined as follows: $u_{icst} \equiv \varepsilon_{icst} - \varepsilon_{icst-2}$, with mean zero and constant variance. The variables are defined as follows:

$\Delta \ln \square$ (t): change in log employment

$\Delta \ln \square$ (t): change in log of real capital stock

$\Delta \ln \square\square$ (t): change in log of total wage costs per employee, deflated by an industry-specific value added deflator

ICT: vector of various ICT/e-commerce indicators measured as absolute changes over a two-year period, including:

- Measures of ICT as enabling technology (change in the percentage of firms with broadband internet access, change in the percentage of firms with mobile internet access)
- Measures of ICT system applications (change in the percentage of firms with ERP systems)
- Measures of ICT tools that foster e-commerce (change in the percentage of firms with e-sales, change in the percentage of firms with a website, change in the percentage of firms engaged in e-commerce, change in the percentage of firms that accept orders online, change in the share of sales generated through computer networks).

DC, *DSEC*, *DSIZE*, and *DYR* represent country, sector, size, and time dummies, respectively.

Country and sector dummies capture both institutional, economic and sectoral differences in changes of labour demand that are not explained by changes in wages, capital and different types of ICT. The employment growth equation [2] can be estimated by OLS with heteroscedasticity-consistent standard errors. Since OLS estimates based on cross-sectional data are likely to be sensitive to influential observations, the employment equation is estimated using the robust regression method. This regression technique is a weighted least-squares procedure that puts less weight on outliers by using Cook's distance and then performing Huber iterations. In order to allow for differences in the relationships at hand, we estimate the employment equation [2] separately for broad industry groups, the subgroup of small and medium-sized enterprises, and large firms.

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[3] Two-year differences of the variables are used rather than annual growth rates to smooth over any year-to-year fluctuations.

There are two main disadvantages to estimating [2] based on two year differences. First, it does not support any conclusions regarding the long-run relationship between ICT and employment. This is relevant because, as documented by the literature exploring the employment effects of process innovations (Lachenmaier and Rottmann, 2011), it is possible (and perhaps likely) that ICT usage influences employment growth only after a delay. Second, estimation based on differences is valid only when the dependent variable is exogenous (i.e. the direction of causality goes from ICT enablers/system applications/e-commerce practices to employment growth). However, these ICT indicators are most likely a response to changes in output and to unobservable factors that affect both output and the ICT indicators.

The system GMM panel data estimator (Blundell and Bond, 1998) can be used to account for the correlation of ICT enablers/system applications/e-commerce practices with the error term. This estimator is particularly useful for panel data with a relatively large number of cross-sectional units and a small time dimension, as is the case here with an unbalanced panel data set comprising multiple countries, industries, and size classes and four time periods. Moreover, a dynamic panel data model like this enables us to estimate long-run elasticities, and is hence the optimal solution to the two problems mentioned above.

The dynamic form of the labour demand model can be expressed as follows:

$$\ln(L_{icst}) = \alpha_1 \ln(L_{icst-1}) + \alpha_2 \ln(K_{icst}) + \alpha_3 \ln(WP_{icst}) + ICT_{icst}\theta_1 + ICT_{icst-1}\theta_2 + \mu_{ics} + \lambda_t + u_{icst} \quad [3]$$

where μ_{ics} denote fixed effects (country-industry-size class combinations) and λ_t time effects. The long-run effect of the ICT indicator on employment growth is given by $(\hat{\theta}_1 + \hat{\theta}_1)/(1-\hat{\alpha}_1)$. The regression equation is derived by taking first differences in order to remove the unobserved time-invariant effects (for the sake of convenience, *X*s comprising *WP* and *K* are suppressed):

$$\begin{aligned} \ln(L_{icst}) - \ln(L_{icst-1}) &= \tilde{\alpha}(\ln(L_{icst-1}) - \ln(L_{icst-2})) + \tilde{\beta}_1'(ICT_{icst} - ICT_{icst-1}) \\ &+ \tilde{\beta}_2'(\ln(ICT_{it-1}) - \ln(ICT_{it-2})) + \lambda_t + (\varepsilon_{it} - \varepsilon_{it-1}). \end{aligned} \quad [4]$$

Assuming that the residuals of the level equation are serially uncorrelated, the right hand variables lagged by two periods or more can be used as instruments in the first-differenced equation. The dynamic labour demand is estimated using the system GMM estimator introduced by Blundell and Bond (1998), which builds on two equations: the first is based on the first difference specification, and the second on the equation in levels. Variables in the equation in levels are instrumented with lags of their own first differences. As a rule of thumb, the number of instruments should not exceed the number of groups in the regression (Roodman, 2009). The two-step estimator is used to estimate the labour demand equation with the finite sample correction developed by Windmeijer (2005). The ICT indicators are treated as endogenous (and predetermined).

3. Data and descriptive statistics

The data is based on the meso-aggregated Micro Moments Database. This database contains linked and micro-aggregated information on firms drawn from the national statistical offices of 12 European countries (Austria, Denmark, Finland, France, Germany, Ireland, Italy, the Netherlands, Norway, Sweden, Slovenia, and the United Kingdom). For these European countries, firm-level information from the business register (BR), the production survey (PS), the ICT usage (EC) survey, and the Community Innovation (CIS) survey has been harmonized and then merged according to the distributed microdata approach (Bartelsman, 2004). The data is available at the two-digit industry level and for the EUKLEMS alternative hierarchy. The dataset is also available in several other dimensions, such as size class (10-19, 20-49, 50-249, and 250+ employees) and age (<5 years, >=5 years) combined with firm size (<50 and >=50).

The industry classification is based on NACE rev 1.1 (5-37 and 50-99, excluding energy, water, and construction – industries 40-45 – and containing information for the period 2000-2010). Note that industries 75-99 are partially covered. All series are adjusted for the change in industry classification from NACE rev 1.1 to NACE rev. 2 starting from 2008 onwards. In particular, a concordance file based on the possible overlap between two industry classifications in a single year is used to change NACE rev. 2 industry codes to NACE rev 1.1 (at the firm level) from 2008 onwards (Bartelsman et al., 2017).

This study’s analysis is based on two estimation samples: (i) one including information at the two-digit industry level and (ii) another that includes broad industry classes based on the EUKLEMS definition and cross-classified by size class. The latter contains information for combinations of six broad industry classes and four firm-size classes (10-19, 20-49, 50-249, and 250+ employees). The six broad industry classes can be divided into ICT-producing and ICT-using classes. ICT-producing industries include electrical machinery, postal services, and communication services. ICT-using manufacturing industries include (i) consumer manufacturing, (ii) intermediate manufacturing, and (iii) investment goods; high-tech industries are excluded. ICT-using service industries include (i) distribution and (ii) financial and business services (excluding real estate, but including software services).

While this study uses aggregate data to study the impacts of ICT, it is also possible to investigate the employment effects of ICT at the firm level (see Pantea et al., 2015). Due to the rotating design of the ICT/e-commerce survey, however, linking several waves of the ICT/e-commerce survey over time leads to a high degree of sample attrition. Therefore, panel data based on aggregate data at the industry- or firm-size level offers some advantages.

In order to obtain an initial idea of the pattern of association between employment growth and ICT enablers/system applications/e-commerce activities, select scatter plots are presented. Figure 1 in appendix plots the change in employment growth against the change in the share of e-sales in total sales for two service industries – distribution and financial and business services – for four given size classes (10-19, 20-49, 50-249, and 250+ employees). Figure 2 in the Appendix shows the evolution of usage of different types of Information and communication technologies.

4. Empirical results

Table 1 shows robust regression estimates from equation [2]. These estimates capture how different types of ICT usage and e-commerce activities influenced the annual growth rate of employment in the period 2002-2008, with the variables calculated as changes over two-year intervals. The sample is restricted to the period before the financial and economic crisis because employment growth during the 2008-2010 period was strongly influenced by the fall in demand rather than by ICT infrastructure or other structural characteristics. Separate results for SMEs (10-249 employees) and for large firms (defined as those with 250 employees or more) are provided. All regressions include country, industry, and size-class dummy variables. The main result is that the different types of ICT/e-commerce activities (measured as changes) are not significantly related to employment growth when controlling for the impact of changes in real wages, capital stock, and other control variables. The insignificant effects also hold true for ICT enabling technologies, more advanced ICT applications such as enterprise resource planning systems and e-commerce activities. The results are in line with Pantea et al. (2015) based on firm-level data for seven EU countries. Wage growth and growth of capital stock show the expected signs and are significant at the five per cent level in the majority of cases. However, the size of the wage and capital effects is rather small in absolute terms: Short-run wage elasticity is about -0.10 in the majority of specifications, and capital stock elasticity is about 0.01.

When we use the sample that distinguishes among (i) ICT-producing manufacturing (electrical machinery) and services (postal and communication services), (ii) ICT-using manufacturing, and (iii) ICT-using services, the results again show that the different types of ICT/e-commerce indicators (measured as changes) are not significantly related to employment growth (Table 2). One exception involves changes in e-sales activity in the ICT-using service sector, where we find a positive and significant relationship at the 10 per cent level. The 0.08 coefficient on changes in e-sales means that an increase in the ratio of e-sales to total sales by one percentage point (say, from the average of 25 to 26 per cent) is associated with an increase in employment growth rate of almost 0.1 percentage point per year. The magnitude of this relationship is quite small given the 1.5 per cent average annual employment growth in financial and business services in the 10 European countries in question for the period 2002-2008.

Several robustness checks have been conducted. First, we also use changes in ICT indicators that are lagged by one or two years. Unreported results confirm that the lagged changes are not significant at the conventional significance levels. Second, we use lagged levels of the ICT indicators and find once again that they are not significant.

The next step is to investigate the employment effects of ICT using dynamic panel data methods while accounting for the endogeneity of the ICT and e-sales variables. Table 3 shows the results of the two-step system GMM estimator of equation [4] for the sample of manufacturing industries. Table 4 presents the corresponding estimations for the service industries.[4] The GMM regressions use robust standard errors and treat all explanatory variables as predetermined. We focus on four e-commerce indicators and two ICT indicators (share of employees with broadband internet access and percentage of firms with a website) for which we have a time span of significant length. In addition, we use the percentage of firms with ERP systems. For manufacturing, estimates are provided for the total sample period (2002-2010). For service firms, estimates are provided for the period prior to the financial and economic crisis.[5] The Hansen J-test supports the validity of the instruments in all cases. For manufacturing in the period 2002-2010, we find a statistically significant positive relationship between the percentage of firms using ERP systems and employment. The short-run coefficient is 0.39 and significant at the 5 per cent level. This indicates that a one percentage point increase in the share of firms with ERP systems is associated with an increase in employment by 0.39 per cent. Therefore, manufacturing industries in which the

[4] The GMM estimations are carried out using the XTABOND2 (updated 27 July 2014) command in STATA 13 (see Roodman, 2009).
[5] Extending the estimation sample to 2010 leads to implausible estimates for the lagged dependent variable.

number of firms with ERP systems rises exhibit higher employment growth. This result stands in contrast to the specifications in first differences. In general, however, GMM panel data estimates are preferable to robust regression estimates based on the first-difference specification because the use of lagged variables as instruments reduces possible bias due to measurement errors. The estimates for the remaining e-commerce indicators are not conclusive. E-sales activities appear to be insignificant, while for e-buying activities, our results are mixed: when measured by the percentage of firms with e-buying activities, the coefficient is negative and significant, but is then insignificant when measured as the share of online orders in total orders. The share of employees with broadband access does not appear to have a significant effect on manufacturing employment. Furthermore, we find that wages are significantly and negatively related to employment, with a short-run elasticity of about -0.20. In addition, capital stock is never significant, indicating that higher investment does not lead to more jobs.

For services, we again find that ICT and e-commerce activities are not significantly related to employment (Table 4). As in manufacturing, for instance, the share of employees with broadband access is negative but not significant. The percentage of firms with a website, however, is an exception. Here we observe a significant and positive relationship with a coefficient of 0.58. Wages show the expected negative sign, but are not significant at conventional levels. Similarly, capital stock is not significantly related to employment. The insignificance of traditional determinants of labour may be due to the strong persistence in employment, as indicated by the large coefficient of lagged employment. In services, employment appears to be much more strongly influenced by past levels than by the classical determinants of labour demand.

Overall, we find no negative employment effects of ICT and e-sales activities. If anything, there is some evidence that ERP systems have positive effects in manufacturing, as do websites in services. The coefficients on the remaining ICT and e-commerce indicators are not significantly different from zero.

5. Discussion

The debate about workers being replaced by information and communication technologies is certainly not new. Recently the accelerating pace of digitalisation has led to increased fears of massive job losses. However, the main conclusion from this study is that the growing use of ICT applications and E-commerce activities has not lead to a reduction of jobs. Creation of new jobs is one of the key goals of the EU 2020 strategy. In particular, the 'Agenda for new skills and jobs', which is part of the Europe 2020 strategy, emphasises the modernisation of labour markets by allowing the work force to develop and improve skills throughout the work life (European Commission 2010a). The main goals are an increase in labour participation and a better match of labour supply and demand. Meanwhile, the Digital Agenda forms another pillar of the Europe 2020 Strategy (European Commission 2010b). Digital literacy, e-skills and further investment in high speed internet are priorities of the initiative. The aim to create more jobs and at the same time foster digitalisation is often seen as conflicting. Brynjolfsson and McAfee (2014) argue that ongoing digitalisation in the form of new robotic technologies, artificial intelligence and machine learning will lead to a replacement of white collar jobs, similar to the substitution of blue collar jobs by robotics one decade ago. This means that the total number of available jobs will decline as digitalisation continues. Our study comes to the conclusion that great fears of job losses due to increased ICT usage are not justified. This does not necessarily mean that there are no losers of digitalisation but on average winners outweigh those who are replaced. However, the study does not take into account the recent strong increase in the number of robots. Basu (2016) suggests that the number of industrial robots sold worldwide increased by an exponential rate in 2015.

Therefore, government policy in general can take responsibility in the following ways. One action is the completion of the single digital market through further investment in the broadband infrastructure, preferably through private public partnerships. Government support is also required in the area of education, worker training and lifelong learning. Management should invest further in new ICT applications and expand e-commerce activities. ICT usage is widespread among large and medium sized firms but space still exists for further investments among small firms and in some industries. Further, firms should increase investment in ICT related training and retraining programmes. There are also implications for unions and employees. Employees have to give up resistance to innovation and instead actively support the process of implementation of new ICT technologies.

6. Conclusions

This study presents further insights into the impacts of different ICT applications and indicators of e-commerce activities on employment using internationally comparable micro-aggregated data for 10 European countries. In the absence of access to linked firm-level data sets, the use of representative micro-aggregated data (by firm size and industry group) can provide useful results on the impacts of ICT. In fact, compared to firm-level data, micro-aggregated data suffers less from attrition and sample selection, both of which are due to the rotating nature of the ICT/e-commerce survey.

The data for this analysis was obtained from the ESSLait Micro Moments Database. This database contains linked and micro-aggregated business information sourced from the national statistical offices of the firms' respective home countries. Information is available from business, trade, and education registers and from surveys on production, ICT usage, and innovation activities for the years 2001-2010. A key feature of our analysis is its use of different types of advanced ICT indicators.

The main result of our study is that we find no evidence supporting the hypothesis that ICT applications destroy jobs. In fact, ICT enablers (capturing the diffusion of broadband or mobile connections among workers) and most ICT system applications are rather neutral to employment, indicating that the substitution effects and the compensation effect tend to cancel each other out. For manufacturing, however, ERP systems tend to be positively related to employment. This result is somewhat surprising since ERP is often associated with employment losses due to complementary changes in organizational structures. These findings are robust not only to the model specification, but also to the estimation method applied.

The fact that we do not find reason to believe that ICT applications negatively affected employment in the 10 European countries during the period under review does not mean that we can safely exclude the possibility of circumstances changing in the future. As Brynjolfsson and McAfee (2012, 2014) point out, innovation happens very quickly in the ICT sector and spreads to the rest of the economy with similar speed. To the extent that countries are able to take advantage of the technological and market-related opportunities offered by ICT, it will be possible to ensure that the compensating effects outweigh the displacement effects. For this to happen, it will be necessary to provide for adequate ICT innovation ecosystems and to foster the use/adoption of ICT across all sectors of the economy. One study limitation is the time period of 2002-2008. It might still be too early to observe the effects of the current trend of data exchange, IT-controlled production processes and cloud computing on labour demand.

Appendix

Literature

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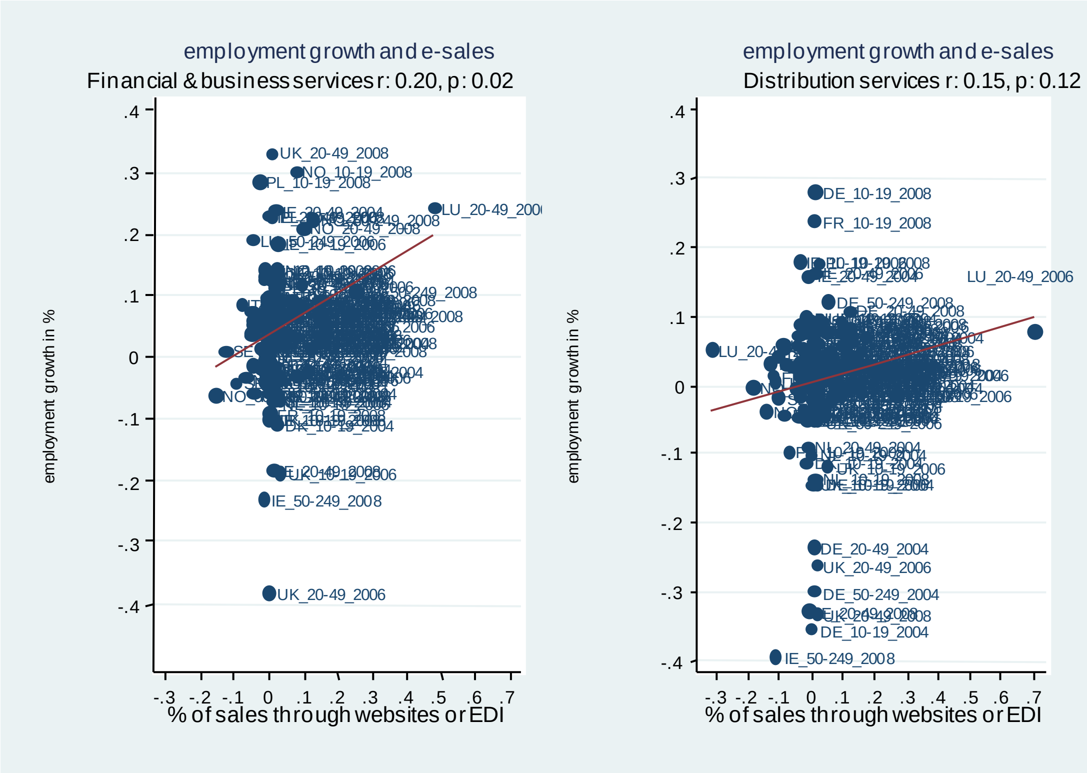
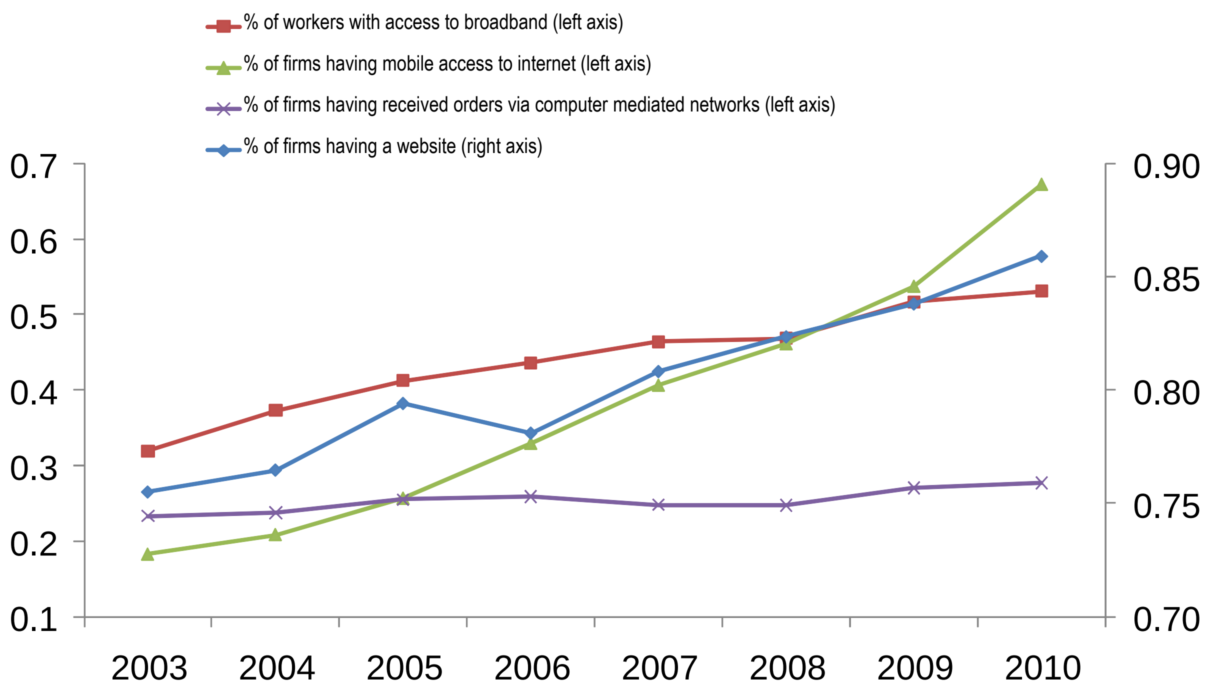
Figure 1: Relationship between employment growth and changes in the share of e-sales generated through websites



Source: ESSLait Micro Moments Database.

Figure 2: Evolution of different ICT indicators over time



Source: ESSLait Micro Moments Database.

Table 1: Impact of ICT and e-commerce activities on employment growth for SMEs and large firms (robust regression estimates based on the multi-industry size class panel)

	total			SMEs			large firms		
	coeff.		t	coeff.		t	coeff.		t
change in % of firms with e-sales	-0.00		-0.47	-0.01		-1.08	0.01		0.75
change in log real wages	-0.09	***	-3.51	-0.02		-0.83	-0.17	***	-2.61
change in log real capital stock	0.01	***	3.43	0.04	***	8.26	0.01	**	2.22
constant	-0.05	***	-3.87	0.01		1.20	0.09		1.50
number of observations	728			544			184		
	coeff.		t	coeff.		t	coeff.		t
change in % of firms with broadband internet access	0.02		1.07	0.02		0.84	0.02		0.51
change in log real wages	-0.10	***	-4.13	-0.09	***	-3.45	-0.13	**	-2.13
change in log real capital stock	0.01	***	4.17	0.04	***	7.67	0.01	***	3.00
constant	-0.02	*	-1.76	0.01		0.66	0.02		0.93
number of observations	852			637			215		
	coeff.		t	coeff.		t	coeff.		t
change in % of firms with a website	0.01		0.58	0.00		0.29	0.03		1.47
change in log real wages	-0.09	***	-3.45	-0.02		-0.62	-0.17	***	-2.78
change in log real capital stock	0.01	***	3.35	0.04	***	7.77	0.01	**	2.48
constant	-0.03	**	-2.15	-0.03	**	-2.02	-0.06	***	-2.80
number of observations	704			526			178		
	coeff.		t	coeff.		t	coeff.		t
change in % of firms with mobile internet access	0.00		0.36	-0.01		-0.66	0.02		1.56
change in log real wages	-0.19	***	-6.89	-0.18	***	-5.96	-0.22	***	-3.00
change in log real capital stock	0.05	***	9.02	0.05	***	9.21	0.05	**	2.02
constant	-0.00		-0.25	-0.01		-0.57	-0.05	**	-2.20
number of observations	542			404			138		
	coeff.		t	coeff.		t	coeff.		t
change in % of firms engaged in e-commerce	0.02		1.33	0.02		1.23	0.00		0.08
change in log real wages	-0.11	***	-3.99	-0.07	**	-2.28	-0.13	*	-1.91
change in log real capital stock	0.01	***	3.92	0.04	***	7.94	0.01	*	1.95
constant	-0.02		-1.54	-0.03	*	-1.79	0.05		1.01
number of observations	739			554			185		
	coeff.		t	coeff.		t	coeff.		t
change in % of firms with ERP systems	0.01		1.03	-0.01		-0.80	0.00		0.23
change in log real wages	-0.25	***	-5.91	-0.52	***	-11.06	-0.50	***	-4.09
change in log real capital stock	0.04	***	4.49	0.04	***	4.72	0.03		1.17
constant	-0.01		-1.11	0.21	***	14.70	0.02		1.17
number of observations	153			117			39		
	coeff.		t	coeff.		t	coeff.		t
change in % of orders received online	-0.02		-0.40	0.01		0.15	-0.10		-1.27
change in log real wages	-0.11	***	-4.06	-0.07	**	-2.30	-0.12	*	-1.73
change in log real capital stock	0.01	***	3.86	0.05	***	8.05	0.01	**	2.13
constant	-0.02	*	-1.66	0.04	***	2.67	-0.07	***	-2.72
number of observations	741			556			185		
	coeff.		t	coeff.		t	coeff.		t
change in share of sales through computer networks	0.02		1.18	0.01		0.45	0.02		0.66
change in log real wages	-0.11	***	-4.01	-0.07	**	-2.24	-0.12	*	-1.86
change in log real capital stock	0.01	***	3.88	0.04	***	8.21	0.01	**	2.13
constant	-0.06	***	-4.46	0.00		-0.09	-0.06	**	-2.49
number of observations	774			578			196		

Note: The dependent variable is the change in log employment over two-year intervals (2002-2004, 2004-2006, and 2006-2008). All regressions include country, industry, and size-class dummy variables (the latter are not included in the sample of large firms). ***, **, and * denote significance at the 1, 5, and 10 per cent levels, respectively. Source: ESSLait Micro Moments Database.

Table 2: Impact of ICT and e-commerce activities on employment growth for industries that produce and use ICT (robust regression estimates based on the multi-industry size class panel)

	ICT-using manufacturing			ICT-using services			ICT-producing sector		
	coeff.		t	coeff.		t	coeff.		t
change in % of firms with e-sales	-0.01		-1.08	0.01		0.64	0.02		0.62
change in log real wages	0.08		1.31	-0.29	***	-4.47	-0.19	***	-3.63
change in log real capital stock	0.01	**	2.41	0.01	*	1.97	0.08	***	4.94
constant	0.02		1.60	0.03	**	2.14	0.03		0.58
number of observations	374			234			117		
	coeff.		t	coeff.		t	coeff.		t
change in % of firms with broadband internet access	0.01		0.67	-0.01		-0.18	0.08		1.50
change in log real wages	-0.02		-0.52	-0.26	***	-4.48	-0.12	**	-2.58
change in log real capital stock	0.02	***	3.13	0.01	**	2.53	0.01	*	1.71
constant	-0.01		-0.88	-0.03	**	-2.17	-0.02		-0.47
number of observations	438			274			138		
	coeff.		t	coeff.		t	coeff.		t
change in % of firms with a website	0.00		0.33	0.01		0.45	0.03		0.81
change in log real wages	0.07		1.17	-0.31	***	-4.64	-0.20	***	-3.91
change in log real capital stock	0.01	**	2.36	0.01	*	1.89	0.08	***	5.21
constant	-0.04	**	-2.51	-0.07	***	-3.83	0.02		0.54
number of observations	362			226			113		
	coeff.		t	coeff.		t	coeff.		t
change in % of firms with mobile internet access	0.00		0.02	-0.01		-0.94	0.01		0.26
change in log real wages	0.14	*	1.78	-0.34	***	-4.88	-0.32	***	-6.28
change in log real capital stock	0.17	***	20.72	0.03	***	3.53	0.07	***	4.82
constant	0.02		0.77	-0.05	*	-1.75	0.01		0.22
number of observations	279			177			86		
	coeff.		t	coeff.		t	coeff.		t
change in % of firms engaged in e-commerce	0.01		0.39	0.04		1.49	0.03		0.86
change in log real wages	0.03		0.45	-0.29	***	-4.17	-0.18	***	-3.61
change in log real capital stock	0.02	***	2.79	0.01	**	2.29	0.06	***	3.94
constant	0.02		1.38	0.02		0.93	-0.06		-1.62
number of observations	380			233			123		
	coeff.		t	coeff.		t	coeff.		t
change in % of firms with ERP systems	0.01		0.97	-0.02		-1.02	-0.02		-0.43
change in log real wages	0.30	**	2.32	-1.06	***	-11.50	-0.60		-1.22
change in log real capital stock	0.16	***	10.19	0.06	***	3.76	0.04		1.16
constant	-0.01		-0.69	0.03	**	2.28	-0.01		-0.10
number of observations	80			48			23		
	coeff.		t	coeff.		t	coeff.		t
change in % of orders received online	-0.06		-0.80	0.00		-0.07	0.02		0.19
change in log real wages	0.03		0.48	-0.33	***	-4.58	-0.18	***	-3.50
change in log real capital stock	0.02	***	2.77	0.01	**	2.13	0.06	***	4.16
constant	0.02		1.35	0.02		0.86	-0.02		-0.26
number of observations	381			233			124		
	coeff.		t	coeff.		t	coeff.		t
change in share of sales through computer networks	0.00		0.24	0.08	*	1.85	0.03		0.51
change in log real wages	0.02		0.44	-0.28	***	-4.31	-0.17	***	-3.34
change in log real capital stock	0.02	***	2.79	0.01	**	2.43	0.05	***	3.52
constant	0.03	*	1.85	0.03	*	1.79	0.00		-0.11
number of observations	379			250			124		

Note: The dependent variable is the change in log employment over two-year intervals (2002-2004, 2004-2006, and 2006-2008). ***, **, and * denote significance at the 1, 5, and 10 per cent levels, respectively. Source: ESSLait Micro Moments Database

Table 3: Impact of changes in different ICT indicators on employment in manufacturing (system GMM estimates)

	(i)			(ii)		
	coeff.		t	coeff.		t
log employment t-1	1.02	***	133.00	1.00	***	72.29
% firms with e-sales	0.00		0.04			
% firms with e-purchasing				-0.09	**	-2.04
log real wages	-0.19	**	-2.19	-0.16	*	-1.94
log real capital stock	-0.01		-1.63	-0.01		-0.98
year dummies						
constant	0.72	*	1.77	0.78	**	2.25
number of observations	913			913		
number of groups	110			110		
number of instruments	117			117		
Hansen test (p-value)	0.48			0.42		
		(iii)			(iv)	
	coeff.		t	coeff.		t
log employment t-1	1.02	***	89.45	1.02	***	84.90
% sales through computer networks with e-sales	-0.10		-0.99			
% orders through computer networks with e-sales				0.23		1.36
log real wages	-0.18	**	-2.24	-0.17	**	-2.42
log real capital stock	-0.02		-1.11	-0.02		-1.35
year dummies	yes			yes		
constant	0.61	*	1.69	0.65	**	2.07
number of observations	913			814		
number of groups	110			110		
number of instruments	117			117		
Hansen test (p-value)	0.41			0.44		
		(v)			(vi)	
	coeff.		t	coeff.		t
log employment t-1	1.02	***	69.20	1.01	***	60.21
% firms with a website	-0.02		-0.16			
% employees with broadband access				-0.15		-1.25
log real wages	-0.18	**	-2.01	-0.10		-0.96
log real capital stock	-0.02		-1.50	-0.01		-0.31
year dummies	yes			yes		
constant	0.79	***	2.31	0.38		0.93
number of observations	880			913		
number of groups	110			110		
number of instruments	117			116		
Hansen test (p-value)	0.54			0.44		
		(v)			(vi)	
	coeff.		t			
log employment t-1	1.00	***	47.03			
% firms w. ERP systems	0.39	**	2.44			
log real wages	-0.43	***	-2.87			
log real capital stock	0.00		-0.21			
year dummies	yes					
constant	1.32	*	1.80			
number of observations	429					
number of groups	110					
number of instruments	52					
Hansen test (p-value)	0.05					

Note: ***, **, and * denote significance at the 1, 5, and 10 per cent levels, respectively. The table reports two-step GMM results with the Windmeijer correction for small samples. The ICT indicators, the wage variables, and capital stock are treated as predetermined (endogenous). The Hansen J-test checks the validity of the instrumental variables. The lag limit for the instruments is restricted to lag one and lag two. The time period refers to the period 2002-2010. The estimates are based on two-digit industry-level data (15a6, 17t9, 20, 21a2, 23t5, 26, 27a8, 29, 30t3, 34a5 and 36a7) and 10 European countries (AT, DE, DK, FI, FR, IT, NL, NO, SE and UK).

Table 4: Impact of changes in different ICT indicators on employment in services (system GMM estimates)

	(i)			(ii)		
	coeff.		t	coeff.		t
log employment t-1	0.91	***	9.51	0.95	***	12.86
% firms with e-sales	0.15		0.42			
% firms with e-purchasing				0.41		1.21
log real wages	-0.72		-1.07	-0.74		-0.82
log real capital stock	0.02		0.17	-0.02		-0.33
year dummies	yes			yes		
constant	3.42		1.15	3.41		0.86
number of observations	381			381		
number of groups	72			72		
number of instruments	50			50		
Hansen test (p-value)	0.24			0.09		
		(iii)			(iv)	
	coeff		t	coeff		t
log employment t-1	0.91	***	6.63	0.96	***	14.33
% sales through computer networks with e-sales	-0.07		-0.18			
% order through computer networks with e-sales				0.23		0.67
log real wages	-0.89		-1.51	-0.26		-0.60
log real capital stock	0.04		0.29	-0.01		-0.12
year dummies	yes			yes		
constant	3.68		1.38	1.63		0.72
number of observations	379			383		
number of groups	72			72		
number of instruments	49			50		
Hansen test (p-value)	0.37			0.28		
		(v)			(vi)	
	coeff		t	coeff		t
log employment t-1	0.96	***	13.18	0.92	***	8.02
% firms with a website	0.56	**	2.08			
% employees with broadband access				-0.25		-1.26
log real wages	-0.89		-1.16	-0.47		-0.68
log real capital stock	0.00		-0.02	0.03		0.30
year dummies	yes			yes		
constant	3.34		0.97	2.41		0.80
number of observations	357			389		
number of groups	72			72		
number of instruments	50			49		
Hansen test (p-value)	0.13			0.30		

Note: ***, **, and * denote significance at the 1, 5, and 10 per cent levels, respectively. The table reports two-step GMM results with the Windmeijer correction for small samples. The ICT indicators, the wage variables, and capital stock are treated as predetermined (endogenous). The Hansen J-test checks the validity of the instrumental variables. The estimates are based on the collapsed instrument set to reduce instrument count. The time period refers to the period 2002-2007. The estimates are based on two-digit industry-level data (50, 52, 55, 60t3, 64, 65t7, 71a4, 72 and 73) and 10 European countries (AT, DE, DK, FI, FR, IT, NL, NO, SE and UK).