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Efficiency impact of ICT and the role of Product Market Regulation: Sectoral Analysis across a panel of EU economies

Sophia P. Dimelis[a] and Sotiris K. Papaioannou[b]

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[a] Athens University of Economics and Business, Address: 76 Patission Street, 10434 Athens, Greece, Phone Number: +30-210-8203237 e-mail: dimelis@aueb.gr.
[b] Centre of Planning and Economic Research, Address: 11 Amerikis Street, 10672 Athens, Greece, Phone Number: +30-210-3676426, e-mail: sopa@kepe.gr.

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Οι επιπτώσεις των Τεχνολογιών Πληροφορικής και Επικοινωνίας στη τεχνική αποτελεσματικότητα και ο ρόλος των ρυθμίσεων στις αγορές προϊόντων: Τομεακή ανάλυση σε επιμέρους οικονομίες της Ευρωπαϊκής Ένωσης

Σοφία Δημέλη & Σωτήρης Παπαϊωάννου

ΠΕΡΙΛΗΨΗ

Σε αυτή την εργασία διερευνάται κατά πόσον η διάχυση των Τεχνολογιών Πληροφορικής και Επικοινωνίας (ΤΠΕ) έχει επηρεάσει την τεχνική αποτελεσματικότητα των τομέων της μεταποίησης και των υπηρεσιών σε επιμέρους οικονομίες της Ευρωπαϊκής Ένωσης. Επίσης, δεδομένου ότι στις περισσότερες χώρες παρατηρήθηκαν σημαντικές αλλαγές στο ρυθμιστικό περιβάλλον, οι οποίες μπορεί να έχουν επηρεάσει τη διάδοση των ΤΠΕ, η προσέγγιση που ακολουθείται ενσωματώνει και τις επιπτώσεις ενός δείκτη ρύθμισης στις αγορές προϊόντων στην αποτελεσματικότητα των επιμέρους τομέων. Για τη διεξαγωγή της εμπειρικής ανάλυσης χρησιμοποιούνται στατιστικά δεδομένα από εννέα οικονομίες της Ευρωπαϊκής Ένωσης κατά την περίοδο 1995-2005 ενώ εκτιμάται ταυτόχρονα μια στοχαστική συνάρτηση παραγωγής και ένα υπόδειγμα τεχνικής αναποτελεσματικότητας. Οι οικονομετρικές εκτιμήσεις αναδεικνύουν μια έντονα αρνητική επίδραση των επενδύσεων σε ΤΠΕ (κυρίως των επενδύσεων σε λογισμικό και εξοπλισμό επικοινωνιών) στην τεχνική αναποτελεσματικότητα, κυρίως στους τομείς των υπηρεσιών. Οι επιπτώσεις των ΤΠΕ παραμένουν αρνητικές και στατιστικά σημαντικές ακόμα και μετά από την ενσωμάτωση του δείκτη ρύθμισης στις οικονομετρικές εκτιμήσεις. Ο αντίκτυπος, ωστόσο, του δείκτη ρύθμισης δεν είναι ομοιόμορφος και ποικίλλει σε μέγεθος και στατιστική σημαντικότητα μεταξύ των επιμέρους τομέων.

CONTENTS

ABSTRACT

In this paper we explore whether the diffusion of Information and Communication Technologies (ICT) has affected technical inefficiency in manufacturing and service sectors for a number of EU economies. Also, given that in most countries significant changes were observed in the regulatory environment, which may have affected the ICT diffusion, an integrated approach is followed by incorporating the impact of Product Market Regulation (PMR) in estimating technical efficiency gains. The overall ICT effect is further elaborated by breaking it down to the effects of its components: that is computing equipment, communications' equipment and software. A stochastic production frontier is simultaneously estimated with a technical inefficiency model, using manufacturing and service sectors data for nine EU economies in the period 1995-2005. The estimates indicate a strongly negative impact of ICT capital (in particular software and communications' equipment) on technical inefficiency in most EU service sectors. The ICT effects remain robust after accounting for the degree of regulation through the inclusion of PMR. The impact of PMR however is not uniform and varies in size and statistical significance across sectors.

JEL classification: O30, O43, O52

Keywords: ICT, Product market regulation, Technical efficiency, Stochastic frontier analysis

1 Introduction

The emergence of Information and Communication Technologies (ICT) in the second half of the 90s has been considered as a major factor for higher labor productivity growth witnessed in the US, as well as in several EU countries (Van Ark et al. 2003). Although ICT is a technology readily available in world markets, it seems that only few countries have managed to fully realize the benefits from its use. This partly reflects the existence of different institutions and policies among countries which, in turn, influence the firms' decisions to invest and introduce ICT in the production process.

It has been argued that the incentive to invest in ICT in order to increase productivity and retain market share may be stronger in sectors characterized by high competitive pressures as compared to sectors which remain protected from competition. In this spirit, Conway et al. (2006) have shown that anti-competitive regulation has negatively affected the diffusion of ICT in several OECD countries, with more liberal countries being more successful at incorporating ICT in their economies. Therefore, looking at the effects of ICT on productivity without considering the impact of regulation, as done in most empirical literature, may lead to biased conclusions. Furthermore, the majority of studies so far have either examined the productivity impact of ICT or have investigated the influence of regulation on productivity, without having controlled for possible association between them.

This study attempts to fill the gap of the relevant literature by using an econometric framework in which the effects of ICT and Product Market Regulation (PMR) are jointly considered in a technical inefficiency model, which is simultaneously estimated with a stochastic production frontier. The EU area constitutes a particularly interesting case to study these issues, since large regulation policy changes have taken place in the EU economies during the last 20 years. We, also, contribute in this field by treating ICT as an input which affects growth through the channel of technical efficiency, in contrast to most of the existing studies having so far examined the role of ICT mainly through the channel of capital deepening and labor productivity growth. We further elaborate on the impact of ICT by breaking it down to the effects exerted by its individual components (computing equipment, communications' equipment and software).

In implementing the model, we follow the approach of Battese and Coelli (1995) and estimate simultaneously a stochastic production frontier and a technical inefficiency model using panel data from manufacturing and service sectors in nine EU economies over the period 1995-2005. In this period we observe significant increases in ICT investments in most of the countries and sectors under consideration and, therefore, it would be quite interesting to focus on the effects observed over this period.

The econometric estimates indicate that ICT contributes significantly in reducing technical inefficiency in most service sectors. These results remain robust after controlling for the impact of PMR. Furthermore, the most significant effect is exerted by software and communications' equipment, however their impact is not uniform across sectors. The inefficiency impact of PMR varies in sign and statistical significance across sectors, with a non linear relationship arising in the sectors of wholesale and retail trade and financial intermediation.

The rest of this paper is organized as follows. Sections 2 and 3 summarize the relevant theoretical and empirical literature. Section 4 discusses the econometric specification of the paper. In Section 5 the data are described and some descriptive statistics are shown. Sections 6 and 7 present and discuss the empirical results. Finally, Section 8 concludes.

2 Theoretical background

ICT is considered as a major technological breakthrough which shares all the characteristics of general purpose technologies (Bresnahan and Trajtenberg 1995). Besides standard capital deepening effects of technology investment on labor productivity, capital embodied technological progress brought by general purpose technologies plays a catalyst role in the process of long run economic growth. The economic implementation of ICT requires the development of a wide range of complementary products, such as software and networks. Furthermore, ICT is a technology which has a wide applicability in many uses and sectors of the economy. Although the rapid change and wide reach of ICT requires costly adjustment (capital obsolescence, creation of complementary products and skills training) at initial stages of implementation, the long run economic impact of ICT is expected to be of high importance[1].

Some characteristics of ICT that might affect economic efficiency include trade of goods and services at low cost, leading to gains through scale economies and realization of comparative advantage (Harris 1995). Other benefits include low transaction costs, efficient management of information,

[1] The case of the US economy constitutes a representative example with TFP and labor productivity losses in the 80s and the first years of the 90s.

reduction of operational costs, improved business to business communications, as well as reorganization of production and distribution of goods and services.

The decision to invest in ICT may be stronger in sectors characterized by lower regulation. The existing theoretical literature argues that market regulation can influence productivity by distorting the incentives to invest in new technologies. Parente and Prescott (1994) assumed a model of technology adoption where the decision of a firm to invest in technology depends on the degree of legal and regulatory barriers, the existence of which increases the cost of technology adoption. Alesina et al. (2005) argue that fewer regulations lower the cost of expanding capital stocks of firms and argue that the cost of reorganizing the production process after adoption of a new technology is lower in regulatory friendly environments.

Acemoglu et al. (2006) showed that institutions and policies which are designed towards technology adoption in backward economies may not be appropriate for economies closer to the productivity frontier[2]. They argue that it is optimal for countries which are away from the productivity frontier to rely on factor accumulation and adoption of foreign technology, which can both prosper under conditions of limited competition. In more advanced countries where the possibilities for further growth through factor accumulation and imitation have been exhausted, innovation becomes the main vehicle for higher growth. To the extent that a higher innovation rate depends on higher competition, countries should move to more competitive patterns.

Aghion and Griffith (2005) argue that still economics has a limited and contradictory understanding on the effects of competition on innovation and economic growth. On the one hand there exist theoretical arguments in favor of a negative effect of competition. The early Schumpeterian view stresses that competition discourages innovation, since it reduces post entry rents. In the same spirit, endogenous models of economic growth predict that engaging in R&D and innovation is the result of property right protection of patents (Romer 1990; Grossman and Helpman 1991; Aghion and Howitt 1992).

However, more recent views argue that competition enhances growth since it forces firms to innovate in order to retain their market shares. In particular, neo-Schumpeterian analyses show that

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[2] Aghion et al. (2006) argue that the post war catching-up of the European economies to the US slowed down as the relative technology gap narrowed. They argue that policies and institutions which were designed towards technology adoption are not now appropriate for most European economies which are now closer to the technology frontier and, therefore, they stress the need for policies in favour of higher competition in the markets, which in turn will affect positively innovation and growth.

there exists an inverse-U relationship between competition and innovation (Aghion et al. 2005). Essentially, at low stages of competition, an increase in competition will increase innovation, since the escape competition effect dominates the Schumpeterian effect and pushes firms in an industry to innovate in order to avoid losing market shares. At higher levels of competition, the Schumpeterian effect is more likely to dominate, so that an increase of competition will result in lower innovation activity. Therefore, an increase of competition would have a positive impact on growth, at low levels of competition. At higher levels of competition, the growth effect diminishes, as competition increases.

3 Empirical literature

Recent literature has verified the significant impact of ICT on growth and productivity in both the USA and the EU (Van Ark et al. 2003; Inklaar et al. 2008). However, the impact of ICT differs across countries, with higher effects observed either in countries with high levels of ICT capital (Ketteni, Mamuneas and Stengos 2007) or in countries with high levels of human capital (Ketteni, Mamuneas and Stengos 2011).

Earlier empirical studies conducted at the firm level (Lee and Barua 1999; Milana and Zeli 2002; Becchetti et al. 2003) or at the cross country level (Thompson and Garbacz 2007; Repkine 2008) provided preliminary evidence in favor of a positive link between ICT and higher efficiency. These results have also been verified with panel data from developed and developing countries (Dimelis and Papaioannou 2011). More recently, Grimes et al. (2012) studied the effects of broadband access on productivity at the firm level. Their results indicated that broadband adoption boosts firm productivity on average by 7–10%.

The incentives of firms to invest in ICT seem to be highly influenced by institutions and policies that favor competition in product markets. The empirical results of Gust and Marquez (2004), Conway et al. (2006), as well as Van Ark et al. (2008) indicate that differences in policies and institutions have a strong impact in the decisions of firms to adopt new technologies. In this spirit, most of the existing empirical literature has established a positive relationship between productivity and competition. Nickell (1996) as well as Nickell et al. (1997) have shown that higher competition has a positive impact on Total Factor Productivity (TFP). Hay and Liu (1997) based on an empirical study of UK manufacturing firms, showed that in a more competitive environment, firms have a strong incentive to increase their investments in order to improve their efficiency performance.

Christopoulos and Tsionas (2001) have provided quantitative evidence that efficiency improves drastically in the period after deregulation. Nicoletti and Scarpetta (2003) looked at the effects of regulation on productivity of manufacturing and services across 18 OECD countries for the period 1984-1998. Their results showed that market regulation on its own had no impact on productivity. However, when interacted with the technology gap, the estimates indicated that that lower regulation helps industries catch up with the technology frontier. Tsionas and Papadogonas (2006) examined how technical inefficiency is related to firm exit and found significant positive effects from technical inefficiency on the probability of exit of firms.

Arnold et al. (2008) provided industry level evidence that tight market regulations in service sectors of continental EU countries affect productivity growth by hindering the allocation of resources towards most efficient firms. Barone and Cingano (2011) indicated that lower regulation increases the growth rate of value added, productivity and exports of manufacturing industries in OECD countries. Finally, Bena et al. (2011) showed that the higher degree of liberalization had a positive impact on TFP growth of European network firms, during the period 1998-2007.

From the above literature review it can be concluded that the majority of empirical studies so far have either examined the productivity impact of ICT or have investigated the influence of regulation on productivity, without having controlled for possible association between them. This study attempts to fill the gap of the relevant literature by using an econometric framework in which the effects of ICT and regulation are jointly considered in a technical inefficiency model, which is simultaneously estimated with a stochastic production frontier.

4 Econometric specification

In this study, we follow stochastic frontier analysis, as it enables us to disentangle inefficiency effects from the stochastic errors.[3] We base our analysis on the model specification proposed by Battese and Coelli (1995) in which the technical inefficiency model is simultaneously estimated with the stochastic production frontier model at one stage[4]. In this context, we model for the existence of unobserved inefficiency across countries in a given sector with a stochastic frontier model described as follows:

[3] Stochastic methods are able to distinguish the error component from non negative inefficiency, but they assume the same production technology across production units. On the other hand, non-parametric methods, like the Data Envelopment Analysis, do not impose this restriction, however the distinction between inefficiency and the stochastic term is not feasible.

[4] In earlier studies, a two-stage estimation procedure was used, where the production frontier and

$$Y_{it} = f(X_{it};\beta)\cdot \exp\{V_{it}\}\cdot TE_{it} \quad (1)$$

where Y_{it} is the output of country *i* at time *t*, X_{it} is a vector of production inputs and β are the production function parameters to be estimated. $f(X_{it};\beta)$ is the production frontier, common to all countries in a given sector, while $\exp\{V_{it}\}$ is a stochastic component that describes random shocks to production, which are country specific. Consequently, $f(X_{it};\beta)\cdot \exp\{V_{it}\}$ forms the stochastic production frontier, with TE_{it} being the output oriented technical efficiency of each country in a given sector. TE_{it} can be described as:

$$TE_{it} = Y_{it} / f(X_{it};\beta)\cdot \exp\{V_{it}\} \quad (2)$$

with Y_{it} reaching its most efficient level, equal to $f(X_{it};\beta)\cdot \exp\{V_{it}\}$, when TE_{it} = 1. When TE_{it} < 1, we observe a deviation of output from its most efficient level. A common assumption is that technical efficiency is a positive random variable, denoted as $TE_{it} = \exp\{-U_{it}\}$. Therefore, output is expressed as:

$$Y_{it} = f(X_{it};\beta)\cdot \exp\{V_{it}\}\cdot \exp\{-U_{it}\} = f(X_{it};\beta)\cdot \exp\{V_{it} - U_{it}\} \quad (3)$$

Using a Cobb Douglas production function for each individual sector, we can express output of equation (3) as:

$$Y_{it} = A\, e^{\lambda t}(L_{it})^{\beta 1}(K_{it})^{\beta 2}\exp^{(V_{it} - U_{it})} \quad (4)$$

with *Y* denoting output (value added in 2000 prices in this case). *A* is the level of existing technology, λ is the rate of technical change and *t* is a time trend which captures technical progress over time. *L* is the labor input expressed as the number of full time equivalent persons employed and *K* is the capital input, measured as the value of total physical capital stock (in 2000 prices). The parameters β_1 and β_2 are the value added elasticities of labor (*L*) and capital (*K*), respectively. V_{it} and U_{it} are the two components of the error structure, which compose the main feature of the stochastic frontier. In particular, V_{it} is a

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efficiency measures were estimated at the first stage and then the efficiency levels were regressed on a number of explanatory variables, assumed to influence efficiency. However, this two stage estimation procedure has serious drawbacks if the vector of efficiency variables is correlated with the vector of production function parameters, rendering the coefficient estimates of the production function biased (Kumbhakar and Lovell 2000; Wang and Schmidt 2002).

standard random residual assumed to be i.i.d. following a normal distribution $N(0, \sigma_v^2)$. U_{it} is a nonnegative random error, associated with technical inefficiency of production and assumed to be independently distributed of V_{it}. Thus, U_{it} has an asymmetric distribution equal to the upper half of the $N(0, \sigma_u^2)$ distribution. After taking a logarithmic transformation of equation (4), value added in each sector can be expressed as:

$$\ln(Y_{it}) = \beta_0 + \lambda t + \beta_1 \ln(L_{it}) + \beta_2 \ln(K_{it}) + V_{it} - U_{it} \quad (5)$$

As a way to study the influences of ICT and PMR on technical inefficiency, we model the mean μ_{it} of the truncated distribution of U_{it} as follows:

$$\mu_{it} = \delta_0 + \delta_1 \text{ ICT} + \delta_2 \text{ PMR} + W_{it} \quad (6)$$

where ICT is the share of ICT capital in total physical capital and PMR an indicator ranging from 0 to 6 with higher values implying more restrictive product market regulation. W_{it} is a random variable, defined by the truncation of the normal distribution. Equation (6) includes a time trend to control for common productivity shocks in each sector, while country dummies are also considered in this model to account for unobserved country specific effects[5].

All parameters included in the log linear production function (5) and the technical inefficiency model (6) along with the models' variances $\sigma^2 = \sigma_v^2 + \sigma_u^2$ and $\gamma = \sigma_u^2 / (\sigma_v^2 + \sigma_u^2)$ are estimated simultaneously at one stage by using maximum likelihood[6]. By applying likelihood ratio tests several hypotheses can be tested. Such an important hypothesis is whether $\gamma=0$. A rejection of the null hypothesis that $\gamma=0$, against the alternative that $\gamma>0$ would imply that deviations from the frontier are due to inefficiency effects.

The technical efficiency level for a country *i* in a given sector at time *t* is given by:

$$TE_{it} = \exp(-U_{it}) \quad (7)$$

However, U_{it}'s are not observable since they are a portion of the estimated residuals $\varepsilon_{it} = V_{it} - U_{it}$. Battese and Coelli (1993) suggest to use as predictor of the technical efficiency level TE_{it} its conditional expectation given the random variable ε_{it}:

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[5] We should note that there exist several other variables which might affect inefficiency and could be included in equation (6), like, for example, foreign direct investment flows, as well as, the degree of trade openness. However, it was not possible to find data describing these variables for all countries and sectors.

[6] The parameter σ^2 is the overall variance of the error term, σ_v^2 is the variance of V_{it}, while σ_u^2 is the variance of the inefficiency term U_{it}.

$$T\hat{E}_{it} = E\left[\exp\left(-U_{it}\right)| \varepsilon_{it}\right] = \left\{\exp\left[-\mu_{it} + \frac{1}{2}\bar{\sigma}^2\right]\right\} \cdot \left\{\Phi\left[\frac{\mu_{it}}{\bar{\sigma}} - \bar{\sigma}\right] / \Phi\left[\frac{\mu_{it}}{\bar{\sigma}}\right]\right\} \quad (8)$$

where Φ(.) is the distribution function of the standard normal,($\varepsilon_{it} = V_{it} - U_{it}$), $\mu_{it} = (1-\gamma) \cdot \left[\delta + \sum_{j=1}^{n} \delta_j z_{j,it}\right] - \gamma\, \varepsilon_{it}$, and $\bar{\sigma}^2 = \gamma(1-\gamma)\sigma^2$. By substituting the unknown parameters in equation (8) with the maximum likelihood estimates, we obtain estimates of the technical efficiency levels for each country *i* in a given sector at time *t*.

5 Data, descriptive statistics and stylized facts

The empirical analysis of this paper is based on data from manufacturing and four service sectors (wholesale & retail trade, hotels & restaurants, financial intermediation and real estate, renting & business activities) of nine EU countries (Austria, Czech Republic, Denmark, Finland, Germany, Italy, Netherlands, Spain and the United Kingdom). The choice of sectors and countries is based on the availability of data and time spans over the period 1995-2005.

Data regarding ICT were provided by the EU KLEMS database[7]. From the figures reported in Table 1, we can see that the share of ICT capital in total physical capital has more than tripled in most sectors and countries under consideration between1995-2005. Furthermore, we are able to distinguish that, in 2005, the highest use of ICT capital was observed in Denmark, Finland and the UK, while the lowest one in Italy and Spain. The service sector with the highest use of ICT is by far the financial intermediation sector (ICT capital shares range on average from 16% in Austria to 66% in Finland), followed by wholesale and retail trade (average shares range from 4.4% in Spain to 20.5% in Denmark). The sectors of manufacturing, hotels and restaurants, as well as real estate, renting and business activities show relatively lower shares of ICT in total physical capital.

As a measure for the degree of regulation we use the OECD indicator of PMR in network industries, which summarizes regulatory conditions in seven network services: electricity and gas, post and telecommunications, road freight, railways and airlines. It is a time varying indicator and covers a number of regulatory areas such as barriers to entry, state control, price controls and market structure in the sectors of electricity, transports and communications. It ranges from 0 to 6, with higher values of

[7] For further details, see Timmer et al. (2007).

this indicator implying more restrictive regulatory environments. Details about the construction of this index can be found in Conway and Nicoletti (2006).

The main advantage of this indicator is its time dimension, including sectors in which much anti-competitive regulation is concentrated for most OECD countries. Although this indicator covers certain industries, it can be used as a proxy for assessing the impact of the economy wide regulatory environment (Scarpetta and Tressel 2002; Conway et al. 2006) since it is highly correlated with the economy wide PMR indicator in the years in which they overlap (Conway et al. 2006). A further advantage of this indicator is that it can be treated as an exogenous measure of regulation, which is not affected by productivity outcomes.

From Figure 1, it is clear that the degree of PMR has decreased significantly between 1998 and 2005 in all EU countries included in the sample. It is also evident that the degree of PMR was relatively high in 1998 in Italy, Czech Republic, Spain and Austria. Moderate degrees of PMR were observed in Denmark, Netherlands, Finland and Germany, while the UK was the only country which already had a low degree of product market restrictions in 1998. The UK and Denmark were the less restrictive countries in 2005, with 0.9 and 1.2 scores, respectively, while Finland and the Czech Republic were the most restrictive ones with scores above 2.0. Although the PMR indicator has decreased in European economies, it seems that considerable divergence still exists between countries.

The data for gross value added, physical capital and employment in each sector were taken form the OECD STAN Industrial Database (2012). Table 2 provides a definition of all variables used in the empirical analysis, while Table 3 shows selected descriptive statistics for all variables used in the econometric analysis.

6 Empirical results

6.1 Main econometric estimates

Table 4 presents the maximum likelihood estimates of the stochastic production frontier and of the inefficiency model for the pooled sample of all sectors. The production function regression includes the inputs of labor (L) and physical capital (K), as well as a time trend (*t*) to proxy for technological progress. The technical inefficiency equation is simultaneously estimated using as basic regressors the ratio of ICT capital to total physical capital (ICT), the degree of regulation (PMR), as well as a time trend to account for the existence of common time effects on technical inefficiency (*t*). Country and industry specific dummies are considered in this model to account for unobserved country and industry specific effects.

To determine whether deviations from the estimated frontier are due to inefficiency effects, we test the null hypothesis that $\gamma=0$, against the alternative that $\gamma>0$. As it is evident, the parameter γ is positive and statistically significant. This implies the existence of inefficiencies and justifies the econometric estimation of the parameters related to technical inefficiency.

The econometric results of column 1 show that a rise in the share of ICT capital contributes significantly in reducing inefficiencies in all sectors and countries under consideration. In column 2 of Table 4, PMR has been included as a regressor in the technical inefficiency equation. The results indicate the existence of a negative but not statistically significant impact of market regulation on technical inefficiency. In column 3, the regression is extended to cover both the impact of ICT, as well as the impact of PMR, while, in column 4, the quadratic term PMR^2 is introduced to account for non-linear effects from PMR, as documented in section 2 earlier. The econometric results of columns 3 and 4 still indicate the existence of a significantly negative relationship between information technology and technical inefficiency. These effects seem to be robust to the presence of market regulation as captured by the PMR indicator in the inefficiency equation. Results of Table 4 further indicate the absence of any linear or quadratic effects of PMR on technical inefficiency.

Overall, the regression estimates reported in Table 4 are in favor of the hypothesis that more ICT capital helps in the reduction of inefficiencies observed among sectors and countries under consideration. However, in these regressions, we have implicitly imposed the same production technology across all sectors. This is probably an unrealistic assumption, given the large heterogeneity among sectors in terms of productivity performance and ICT diffusion and, therefore, pooling all sectors together in econometric analysis cannot be sufficiently justified (Inklaar et al. 2008).

We continue our empirical investigation by explicitly recognizing the existence of industry heterogeneity. Tables 5 to 9 present the maximum likelihood estimates of the stochastic production frontier and of the inefficiency model for each sector. In all regressions, we have introduced country dummies to control for the existence of country specific effects.

The results of Table 5 refer to the manufacturing sector and are not in agreement with the effects estimated from the pooled sample. In fact, the estimates of the impact from ICT turn out to be insignificant, as opposed to PMR that seems to exert a significantly negative effect on inefficiency (columns 2 and 4). The estimates in column 4 indicate that this effect is linear as the coefficient of the quadratic term (PMR^2) is statistically insignificant.

Table 6 presents the maximum likelihood estimates for the sector of wholesale and retail trade. Here, we find strong evidence that the share of ICT capital contributes significantly in reducing inefficiencies in this sector. This result is verified in all regression estimates and irrespective of the presence of PMR, indicating that ICT is an important factor for the elimination of technical inefficiency in wholesale and retail trade. The results with respect to PMR are negative and statistically significant (columns 3 and 4), while the sign of the quadratic term is positive and statistically significant (column 4) indicating the existence of a U-shaped relationship between PMR and inefficiency.

The results shown in Table 7 indicate that the impact of ICT on technical inefficiency of hotels & restaurants is negative but not statistically significant. When taking account for the existence of linear and non-linear effects of regulation (column 4), we obtained a positive and statistically significant (at 10%) coefficient estimate of PMR and a negative and statistically significant estimate of its quadratic term. However, the econometric estimates should be regarded with caution in this case, since the null hypothesis that $\gamma=0$ cannot be rejected in any of the regressions.

The evidence from the financial intermediation sector (Table 8) is very similar to what holds in the wholesale and retail sector (Table 6). A strong ICT effect was estimated in all regressions, while the effects from PMR on inefficiency indicate the existence of a U-shaped pattern (Table 8, column 4). Finally, the results in Table 9 indicate that the ICT effect keeps being strong also in the sector of real estate, renting and business activities, but the impact of PMR, although positive and significant without the presence of ICT, it turns insignificant after the inclusion of ICT.

Upon a closer examination of the behavior of PMR in Tables 5-9, it is noteworthy that its impact changes drastically when estimated with the presence of ICT capital. Cross correlation tests have been used to elaborate on the association between PMR and ICT. The results in Table 10 show a significantly negative association between current and lagged levels of PMR {PMR, PMR(-1), PMR(-2)} and ICT in all sectors under consideration and indicate that the diffusion of ICT is highly associated with the degree of regulation. This in turn implies that the impact of PMR might be indirectly affected by its association with ICT.

6.2 Further econometric evidence

After having estimated the overall ICT effect on inefficiency, an interesting question to answer would be whether this impact differentiates between its components. Thus, we go one step further to estimate the impact of the individual components of ICT {computing equipment (COMP), software (SOFT), communications (COMM)} on technical inefficiency. The regression results are presented in Table 11 and in general, are in line with those presented in Tables 5-9.

More specifically, the most negative influence of ICT on technical inefficiency in manufacturing is exerted by software and communications' equipment. In wholesale and retail trade, all ICT components are negatively and significantly associated with technical inefficiency. In hotels and restaurants, we do not observe any significant effect of ICT components on technical inefficiency, while in financial intermediation, software is the only ICT component that exerts a significantly negative impact on technical inefficiency. Finally, in the sector of real estate, renting and business activities, all components of ICT are negatively but not significantly associated with technical inefficiency.

As a further robustness check for our econometric analysis, we re-estimate the model replacing the economy wide PMR indicator with the sectoral regulation impact indicator (REG), which measures the 'knock on' influence of regulation in each sector separately[8]. Brief descriptive statistics on this variable are presented in Table 3. The results are presented in Table 12 and, in general, confirm the existence of a strongly negative influence of ICT on technical inefficiency levels of most service sectors. With respect to the impact of the REG variable, it is insignificant in most of the cases. The only exception is in the sector of hotels and restaurants where we had a significantly (at 10% level of significance) negative estimate for the REG coefficient.

As discussed in Section 4, we can obtain the predictions of technical efficiency by using the conditional expectation defined in equation (8). Table 13 presents average efficiency measures for each of the nine EU countries in sectors under consideration, over the entire period 1995-2005. Germany and Austria are the most efficient countries in manufacturing with average efficiency scores above 99%, while Italy and Spain are the least efficient countries in this sector. Netherlands and Denmark are the most efficient countries in the sector of wholesale & retail trade, with average efficiency scores above 95%, while on the other hand, Italy and Spain, are the least efficient ones with average efficiency

[8] For more details, see Conway et al. (2006).

scores at 67% and 50%, respectively. In the sector of hotels & restaurants, Czech Republic and Italy are the most efficient countries with efficiency measures quite close to 99%.

In the sector of financial intermediation, Finland and Denmark rank top with average efficiency scores at 98% and 83%, respectively. Finally, the most efficient countries in real estate, renting & business activities are Denmark, UK and Netherlands with average efficiency scores above 90%.

7 Discussion

The results of this study provide us with strong evidence that significant benefits exist from the use of ICT capital, associated with higher technical efficiency in a number of EU service sectors. It seems that the strongest impact of ICT is observed in the sectors where the diffusion of ICT is higher (financial intermediation and wholesale & retail trade). On the other hand, in sectors where the ICT diffusion is lower (e.g. manufacturing), the impact of ICT is not statistically significant.

Our results supplement the existing empirical literature in that ICT can affect growth not only through higher capital deepening and higher labor productivity growth, but also through higher technical efficiency. Additional evidence was further derived regarding the impact from each component of ICT on inefficiency by sector. We are in line with recent empirical evidence provided by Dahl et al. (2011) that ICT has affected positively and significantly TFP growth of European sectors after 1995. We also agree with Venturini (2009), having provided evidence in favor of an impact of ICT well above its income share.

It should be noted that there exists significant divergence in terms of ICT diffusion across EU countries and sectors. Uppenberg and Strauss (2010) have shown that service sectors in north Europe (Denmark, Sweden and the UK) allocate 30%-40% of their fixed investment in ICT equipment, as compared to 20% in the rest of the EU. Timmer and Van Ark (2005) complement this evidence by showing that several disparities exist within EU countries, with respect to the benefits from the use of ICT. They argue that northern EU countries have benefited more from ICT use, as opposed to the rest of the EU, where benefits from ICT are much smaller.

More importantly, the estimated negative impact of ICT on inefficiency is robust after controlling for PMR. On the contrary, the impact of PMR on inefficiency is not uniform across sectors. Based on estimates reported in the last columns of Tables 5-9, we have been obtained with negative estimates on the impact of regulation in manufacturing. In wholesale & retail trade, as well as in financial intermediation, a U shaped relationship exists between PMR and inefficiency, with the negative effects decreasing at low or at high levels of regulation. For the sectors of hotels & restaurants and real estate, renting & business activities, we were not obtained with statistically significant estimates.

Insignificant or even negative effects of PMR on technical inefficiency may have been intensified by diverging levels of technical efficiency observed within EU sectors (Table 13). Countries that are close to the technology frontier can survive higher competition by innovating. In contrast, countries which are away from the frontier are in a relatively weaker position to fight increased competition. This view has been supported by Aghion et al. (2003), showing that liberalizing and reducing barriers to entry has a positive effect on economic performance of firms and industries which are initially close to the technology frontier. On the other hand, it has a negligible or even negative effect in firms and industries which are far from the frontier and may be damaged by liberalization.

As discussed earlier, absence of a negative impact of lower regulations on technical inefficiency might partially reflect a significant association between ICT and PMR. This argument has been put forward by Hay and Liu (1997), showing that in a more competitive environment, firms have a strong incentive to increase their investments in order to improve their efficiency performance. The negative association between PMR and ICT in all sectors under consideration (Table 10) confirms the view that the incentive to invest in ICT is stronger at lower levels of regulation (Conway et al. 2006; Van Ark et al. 2008) and although presence of correlation does not necessarily imply the presence of causation, we may assume that indirect effects of PMR on technical inefficiency arise as regulation decreases.

This empirical evidence implies that further examination is needed from academics and policy makers to study in detail the relationship between regulation and efficiency. Van Ark et al. (2008) have noted that the extent as well as the impact of regulatory reforms might vary across countries, given different starting points and patterns of reform, while Alesina et al. (2005) argue that the timing, extent and impact of liberalization differ across countries. They, also, argue that there is evidence that the marginal effects of deregulation are higher when the policy reforms are large or when changes start from already low levels of regulation.

8 Conclusion

In this paper, we examined the role of ICT in reducing technical inefficiency levels of European sectors, controlling for the impact of regulation. We estimated simultaneously a stochastic production frontier and a technical inefficiency model using maximum likelihood econometric techniques. We used panel data from manufacturing and service sectors across nine EU economies for the period 1995-2005.

Our results showed that ICT affects negatively and significantly the levels of technical inefficiency observed in most of the EU service sectors examined**,** with the most negative impact exerted by software and communications' equipment. In this way, we add to the existing literature on the growth effects of ICT, providing evidence that the growth impact of ICT is not confined to its contribution as a traditional form of capital, but rather ICT seems to affect positively the efficiency with which the EU sectors produce.

Although the effects of ICT remain robust after accounting for the degree of regulation, the impact of PMR on efficiency varies in size and statistical significance across sectors. In light of these empirical results, it seems that the association between regulation and productivity is an issue which remains open for further research, as to the impact of liberalization in countries and sectors with different initial levels of competition and diverging productivity performance.

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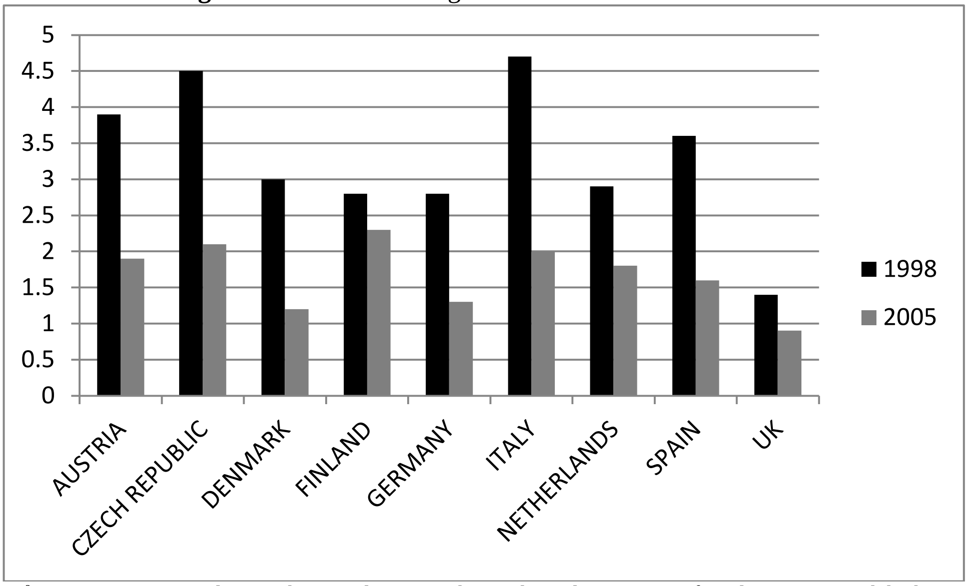
Tables & Figures

Table 1 ICT capital (% of total capital)

	1995	2000	2005	AVERAGE
MANUFACTURING				
AUSTRIA	1.17%	3.63%	7.07%	3.95%
CZECH	1.22%	2.31%	2.65%	2.16%
DENMARK	2.17%	6.11%	8.79%	5.89%
FINLAND	1.94%	3.83%	5.47%	3.57%
GERMANY	2.42%	3.71%	5.01%	3.69%
ITALY	1.35%	2.49%	3.28%	2.35%
NETHERLANDS	2.07%	4.08%	5.16%	3.82%
SPAIN	2.21%	3.48%	4.26%	3.35%
UK	2.57%	5.16%	8.15%	5.18%
WHOLESALE AND RETAIL TRADE				
AUSTRIA	3.12%	9.85%	19.57%	10.62%
CZECH	4.93%	14.24%	13.31%	11.43%
DENMARK	9.53%	21.61%	33.46%	20.48%
FINLAND	7.02%	15.93%	21.10%	14.40%
GERMANY	9.41%	15.49%	19.52%	14.53%
ITALY	3.37%	7.38%	10.21%	6.80%
NETHERLANDS	5.92%	12.89%	19.97%	12.85%
SPAIN	2.24%	4.73%	6.52%	4.41%
UK	10.91%	16.74%	26.14%	17.55%
HOTELS AND RESTAURANTS				
AUSTRIA	1.19%	3.16%	8.11%	3.78%
CZECH	2.25%	1.92%	4.43%	2.96%
DENMARK	7.98%	15.35%	13.32%	13.43%
FINLAND	2.42%	5.85%	8.34%	5.29%
GERMANY	5.35%	6.26%	7.74%	6.36%
ITALY	1.14%	3.06%	4.58%	2.92%
NETHERLANDS	1.37%	3.56%	7.47%	3.93%
SPAIN	1.73%	2.73%	3.89%	2.72%
UK	2.37%	4.90%	10.59%	5.76%
FINANCIAL INTERMEDIATION				
AUSTRIA	6.95%	15.77%	23.82%	15.63%
CZECH	18.77%	25.16%	37.98%	27.82%
DENMARK	13.94%	33.74%	68.48%	37.03%
FINLAND	37.19%	66.36%	89.54%	66.09%
GERMANY	9.90%	16.07%	21.98%	16.10%
ITALY	10.97%	25.22%	33.69%	23.48%
NETHERLANDS	9.15%	21.01%	36.81%	21.66%
SPAIN	20.08%	30.41%	40.24%	30.63%
UK	17.05%	27.95%	46.09%	29.64%
REAL ESTATE, RENTING AND BUSINESS ACTIVITIES				
AUSTRIA	0.34%	1.21%	2.95%	1.41%
CZECH	1.00%	1.66%	4.18%	2.17%
DENMARK	0.80%	2.40%	4.78%	2.48%
FINLAND	0.46%	1.09%	1.61%	1.03%
GERMANY	0.69%	1.72%	2.77%	1.68%
ITALY	0.32%	0.79%	1.57%	0.87%
NETHERLANDS	0.55%	1.60%	2.53%	1.54%
SPAIN	0.35%	0.79%	1.10%	0.74%
UK	1.00%	3.27%	5.35%	3.05%

[a]. Source: EU KLEMS Database.

Fig. 1 Product Market Regulation across OECD countries



[a]. Source: OECD Product Market Regulation Database. This indicator ranges from least 0 to 6, with higher values implying higher degree of regulation.

Table 2 Definition and sources of variables

VARIABLE NAME	DEFINITION	SOURCE
Y	Gross value added (in euros and 2000 prices)	OECD STAN Industrial Database
K	Capital stock (in euros and 2000 prices)	OECD STAN Industrial Database
L	Employment (full time equivalent persons employed)	OECD STAN Industrial Database
PMR	Product market regulation indicator (0-6, from less to higher degree of regulation)	OECD Product Market Regulation Database
REG	Regulation impact indicator	OECD Product Market Regulation Database
ICT	ICT capital (% of total capital)	EU KLEMS Database

Table 3 Descriptive statistics of variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
1. MANUFACTURING					
lnY	99	11.09	0.42	10.30	11.85
lnK	99	11.58	0.46	10.86	12.43
lnL	99	6.21	0.45	5.59	6.93
ICT	99	3.77	1.80	1.17	8.79
PMR	99	2.74	1.03	0.94	5.00
REG	99	0.09	0.03	0.04	0.15
2. WHOLESALE AND RETAIL TRADE					
lnY	99	25.05	0.99	22.88	26.69
lnK	99	25.72	1.01	23.91	27.49
lnL	99	14.09	1.08	12.41	15.62
ICT	99	12.56	6.71	2.24	33.46
PMR	99	2.74	1.03	0.94	5.00
REG	99	0.30	0.08	0.14	0.41
3. HOTELS AND RESTAURANTS					
lnY	99	23.50	1.07	20.96	24.99
lnK	99	24.35	1.26	21.69	26.27
lnL	99	12.83	1.24	11.00	14.49
ICT	99	5.24	3.75	1.14	17.60
PMR	99	2.74	1.03	0.94	5.00
REG	99	0.07	0.02	0.04	0.11
4. FINANCIAL INTERMEDIATION					
lnY	99	24.08	0.89	22.12	25.11
lnK	99	24.84	1.15	22.12	26.20
lnL	99	12.37	1.17	10.56	14.06
ICT	99	29.79	17.91	6.95	89.54
PMR	99	2.74	1.03	0.94	5.00
REG	99	0.25	0.07	0.18	0.41
5. REAL ESTATE, RENTING, AND BUSINESS ACTIVITIES					
lnY	99	25.44	1.00	23.41	26.90
lnK	99	28.09	0.97	26.23	29.40
lnL	99	13.70	1.15	11.94	15.45
ICT	99	1.66	1.16	0.32	5.35
PMR	99	2.74	1.03	0.94	5.00
REG	99	0.15	0.06	0.07	0.24

[a.] Variables are defined in Table 2.

Table 4 Maximum likelihood estimates
(Pooled sample for the period 1995-2005)

Production Function				
	(1)	**(2)**	**(3)**	**(4)**
c	-0.30* (-6.20)	-0.26* (-3.78)	-0.65* (-9.89)	-0.45* (-9.74)
lnK	0.99* (123.85)	0.94* (98.57)	0.99* (78.89)	1.00* (115.89)
lnL	0.01 (0.68)	0.09* (5.00)	0.05** (1.90)	0.01 (0.47)
t	-0.01** (-1.66)	0.002 (0.50)	-0.005 (-1.10)	-0.01 (-1.22)
Inefficiency Model				
c	-0.50* (-8.26)	-0.99* (-5.37)	-0.35* (-3.83)	-0.36* (-3.45)
t	0.01* (3.89)	-0.01 (-0.94)	0.01 (1.10)	0.001 (0.40)
ICT	-0.02* (-14.49)		-0.02* (-16.93)	-0.02* (-17.97)
PMR		-0.05 (-1.09)	-0.06** (-1.82)	-0.10 (-1.34)
PMR^2				0.01 (0.60)
σ^2	0.04* (14.95)	0.07* (7.80)	0.04* (15.09)	0.04* (7.20)
γ	0.11* (8.24)	0.29* (4.34)	0.17* (6.65)	0.13* (8.82)
Log likelihood	85.15	2.92	109.04	105.88
Observations	495	495	495	495
Time effects	included	included	included	included
Industry effects	included	included	included	included
Country effects	included	included	included	included

a. See Table 2 for the definitions of variables.
b. t-statistics are included in parentheses.
c. * and **denote significant at 5% and 10% levels, respectively.

Table 5 Maximum likelihood estimates: Manufacturing

Production Function				
	(1)	**(2)**	**(3)**	**(4)**
c	0.19* (2.01)	0.68 (1.23)	0.88 (0.88)	0.67 (0.41)
lnK	0.91* (9.69)	0.83* (7.86)	0.84** (1.68)	0.59* (3.90)
lnL	0.08* (6.86)	0.15* (5.65)	0.08 (1.10)	0.65* (5.58)
t	-0.01 (-1.14)	-0.02* (-4.56)	0.01 (0.54)	0.002 (0.94)
Inefficiency Model				
c	-0.08 (-1.14)	0.28* (11.70)	0.003 (0.45)	0.81* (6.25)
t	-0.001 (-0.84)	-0.02* (-8.79)	-0.03 (-0.02)	-0.02* (-5.69)
ICT	0.02 (1.44)		-0.05 (-1.10)	-0.002 (-0.40)
PMR		-0.06* (-6.50)	0.04 (1.19)	-0.006* (-2.65)
PMR^2				0.0004 (0.12)
σ^2	0.002* (3.37)	0.006* (6.27)	0.01 (0.02)	0.0005* (6.57)
γ	0.94* (52.18)	0.99* (77.75)	0.93 (0.87)	0.97* (29.69)
Log likelihood	215.23	239.21	127.65	250.85
Observations	99	99	99	99
Time effects	included	included	included	included
Country effects	included	included	included	included

a. See Table 2 for the definitions of variables.
b. t-statistics are included in parentheses.
c. * and **denote significant at 5% and 10% levels, respectively.

Table 6 Maximum likelihood estimates: Wholesale and retail trade

Production Function				
	(1)	**(2)**	**(3)**	**(4)**
c	0.52** (1.66)	0.60 (1.48)	0.47** (1.85)	0.29 (0.93)
lnK	0.84* (71.31)	0.84* (61.74)	0.84* (99.96)	0.84* (130.51)
lnL	0.21* (17.85)	0.22* (27.40)	0.23* (22.62)	0.23* (21.16)
t	0.01* (3.63)	0.01* (5.53)	0.01* (4.17)	0.01* (6.27)
Inefficiency Model				
c	0.21 (1.37)	-1.28* (-1.99)	1.20* (5.47)	1.87* (7.68)
t	0.09* (3.21)	0.06** (1.70)	0.04* (3.48)	0.05* (9.74)
ICT	-0.07* (-3.40)		-0.06* (-6.35)	-0.07* (-30.61)
PMR		0.00 (0.01)	-0.20* (-3.88)	-0.71* (-5.63)
PMR^2				0.09* (4.25)
σ^2	0.08* (2.62)	0.34* (2.94)	0.04* (4.33)	0.03* (5.98)
γ	0.99* (111.81)	1.00* (109.12)	1.00* (105.87)	1.00* (106.45)
Log likelihood	60.94	42.38	71.60	77.70
Observations	99	99	99	99
Time effects	included	included	included	included
Country effects	included	included	included	included

a. See Table 2 for the definitions of variables.
b. t-statistics are included in parentheses.
c. * and **denote significant at 5% and 10% levels, respectively.

Table 7 Maximum likelihood estimates: Hotels and restaurants

Production Function				
	(1)	**(2)**	**(3)**	**(4)**
c	3.95* (7.04)	3.79* (7.66)	3.91* (7.77)	4.30* (9.29)
lnK	0.71* (31.96)	0.70* (30.40)	0.70* (29.23)	0.69* (30.92)
lnL	0.21* (9.43)	0.21* (9.49)	0.22* (9.19)	0.21* (10.18)
t	-0.04** (-1.70)	-0.02* (-3.25)	-0.03* (-2.71)	-0.03* (-3.25)
Inefficiency Model				
c	0.36 (1.21)	0.54 (1.41)	0.60 (1.63)	-0.44 (-0.79)
t	-0.04 (-1.04)	-0.05 (-1.21)	-0.06 (-1.19)	-0.11** (-1.94)
ICT	-0.01 (-0.66)		-0.01 (-0.35)	-0.04 (-1.54)
PMR		-0.11 (-1.20)	-0.11 (-1.56)	0.83** (1.85)
PMR^2				-0.16* (-2.03)
σ^2	0.06* (3.21)	0.05* (7.98)	0.05* (3.61)	0.08* (3.23)
γ	0.29 (1.07)	0.02 (0.26)	0.03 (0.35)	0.38 (1.48)
Log likelihood	5.93	6.86	7.07	6.93
Observations	99	99	99	99
Time effects	included	included	included	included
Country effects	included	included	included	included

a. See Table 2 for the definitions of variables.
b. t-statistics are included in parentheses.
c. * and **denote significant at 5% and 10% levels, respectively.

Table 8 Maximum likelihood estimates: Financial intermediation

Production Function				
	(1)	**(2)**	**(3)**	**(4)**
c	3.91* (10.17)	5.84* (16.31)	3.90* (9.59)	3.49* (10.67)
lnK	0.77* (39.27)	0.73* (40.79)	0.76* (35.04)	0.77* (51.25)
lnL	0.11* (6.95)	0.02 (1.00)	0.13* (8.11)	0.15* (8.01)
t	0.03* (2.47)	0.05* (7.52)	0.03* (2.56)	0.03* (3.34)
Inefficiency Model				
c	0.61* (4.90)	-0.63 (-1.44)	0.81* (4.93)	1.29* (6.59)
t	0.06* (4.56)	0.08* (2.77)	0.06* (3.98)	0.06* (5.24)
ICT	-0.02* (-9.50)		-0.02* (-10.21)	-0.02* (-12.55)
PMR		0.12 (1.56)	-0.04* (-2.09)	-0.34* (-3.91)
PMR^2				0.05* (3.55)
σ^2	0.02* (5.71)	0.09* (3.06)	0.02* (6.28)	0.02* (9.05)
γ	0.48 (1.47)	0.96* (40.90)	0.36 (0.89)	0.52* (4.35)
Log likelihood	56.39	19.64	58.49	65.21
Observations	99	99	99	99
Time effects	included	included	included	included
Country effects	included	included	included	included

a. See Table 2 for the definitions of variables.
b. t-statistics are included in parentheses.
c. * and **denote significant at 5% and 10% levels, respectively.

Table 9 Maximum likelihood estimates: Real estate, renting and business activities

Production Function				
	(1)	**(2)**	**(3)**	**(4)**
c	-1.19* (-2.96)††	-2.86* (-8.58)	-1.50* (-3.09)	-1.50* (-3.13)
lnK	0.85* (59.54)	0.91* (101.21)	0.86* (48.99)	0.86* (50.24)
lnL	0.22* (27.16)	0.21* (38.32)	0.22* (25.51)	0.22* (23.33)
t	0.00 (-0.32)	0.01* (5.51)	0.00 (0.74)	0.00 (0.72)
Inefficiency Model				
c	0.25* (3.43)	-0.66* (-9.40)	0.07 (0.40)	0.07 (0.25)
t	0.03* (3.31)	0.05* (8.72)	0.04* (3.46)	0.04* (3.40)
ICT	-0.18* (-4.57)		-0.15* (-4.12)	-0.15* (-3.89)
PMR		0.16* (7.94)	0.03 (0.84)	0.03 (0.25)
PMR^2				0.00 (-0.03)
σ^2	0.01* (4.61)	0.03* (4.72)	0.01* (4.18)	0.01* (4.33)
γ	0.98* (33.62)	0.99* (107.88)	0.99* (102.85)	0.99* (103.11)
Log likelihood	98.58	84.87	99.02	99.02
Observations	99	99	99	99
Time effects	included	included	included	included
Country effects	included	included	included	included

a. See Table 2 for the definitions of variables.
b. t-statistics are included in parentheses.
c. * and **denote significant at 5% and 10% levels, respectively.

Table 10 Cross correlations (ICT, PMR)

		PMR	PMR(-1)	PMR(-2)
Pooled sample	ICT	-0.18 (-4.18)	-0.17 (-3.74)	-0.16 (-3.27)
Manufacturing	ICT	-0.78 (-12.37)	-0.77 (-11.44)	-0.75 (-10.12)
Wholesale and retail trade	ICT	-0.72 (-10.27)	-0.70 (-9.36)	-0.68 (-8.29)
Hotels and restaurants	ICT	-0.54 (-6.39)	-0.53 (-5.86)	-0.50 (-5.17)
Financial intermediation	ICT	-0.38 (-4.12)	-0.36 (-3.71)	-0.35 (-3.37)
Real estate, renting and business activities	ICT	-0.69 (-9.44)	-0.67 (-8.54)	-0.65 (-7.64)

[a]. t-statistics reported in parentheses.

Table 11 Technical inefficiency impact of the ICT components

	MANUFACTURING	**WHOLESALE AND RETAIL TRADE**	**HOTELS AND RESTAURANTS**	**FINANCIAL INTERMEDIATION**	**REAL ESTATE, RENTING AND BUSINESS ACTIVITIES**
Production Function					
c	0.37* (6.91)	-1.42* (-6.56)	6.73* (15.26)	4.95* (8.84)	-2.14* (-2.15)
K	0.89* (34.62)	0.87* (16.36)	0.53* (29.02)	0.79* (20.76)	0.87* (16.41)
L	0.08* (11.19)	0.29* (3.24)	0.35* (20.29)	-0.03 (-1.11)	0.25* (2.85)
t	0.003* (3.23)	0.01* (10.35)	-0.05* (-10.81)	0.04* (6.10)	-0.001 (-0.03)
Inefficiency Model					
c	0.02 (0.66)	0.65* (7.22)	0.89* (3.71)	0.19* (3.35)	0.01 (0.01)
t	0.002 (1.47)	0.04* (5.47)	-0.04* (-2.27)	0.04* (5.10)	0.03 (0.18)
COMP	0.03 (1.12)	-0.01** (-1.89)	0.03 (0.78)	-0.001 (-0.53)	-0.12 (-0.15)
SOFT	-0.12* (-5.65)	-0.04** (-1.84)	-0.09 (-0.31)	-0.02* (-6.43)	-0.07 (-0.07)
COMM	-0.07* (-2.69)	-0.07* (-6.80)	0.04 (0.45)	0.02 (0.46)	-0.003 (0.00)
σ^2	0.0007* (5.04)	0.004* (5.10)	0.02* (3.34)	0.004* (7.90)	0.02 (0.09)
γ	0.35* (2.93)	0.90* (30.09)	0.83* (20.89)	0.14* (3.07)	0.97 (1.37)
Log likelihood	227.55	168.15	71.03	126.15	89.84
Observations	99	99	99	99	99
Time effects	included	included	included	included	included
Country effects	included	included	included	included	included

[a]. COMP: computing equipment, SOFT: software, COMM: communications' equipment.
[b]. t-statistics are included in parentheses.
[c]. * and **denote significant at 5% and 10% levels, respectively.

Table 12 Econometric results with regulation impact indicator

	MANUFACTURING	**WHOLESALE AND RETAIL TRADE**	**HOTELS AND RESTAURANTS**	**FINANCIAL INTERMEDIATION**	**REAL ESTATE, RENTING AND BUSINESS ACTIVITIES**
Production Function					
c	0.13 (1.07)	-0.82** (-1.80)	8.18* (12.50)	4.69* (11.65)	-1.92* (-2.44)
lnK	0.91* (15.17)	0.86* (22.40)	0.45* (13.70)	0.68* (38.99)	0.87* (21.67)
lnL	0.08* (9.11)	0.27* (15.01)	0.42* (12.67)	0.22* (4.77)	0.21* (9.23)
t	0.01* (6.45)	0.01* (7.25)	-0.06* (-11.46)	0.06* (16.14)	0.01** (1.80)
Inefficiency Model					
c	-0.12 (-0.51)	0.25 (1.13)	1.70* (8.96)	0.42 (1.22)	-1.00 (-1.21)
t	-0.01 (-0.57)	0.04* (5.42)	-0.06* (-5.27)	0.05* (6.17)	0.06 (1.43)
ICT	0.03 (0.79)	-0.02* (-4.39)	-0.02** (-1.85)	-0.004** (-1.91)	-0.11 (-0.75)
REG	-0.87 (-0.89)	2.20 (1.37)	-3.89** (-1.89)	2.72 (1.52)	0.28 (0.08)
REG^2	-0.21 (-0.26)	-3.95 (-1.54)	-9.27* (-2.53)	-8.63* (-3.34)	0.14 (1.18)
σ^2	0.002* (3.22)	0.01* (7.18)	0.01* (5.99)	0.01* (6.26)	0.02 (1.60)
γ	0.97* (69.71)	0.95* (39.88)	0.38* (3.12)	1.00* (10.64)	0.96* (30.06)
Log likelihood	198.81	147.85	119.25	123.85	116.35
Observations	99	99	99	99	99
Time effects	included	included	included	included	included
Country effects	included	included	included	included	included

[a]. See Table 2 for the definitions of variables.
[b]. t-statistics are included in parentheses.
[c]. * and **denote significant at 5% and 10% levels, respectively.

Table 13 Average efficiency scores (1995-2005)

MANUFACTURING		**WHOLESALE AND RETAIL TRADE**		**HOTELS AND RESTAURANTS**		**FINANCIAL INTERMEDIATION**		**REAL ESTATE, RENTING, AND BUSINESS ACTIVITIES**	
GERMANY	99.48%	NETHERLANDS	95.81%	CZECH REPUBLIC	98.95%	FINLAND	98.26%	DENMARK	95.74%
AUSTRIA	99.46%	DENMARK	95.02%	ITALY	98.81%	DENMARK	83.06%	UK	93.64%
DENMARK	96.79%	GERMANY	89.96%	SPAIN	97.89%	SPAIN	75.37%	NETHERLANDS	92.36%
UK	96.56%	AUSTRIA	89.53%	DENMARK	97.52%	CZECH REPUBLIC	66.08%	ITALY	86.01%
FINLAND	93.49%	CZECH REPUBLIC	89.46%	AUSTRIA	97.41%	ITALY	63.78%	GERMANY	82.78%
CZECH REPUBLIC	86.63%	FINLAND	72.38%	NETHERLANDS	95.84%	UK	61.61%	FINLAND	81.76%
NETHERLANDS	84.94%	UK	71.44%	GERMANY	95.58%	NETHERLANDS	56.68%	CZECH REPUBLIC	81.68%
SPAIN	84.31%	ITALY	67.31%	FINLAND	94.30%	GERMANY	51.71%	AUSTRIA	76.40%
ITALY	77.48%	SPAIN	50.01%	UK	88.34%	AUSTRIA	50.96%	SPAIN	63.10%
AVERAGE	**91.02%**	**AVERAGE**	**80.10%**	**AVERAGE**	**96.07%**	**AVERAGE**	**67.50%**	**AVERAGE**	**83.72%**

[a]. Countries are sorted in descending order according to their average efficiency scores.

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