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# E-commerce trends and impacts across Europe

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ABSTRACT

This study investigates patterns in electronic commerce (e-commerce) activities and their impact on labour productivity growth for a group of 14 European countries. At hand for the exercise is a unique panel of micro-aggregated, firm-level data spanning the years 2002–2010. The empirical approach involves two main elements: a static specification and a dynamic panel data model. The former is a difference specification estimated by OLS, and the latter model uses the system GMM estimator to account for endogeneity of e-commerce activities. For the impact analysis, e-commerce is defined specifically as e-sales – that is, orders firms receive electronically (through EDI or websites). Descriptive statistics reveal that the proportion of firms engaging in e-sales activities, after starting from a low level, is slowly growing over time. The OLS estimates, which control for industry, time, and country effects, show that the changes in e-sales activities and labour productivity growth are significantly positively related. Specifically, an increase in e-sales by one percentage point raises labour productivity growth by 0.3 percentage points over a two-year period. Service industries experience a larger impact than does manufacturing. Similar results are produced by the dynamic panel data estimations, which show that the increase in e-sales activities during the period studied accounts for 18 per cent of the total growth in labour productivity. In addition, the results demonstrate that smaller firms gain the most from increases in e-sales. Overall, the magnitude of the estimates differs less across methods than it does between industries or over time.



## 1. Introduction

Uncertainties about both the measurement and impacts of information and communication technology (ICT) – as previously expressed by Solow (1987), for instance – have been replaced by strong empirical evidence that ICT is indeed an important factor of economic growth and firm performance (Dedrick et al., 2003; Van Reenen et al., 2010; Cardona et al., 2013). Over time, however, its features and the channels through which it translates into firm performance seem to be changing from investments solely in hardware to a multi-dimensional palette of advanced ICT systems. Such systems include applications for electronic commerce activities (e-commerce), combined with changes in the structure of the organisation of the firm or the workforce skills. These findings are partly made possible by improvements in measurements over time, where aggregate ICT capital is no longer the sole source. Detailed information on ICT usage in firms is available thanks to pioneering statistical and analytical work by the OECD, the European Commission (Eurostat and EUKLEMS) and UNCTAD.

The main purpose of this study is to go beyond the already extensively researched field of investments in ICT hardware or adoption and concentrate instead on a specific kind of application: e-commerce activities in firms. Indeed, simple systems for e-commerce were available long before the internet, especially for business-to-business exchanges. However, the e-commerce of today typically requires advanced ICT infrastructures to work. We aim to empirically investigate patterns in e-commerce activities and their impact on firm performance, measured as labour productivity growth in a group of European countries. For the impact analyses, e-commerce is specifically defined as electronic sales (e-sales). The empirical approach incorporates two main elements: a static specification and a dynamic panel data model. The former is estimated by OLS in two-year differences and the latter by the system GMM estimator, which makes it possible to account for endogeneity of the e-commerce activities and persistence of labour productivity.

Micro-aggregated (rather than firm-level) data are employed to study the productivity effects of e-sales activities. This means that information has been sourced and linked at the firm level, but due to disclosure issues, the firms in question have then been grouped by industry or some other criterion. There are two reasons for this: First, firm-level data is confidential and difficult to stack in one international dataset. Second, high attrition rates caused by the rotating nature of the ICT/e-commerce surveys mean that the use of panel data methods would offer few additional insights, even with access

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to linked firm-level data. A number of previous studies have applied dynamic panel data methods to impact analyses of ICT investments using multi-country, industry-level datasets (O'Mahony and Vecchi, 2005; Venturini, 2009; Dahl et al., 2011). To the best of our knowledge, no such study is available for e-commerce activities. Nor have we encountered any earlier studies with country coverage this broad or data in as novel dimensions as found in the Micro Moments Database (MMD).[1]

The literature on ICT as an enabler of growth is vast, extending from aggregates (Jorgenson and Stiroh, 1999; Chou et al., 2014) and investments in hardware to more disaggregated studies on selected groups of firms (Black and Lynch, 2001; Brynjolfsson and Hitt, 2003; Bartelsman, 2010 and 2013; Van Reenen et al., 2010). ICT is considered a potential means of improving the quality of production factors. The more productive these factors are, the greater the return on corresponding investments. Related empirical studies often consider ICT and firm performance in conjunction with other important factors, such as skills and organisational structure. However, Cardona et al. (2013) conclude that there is a caveat: ICT needs to be well embedded to render positive effects. Eurostat (2008, 2012 and 2013) reports that employees with broadband internet access represent the kind of usage most clearly related to productivity, at both the firm and industry levels (see also Grimes et al., 2012).

The adoption of e-commerce activities is investigated in several studies (often in business or management literature) that consider factors such as the quality of underlying ICT infrastructure, internal organisation, ICT skills, adjustment costs, uncertainties surrounding e-commerce, competitive pressure, trading partner readiness, and perceived strategic value for the firm to be important determinants for both business-to-business and business-to-consumer e-commerce (Zhu et al., 2003; Grandon and Pearson, 2004; Vilaseca et al., 2007; Hollenstein and Woerter, 2008; Oliveira and Martins, 2010; Ben Aoun and Vicente Cuervo, 2012; Sila, 2013). In addition, Wilson et al. (2008) argue that the adoption of e-commerce occurs in stages. Size is also considered an important factor: Eriksson et al. (2008), for instance, show that Swedish small and medium-sized firms do not utilise advanced ICT systems despite having access to high-level infrastructure.

A growing field of the related literature emphasises ICT as a facilitator of international trade. By using websites for promotion and sales, firms may be able to sell to markets otherwise not reachable due, for instance, to distance or political systems. Fraumeni (2001) reasons that the digital economy and e-commerce activities will expand the global economy, while Morgan-Thomas (2009) finds that several different kinds of online capabilities are important for the internationalisation of firms. According to Terzi (2011), the internet will lead to increased amounts of international e-commerce thanks to its capacity to reduce trade barriers. While the gains from this will initially appear in developed countries, a shift to developing countries is expected in the long run. Martens (2013), meanwhile, shows that ICT and e-commerce are efficient reducers of distance-related trade costs.

Another branch of the literature deals with how e-commerce affects firm performance. Zhu and Kraemer (2005) conclude that both front-end (product information) and back-end (web applications, ICT infrastructure) capabilities increase the value of e-commerce in the retail industry across a group of countries. In developed countries, the back-end capabilities render a stronger influence, while the opposite effect is apparent in developing countries. Vilaseca et al. (2007) show that the motivation behind e-commerce adoption in a group of Spanish firms does not necessarily coincide with their performance over this channel. While the complexity of the competitive environment in question is important for adoption, internal factors related to resources and capabilities determine successful e-sales performance. Sanders (2007) finds that e-commerce impacts firm performance either directly or indirectly through improved internal or external collaboration. In contrast to e-sales processes, Quirós Romero and Rodríguez Rodríguez (2010) uncover that e-purchases have positive effect on the efficiency of Spanish firms between 2000 and 2005.

Positive links to productivity are found by Xia and Zhang (2010) and Liu et al. (2013), although spillover effects within the industry at hand are also important. The former study is based on a small sample of retailers in the United States for the years 1996 to 2008, and the latter relates to Taiwanese manufacturers from 1999 to 2002. Large ICT-intensive firms in Belgium (Konings and Roodhooft, 2002) and firms with advanced ICT systems in Italy (Colombo et al., 2013), exhibit similar positive associations between e-commerce and firm performance. Bertschek et al. (2006) conclude that business-to-business e-commerce and labour productivity are positively related for a group of German firms.

This study is organised as follows: First, we describe the conceptual background and the empirical approach. This is followed by an introduction of the dataset at hand and a section on e-commerce and ICT usage patterns across Europe. We then present and discuss the results of the impact analyses before concluding with suggestions on possible lines of future work.

## 2. Conceptual background and empirical approach

E-sales activities provide alternative channels in which firms can interact with their customers and enter new markets. Instead of improving the quality of production factors (like ICT in general), e-sales is expected to potentially advance the routines of the sales organisations and processes in firms and thus enhancing their efficiency. For instance, e-sales systems make distance less crucial, lead to lower adjustment and transaction costs, facilitate information gathering, consolidate supply and demand, and decrease the need for intermediaries or a physical presence (see, among others, Garicano and Kaplan, 2001; Lucking-Reiley and Spulber, 2001; Zhu et al., 2003; Lohrke et al., 2006; Hollenstein and Woerter, 2008; Sila, 2013; Martens, 2013).

While there is evidence of ICT serving as a general-purpose technology (Brynjolfsson and Hitt, 2003; Basu and Fernald, 2007; Cardona et al., 2013; and others), it is less clear how specific ICT usages or applications should be defined. Literature on the economics of innovation distinguishes among product, process, organisational, and marketing innovations (see the Statistical Office of the European Communities, 2005). Wilson et al. (2008) pick up on this in describing internet applications as a cluster of related innovations, while Bertschek and Fryges (2002) label business-to-business e-commerce a process innovation. Indisputably, ICT is a production factor firms often introduce to reduce costs (through process or organisational innovations). However, e-sales is particularly difficult to squeeze into this narrow definition of innovation because its scope transcends the pure internal operations of firms. For this reason, e-sales is considered an advanced application that is conditional upon an already introduced innovation (broadband internet infrastructure and a website, for instance). This approach is not all that far removed from the perspectives of Forman et al. (2012) and Colombo et al. (2013), who limit themselves to classifying the complexity of different forms of ICT and broadband applications; or from Sanders (2007), who interprets e-business technologies as a factor that influences the internal and external collaboration of the organisation (and potentially its performance, as well).

As highlighted above, e-sales goes beyond the typical process or organisational innovations because it also affects external relations with clients and markets. These effects are expected to be substantial enough to have a positive net influence on labour productivity, although the contribution from output is assumed to be larger than

[1] The Micro Moments Database is available at the Eurostat Safe Centre for research access (http://ec.europa.eu/eurostat/web/microdata/micro-moments-dataset).

from employment (at least in the short run). This assumption is based on the fact that a number of motives to engage in e-sales are related to cost savings, and that in most European countries, staff cannot legally be laid off on short notice. The productivity effects of e-sales are also likely to differ among firms and industries. Certain producers of goods or services may be able to reduce their number of retailers or sales organisations abroad, for instance, leading to a general reallocation within an industry. A typical example of this can be found in book sales, where the traditional channels have been almost wiped out by Amazon (Goldmanis et al., 2010). Given this discussion, the effects e-sales is presumed to have on productivity may be investigated in an augmented production-function framework similar to those used by Brynjolfsson and Hitt (2003) for ICT investments; by Grimes et al. (2012) and Colombo et al. (2013) for broadband technology; and by Konings and Roodhooft (2002), Bertschek et al. (2006), and Liu et al. (2013) for e-commerce.

As an alternative to firm-level information, this analysis employs micro-aggregated data in order to implement dynamic panel data methods in a cross-country setting. Except for Bartelsman (2010, 2013) – who explores the degree to which employees have broadband internet access – earlier analyses using multi-country, industry-level datasets (O'Mahony and Vecchi, 2005; Venturini, 2009; Dahl et al., 2011) mainly centre on ICT investments.

Two different datasets are used: The first consists of two-digit industries, and the second uses data categorised by both broad industry groups and size classes. Based on the multi-country industry panel dataset, the level of labour productivity (in constant prices) in a given industry can be modelled as a function of the proportion of firms with e-sales activities and control variables:

$$\ln(VACP_{ict}/L_{ict}) = \alpha_{ic} + \beta\%esales_{ict} + X_{ict}\gamma + \lambda_t + \varepsilon_{ict} \quad (1)$$

where $i=1,\ldots,25$ denotes the industry, $c=1,..,14$ the country, and $t=2002,..,2010$ the time. *VACP* reflects output (measured as value added in constant prices) and *L* represents employment. The variable *%esales* measures the percentage of firms that sell goods and services over the internet or another form of computer infrastructure. Control variables, such as capital stock and additional ICT usages, are embedded in the vector *X*, while $\lambda_t$ encompasses the time effects and $\alpha_{ic}$ denotes the fixed effects (country/industry pairs). The error term $\varepsilon_{ict}$ is assumed to be independently and identically distributed (iid). The labour productivity equation can be estimated by a two-way fixed effects model, although a difference specification estimated by OLS with heteroscedasticity-consistent standard errors is an attractive alternative. Griliches and Hausman (1986) advocate the long difference specification since it is less sensitive to influential observations and the annual changes are often small. Given the time span of eight years, we opt for a model with two-year differences so as not to lose too many observations over the period. Consequently, taking two-year differences and adding sets of country (*DCO*) and industry (*DSEC*) dummy variables results in the following labour productivity growth equation:

$$\Delta \ln(VACP_{ic}/L_{ic}) = \tilde{\alpha}_0 + \tilde{\beta}\,\Delta\%esales_{ic} + X_{ic}\,\tilde{\gamma} + DCO + DSEC + \lambda_t + \nu_{ic} \quad (2)$$

where $\Delta$ refers to the change in the variables over the two-year interval. Labour productivity is calculated as the growth rate

$$\Delta \ln(VACP_{ic}/L_{ic}) = \ln(VACP_{ict}/L_{ict}) - \ln(VACP_{ict-2}/L_{ict-2}),$$

and the change in e-sales is measured in percentage points:

$$\Delta\%esales_{ic} = (\%esales_{ict} - \%esales_{ict-2}).$$

The new error term $\nu_{ic} \equiv \varepsilon_{ict} - \varepsilon_{ict-2}$ is assumed to be normally distributed with zero mean and a constant variance-covariance matrix.

Since OLS estimates based on cross-sectional data are likely to be sensitive to influential observations, the labour productivity equation is also estimated by the robust regression method. This regression technique is a weighted least-squares procedure that lessens the weight of outliers using Cook's distance and Huber iterations. In order to allow for differences in production technology, the labour productivity equation is estimated separately for manufacturing and service industries.

In general, the direction of causality is assumed to point from e-sales practices to labour productivity growth. This assumption is supported by the fact that the evolution of e-selling firms remained stable on average during the period under observation despite the drastic fall in output following the financial crisis (Diagram 1). However, it could be argued that e-sales activities are endogenous due to changes in output when the economy is booming, or attributable to unobservable factors that affect both output and sales (see, for instance, Bertschek et al., 2006; and Liu et al., 2013). The system GMM panel data estimator (Blundell and Bond, 1998) can be used to account for a possible correlation between e-sales activities and the error term caused by endogeneity. This estimator is particularly useful for panel data with a relatively large number of cross-sectional units and a small time frame, as is the case here with an unbalanced panel spanning 345 country-industry pairs and eight years. Given that the level of labour productivity shows a high degree of persistence, we assume a dynamic adjustment process. Here, the observed shift in labour productivity is a fraction of the change required to reach the optimal level of labour productivity [$\ln(VACP_{ict}/L_{ict})^*$]. The parameter $\omega$ measures the speed of the adjustment process:

$$\ln(VACP_{ict}/L_{ict}) - \ln(VACP_{ict-1}/L_{ict-1}) = \omega\left[\ln(VACP_{ict}/L_{ict})^* - \ln(VACP_{ict-1}/L_{ict-1})\right]$$

By incorporating the partial adjustment mechanism into the static equation, we arrive at the labour productivity equation in its dynamic form:

$$\ln(VACP_{ict}/L_{ict}) = \alpha_1 \ln(VACP_{ict-1}/L_{ict-1}) + \beta\%esales_{ict} + X_{ict}\gamma + \mu_{ic} + \lambda_t + u_{ict} \quad (3)$$

where $\mu_{ic}$ denotes fixed effects (country-industry pairs), $\lambda_t$ represents time effects, and the adjustment parameter can be calculated as $\varpi = (\tilde{\alpha}_1 - 1)$. The long-run effect of e-sales activities on labour productivity can be calculated as $\hat{\beta}/(1-\tilde{\alpha}_1)$.

Alternatively, the panel dataset based on size class/industry pairs can be used to explore whether the influence of e-sales activities ($\beta_s$) varies with firm size:

$$\ln(VACP_{icst}/L_{icst}) = \alpha_{1s} \ln(VACP_{icst-1}/L_{icst-1}) + \beta_s\%esales_{icst} + X_{icst}\gamma_s + \mu_{isc} + \lambda_t + u_{icst} \quad (4)$$

where *i* denotes the sector, *c* the country, and $s=1,..,4$ the size class (10–19, 20–49, 50–250, and 250+ employees) and $\mu_{isc}$ represents the fixed effects (industry-size class pairs for a given

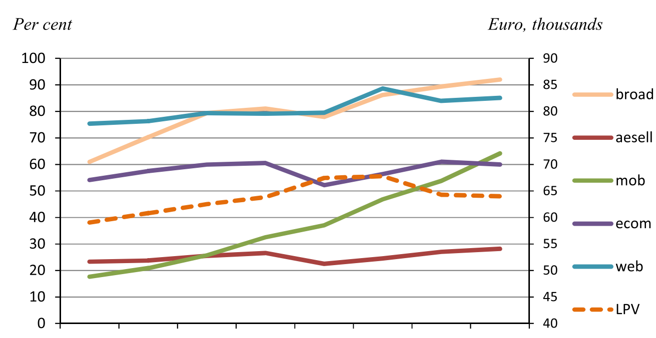



**Diagram 1.** ICT Usage and labour productivity in European firms. *Note:* Average for 13 European countries: Austria, Denmark, Finland, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland Slovenia, Sweden and the United Kingdom. France is excluded because of gap in the time series. The Netherlands is excluded from MOB and WEB also because of gaps. LPV is value added based labour productivity, reported on the right-hand axis. The ICT variables are expressed as the proportion of firms with fixed broadband connections (BROAD), mobile connections (MOB), websites (WEB), online sales (AESELL) or online sales and/or purchases (ECOM).
*Source:* ESSLait Micro Moments Database.

country). The labour productivity equation is estimated separately by system GMM for three size classes (10–19 and 20–49 pooled together, 50–249 and 250+ employees).

The system GMM estimator builds on two equations: one based on the first difference specification, and the other on the equation in levels. The two-step estimator is used to estimate the labour productivity equation with the finite sample correction developed by Windmeijer (2005); the e-sales variable is treated as endogenous (predetermined). The instruments consist of variables from the first to the fifth lag in levels and differences. As a rule, the number of instruments should not exceed the number of groups in the regression (Roodman, 2009).

## 3. Dataset

The data for this analysis originate from the ESSLait Micro Moments Database (MMD), which contains linked and micro-aggregated firm information sourced from the national statistical offices of 14 European countries. [2] Information is taken from registers on business, trade, and education, as well as from surveys on production, ICT usage, and innovation activities for the years 2001–2010. The data is available at the two-digit NACE 1.1 industry level, for the EUKLEMS alternative hierarchy, and in several other dimensions, such as size class, age class, ICT intensity, innovation activity, ownership, affiliation, and international experience. An overview of the industry classification is presented in Appendix B (Table B1 and B2). In this empirical application, the two-digit industry/country panel dataset and data aggregated by both size class and broad industry groups are employed. The availability of variables may vary somewhat across countries depending in part on the feasibility of linking datasets (due to both legal and practical aspects) and in part on the model design of sample surveys, where certain questions are mandatory and others are not.

The Distributed Microdata Approach (Bartelsman, 2004; Eurostat, 2008) has been employed to build the MMD. This approach relies heavily on careful initial metadata analysis that includes strict harmonisation of firm-level variables. With a set of comparable variables, the process of organising the national firm-level datasets in an identical infrastructure can start and a generic code can be developed. This *common code* is then run on the firm-level dataset for each country. The output generated consists of a set of summary tables with descriptive statistics and moments in different dimensions at a level of aggregation where disclosure becomes less of a problem. Finally, each country output is pooled into a cross-country dataset: the MMD.

A firm is considered to be engaged in e-sales when it *receives orders via a website, EDI-type systems, or other means of electronic data transfer*, in accordance with the EU-harmonised survey on ICT usage in enterprises.[3] This means that both the business-to-business and business-to-consumer realms are taken into account. Further, sales through intermediaries are included if they are performed electronically, but orders taken by e-mail are not considered e-sales. The definition does not require electronic transactions or delivery. Two indicators are used to describe the extent of e-sales activities: the percentage of e-selling firms (AESELL) and the proportion of total sales through this channel (AESVALPCT). The additional ICT variables in use are either related to the proportion of employees with fixed (BROADpct) and mobile (MOBpct) broadband internet access or to the proportion of firms with fixed broadband connections (BROAD), mobile connections (MOB), websites (WEB) or e-commerce activities (ECOM, digital sales or purchases). Value added is defined as gross output minus intermediate purchases of goods and services, while employment stands for number of employees. Three subgroups of firms based on size class are used: small, medium-sized, and large, with 10–49, 50–249, and 250+ employees, respectively. Nominal prices have been deflated by EUKLEMS or WIOD two-digit price indexes.[4]

It is important to note that the descriptive statistics presented here may deviate somewhat from official statistics. This has two causes: One stems from the fact that results from single-sample surveys are normally grossed up, while micro-data linking has to be performed on unweighted values. The implication is that the information describes the average firm without taking the size distribution into account. Secondly, several interruptions in the time series have been bridged to the greatest extent possible in the MMD (in contrast to official statistics).

## 4. E-commerce and ICT usage patterns in Europe

Before narrowing down the discussion to e-sales, a broader picture of ICT usage is presented that includes variables representing the basic ICT infrastructures (broadband and websites) on which more advanced applications may rely. ICT usage across Europe reveals several patterns that range from rapid growth to almost no change at all. This is illustrated in Diagram 1, which reports related developments for 13 European countries. Lower or moderate growth in e-commerce might indicate that an underlying ICT infrastructure is an important condition, but not enough for engagement, as suggested by Bharadwaj and Soni (2007).

Websites were in frequent use even before the advent of fixed broadband connections. These connections have become vastly more widespread since the early 2000s, but are now seeing more modest growth as they approach saturation. Mobile connections in firms are an ICT tool that initially showed slow progress, but more recently has surged. This pattern resembles that of broadband connections in earlier years. Despite the strong development of mobile connections in firms, fixed broadband usage has not experienced a corresponding decline, indicating that mobile connections are not (yet) substitutes, but rather complements to fixed broadband connections.

The development of e-commerce activities (e-selling and/or buying) or pure e-sales deviates from the other ICT applications in that it exhibits both a lower level of intensity and slower growth. Approximately one out of four firms is active in e-sales, and just over half of the firms engage in at least one of these two online activities. The temporary dip in both e-sales and e-commerce in 2007 should not be over-interpreted, since it coincides with slight definitional changes in the EU-harmonised questionnaire for ICT usage in enterprises (Eurostat).

In comparison with the other ICT tools, the development of e-commerce and e-sales seems puzzling. Eurostat (2008, 2012, and 2013) suggests that there could be both a threshold and a ceiling regarding the prospect of how firms benefit from ICT usage. This is exemplified by the relationship between employees with broadband Internet access and firm performance. When the intensity of usage nears saturation, the link to firm performance might weaken, although it remains stronger for firms at a lower level of intensity. This pattern is represented by the Nordic countries, which already have a high level of ICT usage and gain less in productivity than countries in Eastern Europe, remaining at a low rate of usage. Similarly, a minimal level of usage is not sufficient to impact firm performance. Bertschek et al. (2013) illustrate this in a study on the early years of broadband adoption at German firms, where no links to labour productivity could be found. Grandon and

[2] The ESSLait Micro Moments Database includes information for Austria, Denmark, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Sweden, Slovenia, and the United Kingdom.

[3] For further information, see http://ec.europa.eu/eurostat/web/microdata/community-statistics-on-information-society.

[4] See www.euklems.net and www.wiod.org.

Pearson (2004) suggest that the adoption of e-commerce is related to the perceived strategic value for each firm. A lack of belief in online commerce could thus be another underlying explanation for the sparse development. Ben Aoun-Peltier and Vicente Cuervo (2012) argue that the uncertainties surrounding e-commerce are barriers to its diffusion, with Hollenstein and Woerter (2008) adding adjustment costs to the related discourse.

While the development of different ICT tools might be affected to a certain degree by the business cycle, no clear evidence of such consequences or the financial crisis are apparent in the descriptive statistics. Indeed, this could be due to the level of the analysis and the possibility of aggregated data obscuring firm-level reactions to the crisis. For instance, Eurostat (2012, 2013) finds that firms with high ICT usage are more volatile than other firms, although the causality is unclear. However, the same does not apply to the development of labour productivity (LPV), which exhibits a clear cyclical pattern as it approaches the end of the decade (right-hand side of the *y*-axis in Diagram 1).

Labour productivity may also be reported for different groups of firms based on their ICT intensity (Diagram 2). Firms with a wider usage of ICT, in this case illustrated by the proportion of employees with broadband Internet access, are operating at a higher level of labour productivity. Still, most firms can be found among those with employee broadband connectivity rates lower than 40 per cent.

A closer look at (mobile and fixed) broadband connectivity in Diagram 3A and B shows that the proportion of employees with access to such infrastructure is increasing over time, although it is not as close to saturation as the corresponding proportion of firms (as illustrated in Diagram 1). The span between types of broadband is also diminishing, with mobile connections rapidly catching up. It is worth noting that the spread between the countries with the lowest and the highest connectivity is less wide for mobile connections.

Beyond the country group average, there is some disparity in the level of intensity with which firms use websites and e-commerce. Smaller countries and those in northern Europe seem to be more inclined to employ websites than larger countries in the south. Finland and Sweden are close to saturation at levels above 90 per cent, while in Italy only every second firm has a website (Diagram 4). This general pattern also holds true for the development of e-commerce and e-sales, although it appears that being the country with the highest percentage of firms with websites does not automatically indicate a similarly high proportion of firms engaged in e-commerce or pure e-sales activities. Norwegian firms are the most intensively engaged, with Irish and Swedish firms not far behind. Austrian firms, which exhibit widespread usage of websites, are keen on e-commerce in general, but less so on e-sales. These variations may well reflect differences in industry structures across countries.

The degree or likelihood of engagement in online sales may be influenced not only by the industry structure, but also by factors such as firm size and age. However, there is no clear difference between service and manufacturing industries in the average uptake of e-sales, although the spread across countries is somewhat larger in manufacturing. Diagram 5 illustrates e-sales activities based on four combinations of size and age classes, where a firm less than five years old is considered "young" and a "large" firm has at least 50 employees.

Besides a certain variation among industries, with the ICT-producing sector (Elecom) being the most active in e-commerce and the services providers (Mserv) among small firms more often offering online ordering functions, it is clear that size has a stronger bearing for e-commerce than age. This holds true also for the manufacturing firms excluding ICT (MexElec).

A more detailed picture of the spread in e-sales activity across industries is presented by Diagram A2 in Appendix A. This reveals that firms involved in consumer goods production, personal services, distribution and ICT are most frequently active in e-sales.

International experience and distance to markets are additional factors that may affect the degree to which firms engage in e-commerce. From Diagram 6, we can infer that exporting firms are indeed more active in online sales; the differences among industries are also less pronounced than in domestic markets.

As an alternative, e-sales can be measured by the proportion such activity accounts for in total sales. Though it remains at a low level overall, this proportion doubled between 2003 and 2009 (Diagram 7). On average, almost one-seventh of sales is conducted through digital systems. In 2010 it became voluntary for statistical offices to include in the EU-harmonised questionnaire a question on the proportion of e-sales. This led to inconsistent coverage across countries, which is why 2010 has been left out of Diagram 7. Information for a smaller subgroup of countries (with Sweden, Italy, and Luxembourg excluded) indicates a downturn in 2010. Detailed data by country is available in Table A1 in Appendix A.

Initially, fast broadband infrastructures in firms and staff skilled enough to operate them may not have been a prerequisite of websites or electronic sales activities, although they are certainly more important now. Despite this, the correlation between the change in the percentage of employees with broadband internet access and the change in the percentage of firms with e-sales activities is moderate, with a correlation coefficient of 0.18 (see Diagram A1 in Appendix A). This emphasises the notion that internet access and e-skills may not be the only important aspects for firms that are considering engaging in online sales.

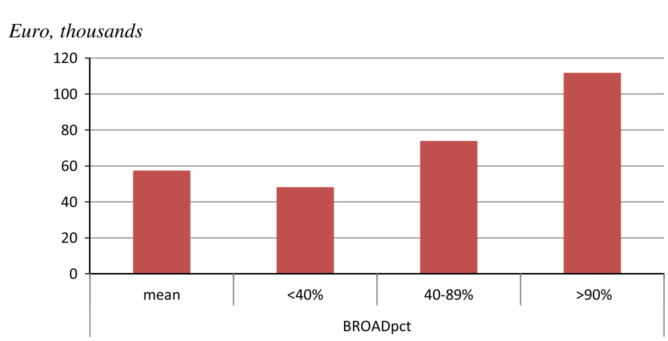


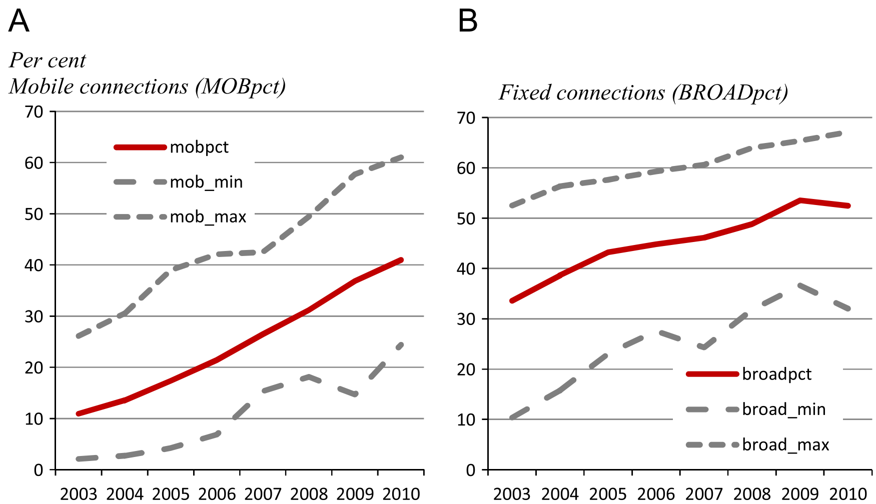

**Diagram 2.** Labour productivity by ICT intensity level of firms in 2010. *Measured as proportion of employees with broadband internet access (BROADpct). Note:* Average for 12 countries: Denmark, Finland, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Slovenia, Sweden and the United Kingdom.
*Source:* ESSLait Micro Moments Database.

## 5. Empirical results and discussion

In order to obtain an initial idea of the association between labour productivity growth and changes in e-sales activities, two scatter plots are presented. Diagram 8 illustrates the change in labour productivity vis-à-vis the change in the percentage of firms engaged in e-sales for both manufacturing and service industries. The time frame (2003–2008) is restricted to the period prior to the recent financial and economic crises. For manufacturing industries, there is a significant and positive correlation between labour productivity growth and a change in e-sales activities. However, the correlation is only significant at the 10 per cent level, and the magnitude is rather low (about 0.22).

In contrast, service industries exhibit a positive and highly significant relationship (0.49 at the 1 per cent level) between labour productivity growth and a change in e-sales activities. This correlation indicates that the connection between e-sales activities and labour productivity growth differs across industry groups. Nevertheless, the relationship should be interpreted with caution because it suffers from omitted-variable bias and does not reflect causal effects.

The next step is to analyse the relationship between labour productivity growth and a change in e-sales activities using regression analyses. Table 1 shows the OLS estimates of the impact of a change in e-sales activities on labour productivity growth. Separate results are provided for manufacturing and service industries. Due to the demand shock the world economy experienced towards the end of the first decade of the 2000s, three different time intervals are estimated: (i) the overall period (2002–2010), (ii) the pre-crisis period (2002–2008) and (iii) the crisis period (2008–2010). Additionally, Table 1




**Diagrams 3.** A and B. Employee broadband connectivity. *Note:* Average for 9 countries: Ireland, Finland, Denmark, Germany, Norway, Poland, Slovenia, Sweden and the United Kingdom. Country with lowest and highest values varies over time.
*Source*: ESSLait Micro Moments Database.

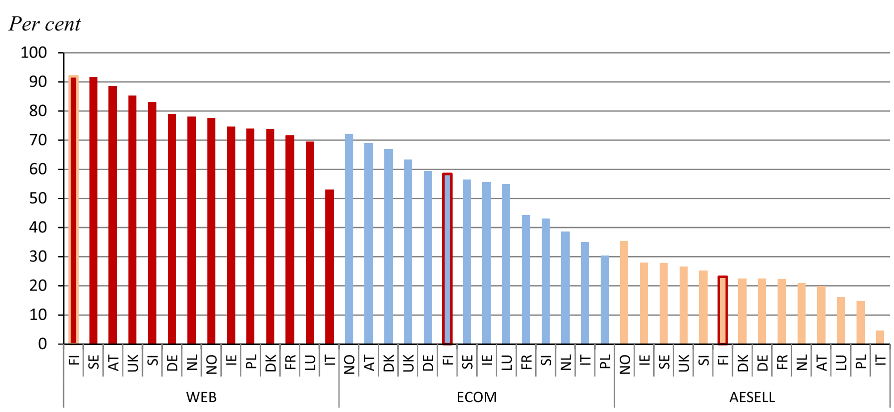



**Diagram 4.** Websites and e-commerce in firms across Europe in 2010. *Note:* WEB means the proportion of firms with websites, ECOM proportion of firms that engages in either e-sales or e-purchases and AESELL proportion of firms with e-sales activities. Italian data refer to the year 2009. All values are weighted with respect to sample size.
*Source*: ESSLait Micro Moments Database.

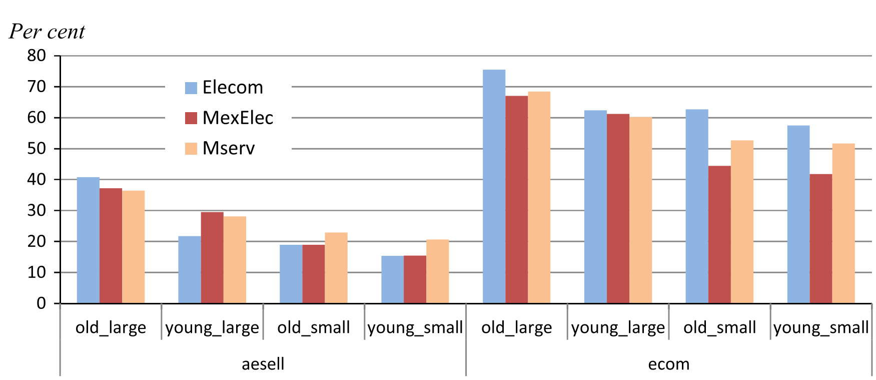



**Diagram 5.** E-commerce by size and age of firms in 2010. *Note:* Averages for 10 countries: Denmark, Finland, France, Ireland, Italy, the Netherlands, Norway, Poland, Slovenia and Sweden. Small indicates fewer than 50 employees and young means less than five years old. Elecom is the ICT sector (NACE rev. 1.1, industries 30–33 and 64), while MexElec and MServ are manufacturing and service industries, exclusive of ICT. AESELL illustrates online sales and ECOM online sales and/or purchases.
*Source*: ESSLait Micro Moments Database.

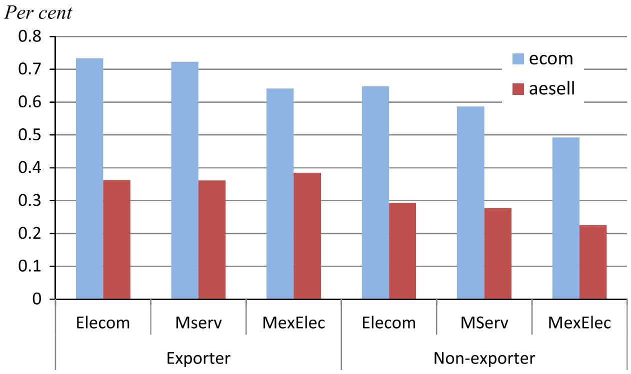



**Diagram 6.** Internationally experienced firms and e-commerce in 2010. *Note:* Average for 10 countries: Austria, Denmark, France, Ireland, the Netherlands, Norway, Poland, Slovenia, Sweden and the United Kingdom. Elecom is defined as the ICT sector (NACE rev. 1.1, industries 30–33 and 64), while MexElec and MServ are manufacturing and service industries, respectively, exclusive of ICT. AESELL illustrates online sales and ECOM online sales and/or purchases.
*Source:* ESSLait Micro Moments Database.

includes results obtained by means of the robust regression method, which reduces the impact of outliers and influential observations in e-sales or labour productivity variables.

For each of the 14 European countries observed, we use data from approximately 25 industries and up to four two-year time periods, resulting in a total of about 1,200 observations. OLS estimations reveal a positive and significant relationship between labour productivity growth and a change in the proportion of firms with e-sales when controlling for industry, country and time effects. This implies that industries that witness an increase in the proportion of firms selling through computer networks experience a higher growth rate in labour productivity. The magnitude of the relationship differs across time periods and between manufacturing and services. In general, robust regression methods produce smaller coefficients with higher significance levels, indicating the presence of outliers. Based on the robust regression method, the coefficient of e-sales amounts to 0.14 for the total period under observation. This indicates that an increase of one percentage point in the share of firms with e-sales activities will lead to a rise in labour productivity growth by 0.14 percentage points over the given two-year period

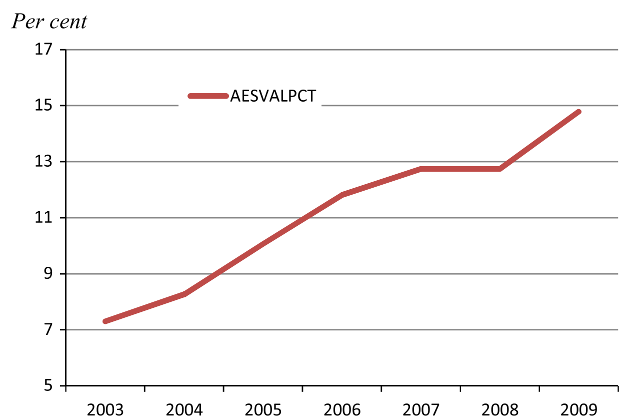



**Diagram 7.** Development of e-sales in firms in relation to total sales. *Note:* Average for 12 countries: Austria, Denmark, Finland, Germany, Ireland, Italy, Luxembourg, the Netherlands, Norway, Slovenia, Sweden and the United Kingdom. France and Poland are excluded due to gaps in time series.
*Source*: ESSLait Micro Moments Database.

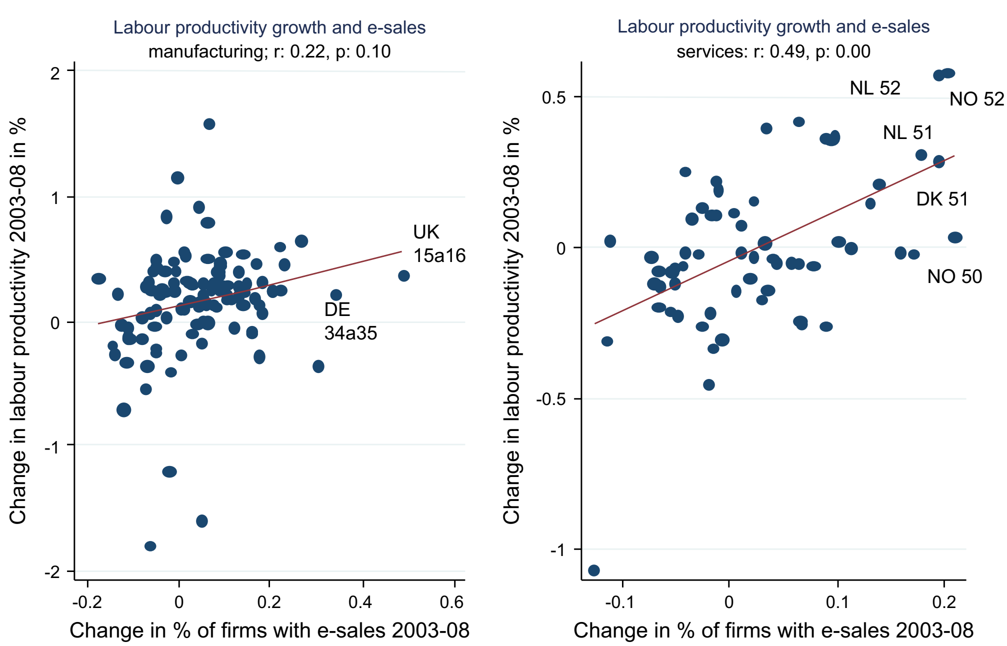



**Diagram 8.** Correlation between growth of labour productivity and e-sales. *Note:* The sample is based on industry level data for 13 EU countries (AT, DE, DK, FI, IE, IT, LU, the NL, NO, PL, SE, SI and the UK). FR is excluded due to a break in the time series. The following industries are included: NACE rev 1.1 15a6, 17t9, 20, 21, 22, 23a4, 25, 26, 27, 28, 29, 30a3, 31, 32, 34, 35, 36a7, 50, 51, 52, 60t3, 64, 71a4, 72, 73.
*Source*: ESSLait Micro Moments Database.

**Table 1**
Impact on labour productivity growth of change in e-sales activities. *OLS and robust regression method.*
*Source*: ESSLait Micro Moments Database and own calculations.

| | Total industry | | Manufacturing | | Services | |
|---|---|---|---|---|---|---|
| | Coeff. | *t* | Coeff. | *t* | Coeff. | *t* |
| | | | OLS estimates 2002–2010 | | | |
| Change in % of firms with e-sales activities | 0.28** | 2.13 | 0.25* | 1.65 | 0.39 | 1.51 |
| Time dummy 2004–2006 | −0.03 | −0.97 | −0.08*** | −2.81 | 0.10** | 2.04 |
| Time dummy 2006–2008 | −0.01 | −0.29 | −0.02 | −0.64 | 0.03 | 0.57 |
| Time dummy 2008–2010 | −0.15*** | −5.87 | −0.17*** | −5.83 | −0.11** | −2.24 |
| Constant | 0.10 | 1.06 | 0.08 | 0.71 | 0.07 | 0.72 |
| # of observations | 1146 | | 791 | | 355 | |
| R-squared | 0.12 | | 0.14 | | 0.18 | |
| | | | Robust regression estimates 2002–2010 | | | |
| Change in % of firms with e-sales activities | 0.14** | 2.37 | 0.12* | 1.71 | 0.32*** | 2.60 |
| Time dummy 2004–2006 | −0.02 | −1.25 | −0.05** | −2.28 | 0.04 | 1.25 |
| Time dummy 2006–2008 | −0.06*** | −3.13 | −0.07*** | −3.42 | −0.01 | −0.32 |
| Time dummy 2008–2010 | −0.16*** | −8.84 | −0.19*** | −8.85 | −0.09*** | −2.83 |
| Constant | 0.11 | 1.04 | 0.14 | 1.30 | 0.07 | 1.12 |
| # of observations | 1146 | | 791 | | 355 | |
| | | | OLS estimates 2002–2008 | | | |
| Change in % of firms with e-sales activities | 0.46*** | 2.95 | 0.40** | 2.17 | 0.66*** | 2.40 |
| Time dummy 2004–2006 | −0.03 | −1.07 | −0.08*** | −2.72 | 0.10* | 1.92 |
| Time dummy 2006–2008 | 0.00 | 0.02 | −0.01 | −0.39 | 0.04 | 0.83 |
| Constant | 0.03 | 0.25 | −0.11 | −1.02 | 0.07 | 0.60 |
| # of observations | 877 | | 606 | | 271 | |
| R-squared | 0.14 | | 0.18 | | 0.17 | |
| | | | Robust regression estimates 2002–2008 | | | |
| Change in % of firms with e-sales activities | 0.22*** | 3.52 | 0.19*** | 2.79 | 0.40*** | 3.06 |
| Time dummy 2004–2006 | −0.02 | −1.20 | −0.04** | −2.23 | 0.04 | 1.23 |
| Time dummy 2006–2008 | −0.05*** | −2.97 | −0.06*** | −3.30 | −0.01 | −0.29 |
| Constant | 0.11 | 0.97 | 0.04 | 0.77 | 0.12 | 1.58 |
| | | | OLS estimates 2008–2010 | | | |
| Change in % of firms with e-sales activities | −0.03 | −0.13 | −0.06 | −0.29 | −0.14 | −0.22 |
| Constant | 0.05 | 0.19 | 0.27 | 1.29 | −0.02 | −0.09 |
| # of observations | 269 | | 185 | | 84 | |
| R-squared | 0.27 | | 0.28 | | 0.42 | |
| | | | Robust regression estimates 2008–2010 | | | |
| Change in % of firms with e-sales activities | 0.07 | 0.43 | 0.07 | 0.39 | 0.11 | 0.28 |
| Constant | 0.06 | 0.76 | 0.07 | 0.74 | 0.01 | 0.09 |
| # of observations | 269 | | 185 | | 84 | |

*Note:* The dependent variable is the two-year change in log labour productivity in constant prices (i.e. 2002–2004,.., 2008–2010). OLS estimates are based on heteroscedasticity consistent standard errors. All regressions include country, industry and time dummy variables, country and industry effects are not reported. NACE rev 1.1: 15a6, 17t9, 20, 21, 22, 23a4, 25, 26, 27, 28, 29, 30a3, 31, 32, 34, 35, 36a7, 50, 51, 52, 60t3, 64, 71a4, 72, 73 are included. Data for industries 55, 65t67 and 90 are excluded due to inconsistent country and time coverage. The country group includes AT, DE, DK, FI, FR, IE, IT, LU, the NL, NO, PL, SE, SI and the UK.

* Denotes significance at the 10 per cent level.

** Denote significance at the 5 per cent level.

*** Denote significance at the 1 per cent level.

(compared to the OLS estimate of 0.28 percentage points). If the most turbulent years of the financial crisis are excluded (2008–2010), the robust regression and OLS estimates are both larger (0.22 and 0.46, respectively) and exhibit a higher significance level than for the total period. Given the low growth rate of labour productivity in most European countries, these effects are not negligible.

When distinguishing between industries, robust regression estimates for the pre-crisis period show that the coefficient of a change in e-sales activities amounts to 0.19 and 0.40 for manufacturing and service firms, respectively. This reveals that the relationship is larger for services than for manufacturing (as already indicated in the scatterplot, Diagram 8). The result for the crisis period (2008–2010) suggests that labour productivity growth is independent of changes in the proportion of firms engaged in e-sales activities.

These findings are consistent with the previous literature. Liu et al. (2013) use a similar approach on a sample of firms from Taiwan and find that e-commerce has a positive impact on productivity, although the effect is stronger in combination with R&D. Xia and Zhang (2010) show that online sales channels increased sales volume for a group of United States retailers, particularly over the longer term. Using firm-level data for Belgium, Konings and Roodhooft (2002) unfold a productivity impact of e-businesses on large ICT-intensive firms, while Bertschek et al. (2006) find positive indirect relationships between e-sales and labour productivity in a sample of German firms.

The related literature is particularly sparse when it comes to the industry-level benefits of e-sales. Colombo et al. (2013) suggest that the likelihood of firms gaining from ICT or more advanced applications is strictly related to industry-specific needs and the enablement of strategic or organisational changes. Hypothetically, this could imply that the larger estimates of labour productivity in the service sector are made possible by the more flexible organisational structures and lower level of fixed capital in these industries. Further, the absence of a clear distinction in the adoption level of e-sales between industries could indicate that the intensity level most beneficial to productivity differs between groups of firms (Eurostat, 2013).

While the static OLS estimations render significant results with the expected signs, possible dynamic mechanisms cannot be taken into account. Given the assumption that e-sales could be endogenous, the dynamic panel data estimations will be informative of the relationship to labour productivity. Table 2 shows the two-step system GMM results

**Table 2**
Impact on labour productivity of change in e-sales activities. *System GMM estimates. Source*: ESSLait Micro Moments Database and own calculations.

| | Total industry | | Manufacturing | | Services | |
|---|---|---|---|---|---|---|
| | Coeff. | *t* | Coeff. | *t* | Coeff. | *t* |
| Log labour productivity t-1 | 0.75*** | 11.61 | 0.79*** | 9.77 | 0.73*** | 7.70 |
| Log labour productivity t-2 | | | | | 0.11 | 1.11 |
| % of firms with e-sales *t* | 0.26** | 2.26 | 0.32** | 2.32 | 0.40*** | 2.61 |
| Year 2004 (ref category Year 2003) | 0.07*** | 5.09 | 0.06*** | 3.72 | 0.08** | 2.49 |
| Year 2005 | 0.06*** | 3.30 | 0.03 | 1.55 | 0.06* | 1.78 |
| Year 2006 | 0.02 | 1.35 | −0.01 | −0.39 | 0.05 | 1.18 |
| Year 2007 | 0.05*** | 2.68 | 0.05** | 2.37 | 0.03 | 0.79 |
| Year 2008 | 0.03* | 1.82 | 0.02 | 1.16 | 0.01 | 0.16 |
| Year 2009 | −0.04** | −2.17 | −0.07*** | −2.61 | −0.07* | −1.94 |
| Year 2010 | 0.00 | 0.21 | 0.00 | −0.10 | −0.03 | −0.57 |
| Constant | 0.92*** | 3.83 | 0.74** | 2.51 | 0.51* | 1.91 |
| Long-run coefficient e-sales | 1.04** | 2.36 | 1.54** | 2.40 | 2.51* | 1.65 |
| # of observations | 2329 | | 1535 | | 752 | |
| # of groups | 317 | | 208 | | 109 | |
| # of instruments | 160 | | 160 | | 85 | |
| AR(1) test (*p*-value) | 0.000 | | 0.000 | | 0.004 | |
| AR(2) test (*p*-value) | 0.003 | | 0.116 | | 0.308 | |
| Hansen test of overid. restr. (*p*) | 0.035 | | 0.186 | | 0.424 | |
| Hansen test excluding group (*p*) | 0.011 | | 0.085 | | 0.617 | |
| Difference (null H=exogenous)[a] (*p*) | 0.927 | | 0.939 | | 0.162 | |

*Note:* The group of industries include NACE rev 1.1: 15a6, 17t9, 20, 21, 22, 23a4, 25, 26, 27, 28, 29, 30a3, 31, 32, 34, 35, 36a7, 50, 51, 52, 60t3, 64, 71a4, 72, 73. The country group includes: AT, DE, DK, FI, FR, IE, IT, LU, the NL, NO, PL, SE, SI and the UK. The table reports two-step GMM results with the Windmeijer correction for small samples. The e-sales variable is treated as predetermined (endogenous). The Hansen *J* test checks for the validity of instrumental variables. The short run elasticity of e-sales on labour productivity is equal to the short-run coefficient (ranging from 0.26–0.40). This coefficient refers to the impact that occurs in year (*t*). The long-run impact is calculated as the short-run coefficient divided by the adjustment parameter.

* Denote significance at the 10 per cent level.

** Denote significance at the 5 per cent level.

*** Denote significance at the 1 per cent level.

[a] reports difference-in-Hansen tests of exogeneity of GMM instruments for levels (*p*-value).

for the total group of industries, as well as separately for service and manufacturing industries.[5] The GMM estimator produces robust standard errors and treats the e-sales variable as predetermined.[6] Similar to the static regressions, these results also reveal a statistically significant and positive relation between labour productivity and e-sales activities. This implies that industries in which the number of firms with e-sales activities increases enjoy higher labour productivity growth. These results hold true for both the total sample and the separate manufacturing and service industries.

The short-run coefficients indicate that an increase of one percentage point in the share of firms with e-sales activities will raise labour productivity by between 0.32 and 0.40 per cent.[7] As expected, the lagged level of labour productivity is highly significant, implying a slow adjustment over time. The adjustment parameters for services and manufacturing are 0.21 and 0.27, respectively, and the corresponding average time lags are 3.8 and 2.7 years (calculated as $(1-\omega)/\omega$). This means that it takes between three and four years for half of the change in e-sales to manifest itself in labour productivity. The long-run impact of e-sales exceeds one and occurs after six years at the earliest.

Separate system GMM estimations by size class confirm the significant impact of e-sales activities, except for large firms (Table 3). The impact is more substantial for small firms (coefficient of 0.36) than for medium-sized firms (0.29). The results follow Colombo et al. (2013), who discover that the productivity of small and medium-sized firms is driven by advanced broadband applications, but contradict Konings and Roodhooft (2002), who report that only the more extensive users of e-sales – that is, larger firms – gain in productivity as a result. The different time frames at hand present a plausible explanation: Larger firms that already engage in online sales more frequently are closer to their saturation level than smaller firms, and thus may have less to win from further online sales. Interestingly, capital stock is not significant, just like in the industry dataset (OLS and GMM regressions). However, this could be due to the fact that the structure of capital (intangible assets, advanced equipment) – rather than its growth – drives labour productivity.

In order to provide an indication of the magnitude of the results, it is possible to calculate how much a change in e-sales activities contributes to labour productivity growth (based on the results in Table 2). Given the short-run coefficient of 0.36 (based on the unweighted average for manufacturing and service industries) and the increase of around 6.3 percentage points in the share of firms with e-sales activities between 2003–2010 (an average of 0.9 percentage points per year), the total effect on labour productivity growth amounts to 2.3 per cent over the sample period (or approximately 0.3 per cent per year). Expressed in relative terms, e-sales activities represent 18 per cent of the total growth in labour productivity for the same period (which itself amounted to 13 per cent). Overall, this indicates that e-sales activities account for a sizable increase in the labour productivity of the business enterprise sector for the sample of EU countries under review. However, the contribution of e-sales activities is lower than that of ICT capital based on the macro productivity literature (Cardona et al., 2013; Spiezia, 2013).

Considering the different estimators used (OLS, the robust regression method, and system GMM), we can conclude that the static approach separates different time periods more efficiently, while the dynamic panel data technique handles endogenous variables. In this case, though, the magnitude of the estimates differs less across estimators than among industries or over time.

A number of robustness checks are conducted to validate the results. First, we re-estimate the labour productivity equation with the percentage of firms with e-sales activities lagged by one year instead of the contemporaneous value. Unreported results show that the impact of e-sales remains significant, although the magnitude of the coefficients is lower. Second, we use the alternative measure of e-sales activities: the proportion of sales generated through websites or EDI. Table A2 in Appendix A shows the results of the system GMM estimator for the labour productivity equation estimated for manufacturing and service industries. Since the contemporaneous value is not significant, the variable is lagged by one year. Despite this, the positive estimates are slightly smaller than for the proportion of firms engaging in e-sales, and the significance level is also lower (10 per cent). While this result holds for both manufacturing and services, it should be interpreted with care,

[5] The GMM estimations are carried out using the XTABOND2 command in STATA 13.1.

[6] The AR(2) test rejects the null hypothesis of second order correlation for the sample of manufacturing and services industries. As expected, there is significant first order serial correlation. Hansen J-test supports the validity of the instruments in most of the cases.

[7] It is important to note that the interpretation of regression estimates differs between OLS and GMM. While a one-percentage-point change in an independent OLS variable affects the dependent variable in equal units, the GMM estimates render a change as a percentage.

**Table 3**
Impact on labour productivity of change in e-sales activities by size-class. *System GMM estimates.*
*Source*: ESSLait Micro Moments Database and own calculations.

| Size class | 10–49 employees | | 50–249 employees | | > 250 employees | |
|---|---|---|---|---|---|---|
| | Coeff. | *t* | Coeff. | *t* | Coeff. | *t* |
| log labour productivity t-1 | 0.81*** | 6.91 | 0.84*** | 14.42 | 0.77*** | 10.43 |
| % firms with e-sales t | 0.36*** | 2.78 | 0.29*** | 2.75 | 0.09 | 0.79 |
| log real capital stock | 0.00 | −0.17 | 0.02 | 1.44 | 0.00 | 0.33 |
| Year 2004 (ref category year 2003) | 0.02 | 0.90 | 0.04* | 1.76 | 0.04 | 1.25 |
| Year 2005 | 0.04** | 2.20 | 0.01 | 0.45 | 0.01 | 0.21 |
| Year 2006 | 0.03 | 1.35 | 0.03 | 1.36 | 0.04 | 1.07 |
| Year 2007 | 0.03 | 1.25 | 0.02 | 0.99 | 0.03 | 1.04 |
| Year 2008 | 0.02 | 0.73 | 0.02 | 1.14 | 0.05* | 1.69 |
| Year 2009 | −0.07*** | −2.71 | −0.07** | −2.46 | −0.06* | −1.69 |
| Year 2010 | −0.04 | −0.97 | −0.03 | −1.00 | 0.00 | −0.06 |
| Constant | 0.70 | 1.11 | 0.36 | 1.63 | 0.88*** | 2.61 |
| Long-run coefficient e-sales | 1.91** | | 1.79** | | 0.40 | |
| # of observations | 931 | | 960 | | 480 | |
| # of groups | 124 | | 128 | | 64 | |
| # of instruments | 103 | | 103 | | 80 | |
| AR (1) test (*p*-value) | 0.00 | | 0.00 | | 0.01 | |
| AR (2) test (*p*-value) | 0.89 | | 0.41 | | 0.06 | |
| Hansen test of overid. restr. (*p*) | 0.359 | | 0.276 | | 0.948 | |

*Note:* The groups of industries include the (i) ICT producers, (ii) consumer manufacturing, (iii) intermediate manufacturing, (iv) investment goods, (v) distribution and (vi) finance and business except real estate. The country group encompasses: AT, DE, DK, FI, IT, the NL, NO, PL, SE, and the UK. The table reports two-step GMM results with the Windmeijer correction for small samples. The e-sales variable is treated as predetermined (endogenous).

* Denotes significance at the 10 per cent level.
** Denote significance at the 5 per cent level.
*** Denote significance at the 1 per cent level.

as it could be affected by definitional changes (in the EU-harmonised ICT usage survey) and uneven coverage across countries over time.

Third, it is possible that the effect of e-sales depends on the underlying infrastructure at hand or complementary factors, such as workforce skills or organisational changes. Combinations of different types of ICT and e-commerce may also render a larger impact on labour productivity growth. Unlike the variable pertaining to employees with broadband internet access – which is clearly significant when used as an instrument for e-sales – unreported results reveal that interaction terms between this and other ICT indicators and the e-sales variable are not significant. Ideally, more stringent variables for the underlying (internal and external) ICT systems would have been preferred as instruments for e-sales. Such variables only exist for a short period of time that unfortunately coincides with the economic crisis period, making them particularly unsuitable for this context.

Our fourth concern is the omitted-variables bias. To account for this, we include a number of variables other than capital stock that may affect labour productivity, such as skills and innovation activities. Unreported results show that the effects of e-sales activities remain robust when different types of technological innovations are included. Finally, we investigate whether the link between e-sales activities and labour productivity remains stable during and after the economic and financial crisis. Here, we augment the dynamic specification with an interaction term between the e-sales variable and the period 2009–2010. The unreported results are not significant at conventional levels for both the industry and size class/industry datasets.

## 6. Conclusions

This study adds to the literature by presenting patterns of and first insights into the productivity effects of e-commerce activities across Europe. To the best of our knowledge, this has not been explored previously in these dimensions for a large group of industries and countries. E-sales, measured as the proportion of firms taking part in this activity, is the main variable in focus. While engagement in e-sales is still not widespread, it is more frequently used by large firms, high-productivity firms, and firms with international experience. The proportion of e-sales continues to grow over time from its low initial level.

In this study, we estimate the relationship between labour productivity growth and firms engaging in e-sales activities based on a sample of micro-aggregated and linked firm-level data covering 14 European countries for the period 2002–2010. The empirical results show that a change in e-sales activities and labour productivity growth are significantly and positively related when controlling for industry, time, and country effects. All of the results are robust across the different specifications and estimation methods used (OLS, the robust regression method and system GMM). The OLS estimates based on a difference specification show that an increase in e-sales will raise the rate of labour productivity by 0.3 percentage points over a two-year period, with a larger impact on service industries despite similar levels of adoption. Hypothetically, this could be explained by the different production modes at hand, which would imply that the most beneficial adoption intensity varies among industries. Dynamic panel data estimates reveal that the increase in e-sales activities accounts for 18 per cent of the labour productivity growth witnessed during the period 2003–2010.

Interestingly, the effects of e-sales are more substantial for small firms than for medium-sized or large firms. This could imply that, in contrast to larger enterprises, small firms still have gains to reap from the use of online sales systems. Further, our analysis indicates that the relationship between e-sales activities and productivity growth may have changed during the economic crisis: When this period is estimated separately, the significant and positive estimates disappear. While it is too early to conclude whether this is a temporary or permanent circumstance, it is important to recollect that the number of employees did not change proportionally (due to the employment protection laws in place in most countries) even as the demand shock of the crisis years led to a dramatic drop in sales, which left labour productivity to dwindle. The results of both the static and the dynamic estimations point unambiguously in the same direction, with a certain degree of fluctuation in the magnitude of the estimates among industries and over time.

Given the threshold reasoning – that is, that certain ICT tools need to reach a critical level before they translate into productivity gains – the modest level of e-sales might hold the potential for larger benefits in the future, especially for small firms. The overall stronger effect on service productivity could relate not only to more flexible organisations (in which staff can collaborate without being in the same location), but to opportunities to deliver services online, as well.

Overall, the results indicate that online sales channels are beneficial to growth. Nevertheless, the moderate usage of e-sales in firms could imply that the costs or legal barriers involved are still too high to allow for realisation of a digital single market (as called for by the Digital Agenda for Europe, which is part of the EU 2020 initiative).[8]

There are several directions future research might take in this field. One possible extension involves investigating the employment impacts of e-commerce activities. The labour productivity effects of e-commerce activities are not necessarily positive, entailing the creation of new jobs; an expansion of such activities could just as well destroy jobs. In particular, moderately skilled or unskilled workers are likely to be more affected by e-commerce activities than are highly skilled workers (Michaels et al., 2014).

Another interesting potential path for future work would include whether complementary factors other than ICT usage, skills, and organisational changes affect the strength of the relationship between e-commerce activities and labour productivity growth. For instance, e-commerce data could be used for marketing purposes and market research (Ramanathan et al., 2012). The impact of e-commerce may be higher when combined with intangible assets (Corrado et al., 2014). A longer time series would also produce more conclusive results regarding the periods during and after the financial crisis.

A third alternative would be to study e-sales patterns and impacts based on data for countries outside Europe (including developing countries). Hypothetically, there are opportunities to benefit from e-sales even when the different stages of ICT usage deviate from what has been known for European firms and industries.

## Acknowledgements

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**Table A1**
Average proportion of e-sales in firms. *Per cent.*
*Source*: ESSLait Micro Moments Database.

| | AT | DE | DK | FI | FR | IE | IT | LU | NL | NO | PL | SE | SI | UK |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2003 | 4.2 | 1.6 | 2.9 | 5.2 | n.a | 2.5 | 2.1 | 17.3 | 2.5 | 23.2 | n.a | 19.5 | 4.8 | 1.7 |
| 2004 | 3.8 | 2.1 | 3.5 | 5.9 | n.a | 2.3 | 13.4 | 13.0 | 2.3 | 23.1 | 2.0 | 22.2 | 4.7 | 3.0 |
| 2005 | 5.0 | 2.9 | 3.9 | 6.6 | n.a | 4.7 | 15.6 | 21.9 | 3.3 | 24.0 | 4.2 | 23.4 | 5.1 | 4.6 |
| 2006 | 5.7 | 3.5 | 9.9 | 6.8 | 8.5 | 5.0 | 15.7 | 32.5 | 5.1 | 22.5 | 3.3 | 25.8 | 4.2 | 5.0 |
| 2007 | 7.0 | 7.5 | 7.1 | 7.5 | 10.6 | 6.5 | 15.8 | 27.9 | 6.4 | 28.8 | 4.2 | 28.6 | 4.2 | 5.6 |
| 2008 | 6.3 | 8.1 | 7.1 | 8.2 | 9.1 | 4.2 | 15.1 | 30.8 | 4.2 | 28.1 | 3.9 | 29.1 | 4.8 | 7.0 |
| 2009 | 8.2 | 9.7 | 6.5 | 8.9 | 8.1 | 7.0 | 19.0 | 29.5 | 12.4 | 30.3 | 5.9 | 30.4 | 5.3 | 10.1 |
| 2010 | 7.7 | 8.6 | 3.1 | 9.4 | 8.6 | 7.6 | n.a. | n.a. | 5.7 | 23.6 | 5.7 | n.a. | 6.0 | 10.5 |

*Note:* In 2010 the question relating to variable AESVALPCT measuring e-sales as a proportion of total sales became voluntary to include in the EU-harmonised questionnaire.

**Table A2**
Impact on labour productivity of change in proportion of e-sales activities *System GMM estimates.*
*Source*: ESSLait Micro Moments Database and own calculations.

| Industry | Manufacturing | | Services | |
|---|---|---|---|---|
| | Coeff. | *t* | Coeff. | *t* |
| Log labour productivity t-1 | 0.83*** | 12.64 | 0.81*** | 7.77 |
| Share of e-sales t-1 | 0.25* | 1.97 | 0.33* | 1.66 |
| Year dummies | yes | | yes | |
| Constant | 0.67* | 2.71 | 0.72* | 1.74 |
| Long-run coefficient | 1.40* | 1.92 | 1.74 | 1.62 |
| # of observations | 1497 | | 779 | |
| # of groups | 207 | | 108 | |
| # of instruments | 160 | | 85 | |
| AR (1) test (*p*-value) | 0.00 | | 0.00 | |
| AR (2) test (*p*-value) | 0.10 | | 0.02 | |
| Hansen test of overid. restrictions | 0.233 | | 0.598 | |
| Hansen test excluding group | 0.258 | | 0.433 | |
| Difference (null H=exogenous)[a] | 0.318 | | 0.798 | |

*Note:* The group of industries include NACE rev 1.1: 15a6, 17t9, 20, 21, 22, 23a4, 25, 26, 27, 28, 29, 30a3, 31, 32, 34, 35, 36a7, 50, 51, 52, 60t3, 64, 71a4, 72, 73. The country group includes: AT, DE, DK, FI, FR, IE, IT, LU, the NL, NO, PL, SE, SI and the UK. The table reports two-step GMM results with the Windmeijer correction for small samples. The e-sales variable is treated as predetermined (endogenous). The Hansen J test checks for the validity of instrumental variables.

* Denotes significance at the 10 per cent level.

*** Denotes significance at the 1per cent level.

[a] reports difference-in-Hansen tests of exogeneity of GMM instruments for levels.

[8] http://ec.europa.eu/digital-agenda/en/our-goals/pillar-i-digital-single-market

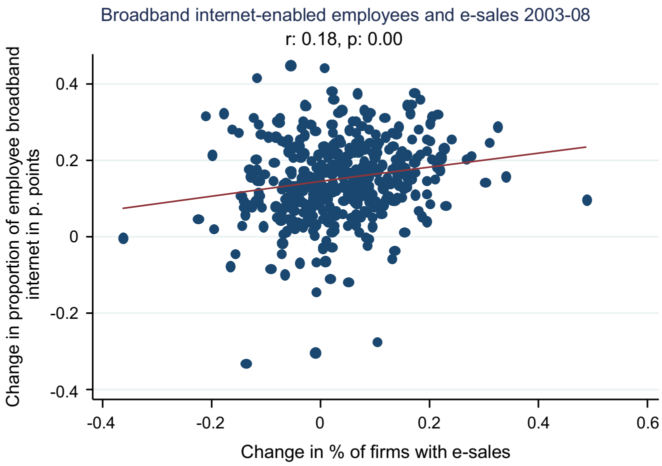


**Diagram A1.** Correlation between change in e-sales and change in broadband employees. *Note:* The sample is based on industry level data for 13 EU countries (AT, DE, DK, FI, IE, IT, LU, the NL, NO, PL, SE, SI and the UK). FR is excluded due to break in time series. The following industries are included: NACE rev 1.1 15a6, 17t9, 20, 21, 22, 23a4, 25, 26, 27, 28, 29, 30a3, 31, 32, 34, 35, 36a7, 50, 51, 52, 60t3, 64, 71a4, 72 and 73.
*Source:* ESSLait Micro Moments Database.

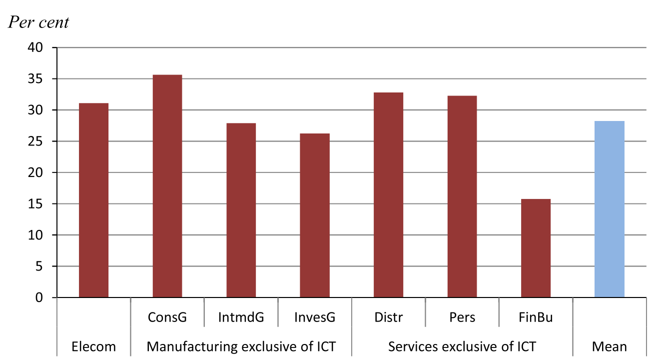


**Diagram A2.** E-selling firms by industry in 2010. *Note:* Average for 14 countries: AT, DE, DK, FI, FR, IE, IT, LU, the NL, NO, PL, SE, SI and the UK. Elecom represents ICT producing industries while ConsG, IntmdG and InvesG are manufacturers producing goods for consumers, intermediate use and for investments, respectively. The services sector includes Distribution, Personal services and Financial business services (Distr, Pers and FinBu).
*Source:* ESSLait Micro Moments Database.

## Appendix A.

See Appendix Tables A1 and A2 and Diagrams A1 and A2.

**Table B1**
EUKLEMS Industry definitions (NACE 1.1).

| | |
|---|---|
| TOT | Total economy |
| 15t37 | Manufacturing |
| 15a6 | Food, beverages and tobacco |
| 17t9 | Clothing |
| 20 | Wood and of wood and cork |
| 21a2 | Pulp, paper, publishing |
| 21 | Pulp, paper and paper |
| 22 | Publishing and printing |
| 23t25 | Refining, chemicals, and rubber |
| 23a4 | Refining and chemicals |
| 25 | Rubber and plastics |
| 26 | Other non-metallic mineral |
| 27a8 | Metals and machinery |
| 27 | Basic metals |
| 28 | Fabricated metal |

**Table B1** (*continued*)

| | |
|---|---|
| 29t33 | Machinery and equipment |
| 29 | Machinery, nec |
| 30t3 | Equipment |
| 30a3 | Office, accounting and computing machinery; sc. eqpt. |
| 31 | Electrical equipment |
| 32 | Electronic equipment |
| 34a5 | Motor vehicles and transport equipment |
| 34 | Motor vehicles, trailers and semi-trailers |
| 35 | Transport equipment |
| 36a7 | Misc manufacturing |
| 40a1 | Electricity, gas and water supply |
| 45 | Construction |
| 50t74 | Market services |
| 50t5 | Trade, hotels, restaurants |
| 50t2 | Trade, hotels, restaurants |
| 50 | Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel |
| 51 | Wholesale trade and commission trade, except of motor vehicles and motorcycles |
| 52 | Retail trade, except of motor vehicles and motorcycles; repair of household goods |
| 55 | Hotels and restaurants |
| 60t4 | Transport and communications |
| 60t3 | Transport |
| 64 | Post and telecommunications |
| 65t7 | Banking |
| 70t4 | Real estate and bus services |
| 70 | Real estate activities |
| 71t4 | Business services |
| 71a4 | Renting of machinery and equipment; oth. bus. svc. |
| 72 | Computer and related activities |
| 73 | Research and development |
| 75t99 | Social services |
| 75 | Public admin and defence; compulsory social security |
| 80 | Education |
| 85 | Health and social work |
| 90t3 | Personal services |
| 90t3x | Personal services excl. media |
| 921t2 | Media activities |

**Table B2**
EUKLEMS ALT Industry definitions.

| ALT | Description |
|---|---|
| Elecom | Electrical machinery, Post and communication services |
| MexElec | Total Manufacturing, Excluding Electrical |
| ConsG | Consumer manufacturing |
| IntmdG | Intermediate manufacturing |
| InvesG | Investment goods, excluding hightech |
| OtherG | Other production |
| MServ | Market services, excluding post and telecommunications |
| Distr | Distribution |
| FinBu | Finance and business, except real estate |
| Pers | Personal services |
| NonMar | Non-market services |

## Appendix B. Industry classifications

See Appendix Tables B1 and B2.

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