Technical efficiency gains in European service sectors:

The role of information and communication technology

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

Abstract

In this paper, we explore the hypothesis that the use of Information and Communication Technologies (ICT) may have an impact on technical inefficiency. We choose to estimate the inefficiency impact of ICT in service sectors, since these are the most intensive users of ICT and, also, account for, almost, 70% of total economic activity in European Union (EU). A stochastic production frontier is simultaneously estimated with a technical inefficiency model using data from four service sectors of nine European countries, during the period 1995-2005. The results indicate a significantly negative relationship between ICT and technical inefficiency in the majority of service sectors of European countries. The most efficient countries are the Netherlands in the sector of wholesale & retail trade, Finland in financial intermediation, and Denmark in hotels & restaurants, as well as in real estate, renting & business activities.

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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.

1. Introduction

The service sector in the European Union (EU) accounts for around 70% of total gross value added and for a major part of GDP growth, in recent years. Although productivity growth is generally lower in services than in manufacturing, the service sector contributes to a significant portion of cross country growth differences, due to its large size. Furthermore, cross country income differences are due to differences in Total Factor Productivity (TFP) growth (Prescott, 1998; Kehoe and Prescott, 2002), or differences in the rate of efficiency gains (Inklaar et al., 2008).

These two elements together suggest that efficiency gains in services may become an important factor for higher growth in Europe[1]. This, in turn, would lead to a higher level of GDP per capita and reduction of the growth gap vis-à-vis the US economy. However, the question arises as to which factors might be linked to higher efficiency gains in the service sector of the EU economy. The existing cross country empirical literature has verified that factors related to trade openness or human capital have a significantly negative effect on aggregate level inefficiencies (Kneller and Stevens, 2006; Henry et al., 2009). At the industry level, there are several studies which measure levels of technical efficiency and explore sources of technical inefficiency in agriculture, banking, transports etc.

In this paper, we contribute to the relevant literature by examining the role of Information and Communication Technology (ICT) in reducing technical inefficiency levels across European services. The service sector is considered as the most intensive

[1] The measurement of technical efficiency might be particularly useful in identifying ways to promote economic growth. A low level of technical efficiency would imply that higher economic growth could be achieved by efficiently producing more output with the same level of inputs. On the other hand, a highly efficient sector should rely more on technical progress and innovative activity in order to achieve higher economic growth.

sector in the use of ICT (Giotopoulos and Fotopoulos, 2010) and, therefore, its impact on technical efficiency would be of high importance for aggregate economic growth.

Economic theory has classified ICT as a general purpose technology with several characteristics that might affect economic efficiency. Some of these include the trade of goods and services at low cost, which lead to gains through specialization, scale economies and realization of comparative advantage (Harris, 1995). Other benefits include low transaction costs, efficient management of information, reduction of operational costs, improved business to business communications, as well as reorganization of production and distribution of goods and services.

At the empirical level, the existing literature has concentrated more on the ICT effects on growth or productivity and, although an essential relationship exists between efficiency and productivity (Grosskopf, 1993), the question of whether ICT affects the level of technical efficiency has been examined in few firm level samples (Lee and Barua, 1999; Milana and Zeli, 2002; Becchetti et al., 2003) and few cross country studies (Thompson and Garbacz, 2007; Repkine, 2008).

We follow the model of Battese and Coelli (1995) in estimating simultaneously a stochastic production frontier and a technical inefficiency model using maximum likelihood techniques. We use panel data from service sectors across nine European countries for the period 1995-2005. The empirical results indicate a significantly negative relationship between ICT and technical inefficiency in service sectors of European countries. The most efficient countries are the Netherlands in the sector of wholesale & retail trade, Finland in financial intermediation, and Denmark in hotels & restaurants, as well as in real estate, renting & business activities.

The rest of this paper is organized as follows. The next section summarizes the results of the relevant literature. Section 3 introduces the theoretical background and

section 4 discusses the econometric specification of the model. In section 5 the data are described and some descriptive statistics are presented, while section 6 provides the empirical results. Finally, section 7 concludes.

2. A survey of the empirical literature

Recent literature has verified that ICT had a significant impact on growth in both the USA and the EU during the late 90s (Van Ark et al., 2003; Inklaar et al., 2008). However, there is no consensus among the economists as to its impact on efficiency and TFP growth (Stiroh, 2002; Inklaar et al., 2008). In this section, we will review some recent cross country and firm level studies, which examine the impact of ICT on technical efficiency or technical inefficiency.

Lee and Barua (1999) examined the impact of Information Technology (IT) by using a stochastic frontier framework in a sample of Italian manufacturing firms for the period 1978–84. Their results show that the firm level inefficiencies were reduced through increases in IT intensity. Milana and Zeli (2002) examined the impact of ICT on technical efficiency in a wide range of Italian firms for the year 1997. They measured technical efficiency of each individual firm by using the non parametric technique of Data Envelopment Analysis (DEA). At a second step, a regression model was used to estimate the impact of ICT on technical efficiency. The authors concluded that a positive relationship could not be rejected in the entire group of firms. Becchetti et al. (2003) analysed the impact of IT on productivity and efficiency in a sample of small and medium sized Italian firms. Their results showed a positive effect of software investment on firm level efficiency for the period 1995-1997.

With respect to aggregate cross country studies, Thompson and Garbacz (2007) considered measures of penetration rates of telecommunication services to

evaluate their impact on technical efficiency. Using a sample of 93 developed and developing countries for the period 1995-2003, they showed that penetration rates of telecommunication services significantly improve the efficiency in the whole group of countries. The effects are quite important for low income countries that operate below the frontier. In contrast, these effects are insignificant for OECD countries since they already operate or are close to the frontier. Finally, Repkine (2008) constructed a measure of telecommunications capital and estimated its impact on technical efficiency. A sample of 50 developed and developing countries was used for the period 1980-2004. It was estimated that telecommunications' capital affects positively the efficiency of production in developing countries only, implying that in developed countries any efficiency gains might have been exhausted.

This study focuses on the industry level, where the existing studies have not yet exploited stochastic frontier analysis to evaluate the efficiency impact of ICT. We wish to contribute towards this direction and will explore the impact of ICT on technical inefficiency by using stochastic frontier analysis across service sectors of European countries.

3. Theoretical background – Channels of ICT impact on technical efficiency

Technological progress is considered as the most important factor for long run economic growth (Grossman and Helpman, 1991). Particularly, economic theory and historical evidence support that General Purpose Technologies (GPTs) play a catalyst role in the process of economic growth (Bresnahan and Trajtenberg, 1995). ICT is considered as a technological breakthrough which shares all the characteristics of GPTs (Bresnahan and Trajtenberg, 1995). Although the ICT revolution is mainly driven by the computer, the economic implementation of this technology requires the

development of a wide range of complementary products, such as software, networks, products incorporating hard coded chips etc. Furthermore, ICT is a technology which has a wide applicability in many uses and sectors of the economy. Some relevant examples include the process of product designing, production control, marketing, finance and distribution of products. 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 development, it is expected that the long run economic impact of ICT will be of high importance[2].

Improvements in communication technologies now allow the trading of services at low cost, driving upwards economic activity. Such developments lead to economic gains through trade specialization, greater scale economies and the realization of comparative advantage (Harris, 1995). Furthermore, ICT allows for a more effective management of information flows. As a result, the need for extra human resources diminishes and firms are led to major management reorganizations. At the first stages of computer introduction, it is quite possible to witness lower productivity, since this new technology requires skills improvement and workplace reorganization (Bresnahan et al., 2002). Thus, ICT investment is likely to move together with organizational changes and with improvement in the firms' skill mix.

An additional feature of ICT is its scale economies and the low marginal cost of production. It would be quite plausible to expect for a firm that wishes to distribute products via the Internet to invest enough money in order to build the necessary infrastructure. However, as soon as this infrastructure is implemented, the firm can trade with its customers at low marginal costs. Thus, the production of network products is generally involved with large start-up costs, but low marginal costs. A

[2] 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.

final characteristic of ICT is its network effects. This means that the value of ICT grows as the number of users increases. We expect that, through these channels, the diffusion of ICT's will raise productive efficiency and will enhance both micro and macro level productivity.

4. Econometric specification

Two main methodologies have been used for production frontier estimation: non parametric methods like the DEA and stochastic frontier techniques. The main advantage of non parametric methods is that they do not impose any restrictions on production technology. On the other hand, the main disadvantage is that such methods are unable to disentangle inefficiency effects from white noise. Stochastic methods are able to distinguish the error component from the non negative component of inefficiency, but their main disadvantage is that they assume the same production technology and rely on the distributional assumptions of the error components.

Earlier studies frequently used to follow a two-stage estimation procedure, where the production frontier and efficiency measures were estimated at the first stage by OLS and then the efficiency levels were regressed on a number of explanatory variables, assumed to influence efficiency. However, this two stage estimation procedure has several drawbacks. Kumbhakar and Lovell (2000) and Wang and Schmidt (2002) argue that if the vector of efficiency variables is correlated with the vector of production function parameters, then the coefficient estimates of the production function will be biased. Even in the case of no correlation between the production function and the efficiency variables, the technical efficiency measures are likely to be spuriously estimated, so that the estimated parameters of the efficiency equation will be biased.

In this study, we follow the model specification proposed by Battese and Coelli (1995). In their setting, the technical inefficiency model is incorporated in the stochastic production frontier model to perform a simultaneous one-stage approach.

4.1 Production frontier modelling

As mentioned in the previous paragraph, the use of stochastic frontier analysis has the disadvantage that it imposes the same functional form and same production technology to all production units. At the aggregate cross country level, there might be large heterogeneity across economies due to differences in the industry structure and, therefore, pooling countries together might not be appropriate. Therefore, we take account for industry level heterogeneity across European countries by using data at the sector level. We consider four broad service sectors: hotels & restaurants, wholesale & retail trade, financial intermediation and real estate, renting & business activities.

For each individual sector we assume a common production technology of a Cobb-Douglas form:

$$Y_{it} = A\, e^{\lambda t} (L_{it})^{\alpha} (K_{it})^{\beta} \mathrm{e}^{(V_{it} - U_{it})} \qquad (1)$$

The subscripts of i and t denote country and year respectively, Y measures value added, A is the level of technology, λ is the rate of technical change and t is a time trend which captures technical progress over time. V and U are the two components of the error structure, which compose the main feature of a stochastic frontier model. The first one, V_{it} is a 'standard' random residual assumed to be independently and identically distributed as $N(0, \sigma_v^2)$ and independent of U_{it}. The later 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. L and K denote the labor and capital inputs, respectively. Labor input is expressed as the number of full time equivalent persons employed, while capital input is the value of capital stock, expressed in 2000 prices. The parameters α and β are the value added elasticities of labor (L) and capital (K), respectively.

After taking a logarithmic transformation, value added in each sector can be expressed as a function of labor and capital:

$$\ln(Y_{it}) = c + \lambda t + \alpha \ln(L_{it}) + \beta \ln(K_{it}) + V_{it} - U_{it} \qquad (2)$$

Following Battese and Coelli (1995), the technical inefficiency effects are assumed to be a function of a set of explanatory variables z_{it} which can be defined as:

$$U_{it} = z_{it}\,\delta + W_{it} \qquad (3)$$

where z_{it} is a vector of variables which will be defined in section 4.2 and assumed to influence inefficiency, while δ is the vector of parameters to be estimated. The random variable W_{it} is defined by the truncation of the normal distribution.

All parameters included in the stochastic frontier production model (2) and the technical inefficiency model (3) 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 using maximum likelihood[3]. 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.

Following the definition of inefficiency in (3), the technical efficiency level of country i at time t is:

$$TE_{it} = \exp(-U_{it}) \qquad (4)$$

[3] 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}.

However, the U_{it}'s defined in (1) 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}:

$$\hat{TE}_{it} = E\left[\exp\left(-U_{it}\right) | \varepsilon_{it}\right] = \left\{\exp\left[-\mu_{it} + \frac{1}{2}\overline{\sigma}^2\right]\right\} \cdot \left\{\Phi\left[\frac{\mu_{it}}{\overline{\sigma}} - \overline{\sigma}\right] / \Phi\left[\frac{\mu_{it}}{\overline{\sigma}}\right]\right\} \quad (5)$$

where $\Phi(.)$ 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 $\overline{\sigma}^2 = \gamma(1-\gamma)\sigma^2$. By substituting the unknown parameters in equation (5) with the maximum likelihood estimates, we obtain estimates of technical efficiency for each sector of country *i* at time *t*.

4.2 Inefficiency variables-The role of ICT

In this paper we use stochastic frontier analysis to obtain an insight as to the causes of inefficiencies at the sector level. More specifically, we consider the effects of ICT on inefficiency by including it as an explanatory variable in vector *z* of equation (3).

It is now almost certain that ICT accounts for a great part of labor productivity growth witnessed in both the US and Europe during the previous decade (Van Ark et al., 2003). However, there is no consensus amongst economists as to the existence of efficiency effects, or positive externalities from the use of ICT (Gordon, 2000; Stiroh, 2002). Such effects imply that the total benefits are higher than the costs paid by the investor and could, also, be caused by spillover effects or by complementary investments, such as organizational change (Inklaar et al., 2008). We test the

hypothesis that ICT reduces inefficiencies at the sector level, by including as a regressor in equation (3) the share of ICT capital in total physical capital.

Equation (3) also includes further variables to control for sector specific effects. Such variables are the value added share of each sector in total economic activity, as well as the investment intensity of each sector. We should note that there exist several other variables which might affect efficiency and could be included in equation (3), like foreign direct investment flows or trade openness. However, it was not possible to find data describing these variables at the sector level.

The parameters of the production function (2) as well as of the inefficiency model (3) are estimated simultaneously at one stage by maximum likelihood using the computer program FRONTIER 4.1 developed by Coelli (1996).

5. Data and descriptive statistics

The empirical analysis of this paper is based on four broad service sectors (wholesale & retail trade, hotels & restaurants, financial intermediation and real estate, renting & business activities) across nine European countries (Austria, Czech Republic, Denmark, Finland, Germany, Italy, Netherlands, Spain and the United Kingdom) for the period 1995-2005. The data for gross value added, physical capital, employment, value added shares and investment intensity in each sector were taken form the OECD STAN Industrial Database (2012). Data regarding ICT (share of ICT capital in total physical capital) were provided by the EU KLEMS database[4].

From the figures reported in table 1, we can see that the share of ICT capital in total physical capital has tripled in most sectors and countries under consideration, during 1995-2005. Furthermore, we are able to distinguish that the northern European

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

countries are those with the highest share of ICT in total physical capital. In the sector of wholesale and retail trade, the countries with the highest average share of ICT, during 1995-2005, were Denmark (21.53%) and the United Kingdom (17.93 %). In hotels & restaurants, Denmark is the country with the highest share of ICT (12.22%), while in financial intermediation, Finland and Denmark have the highest shares (64.36% and 38.72%, respectively). Finally, in the sector of real estate, renting & business activities, UK is the country with the highest ICT share (3.21%). Another descriptive element that deserves to be referred is that the service sectors with the highest average share of ICT in total physical capital are those of financial intermediation (29.79 %) and wholesale and retail trade (12,78 %).

Table 2 presents a detailed description of all variables used in the empirical analysis, while table 3 contains some descriptive statistics for all variables that will be employed in the econometric analysis.

6. Empirical results

6.1 Econometric estimates

Tables 4 to 7 present the maximum likelihood estimates of the stochastic production frontier and the inefficiency model for the panel of nine countries, during the period 1995-2005, as well as for each of the four service sectors. The proposed production function includes the inputs of labor and physical capital, as well as a time trend to proxy for technological progress. The technical inefficiency equation is simultaneously estimated using as regressors the ratio of ICT capital to total physical capital, a time trend to account for the existence of any time specific effects on technical inefficiency (column 2), as well as the variables of the value added share and investment intensity (column 3).

As we can see from the reported results in table 4, physical capital (K) and labor (L) have a significantly positive effect on value added of wholesale & retail trade. The coefficient on time trend (t) appears to be positive but not significant. 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 significantly different from zero and this implies that inefficiency effects are present and that we should proceed with the estimation of parameters related to the sources of inefficiency.

With respect to the impact of ICT on technical inefficiency, the results indicate that a rise in the share of ICT capital (ICT) contributes significantly to the reduction of inefficiencies in the sector of wholesale & retail trade. The time variable (t) seems to have a positive effect on technical inefficiency, while the variables of the value added share (VA) and investment intensity (INV) do not affect significantly technical inefficiency.

Tables 5 to 7 present maximum likelihood estimates for the sectors of hotels & restaurants, financial intermediation and real estate, renting & business activities, respectively. Regarding the sector of hotels & restaurants (table 5), we are able to distinguish a significantly negative effect of ICT on technical inefficiency in most of the regressions reported in columns 1-3. We are, also, able to distinguish a negative impact form the time variable, as well as from the variable of the value added share, a finding which indicates that the size of the sector might have a negative influence on technical inefficiency levels of wholesale & retail trade. From the reported results of table 6, we can also, see that the effect of ICT is significantly negative on technical inefficiency levels of the sector of financial intermediation. Finally, the results of

table 7 confirm that the variables of ICT and technical inefficiency are negatively associated, in the sector of real estate, renting & business activities.

Overall, the regression results with respect to the impact of ICT indicate a negative and significant effect on technical inefficiency. These results provide strong evidence that a rise in the use of ICT has led to increased efficiency of production in European services.

6.2 Efficiency scores across sectors - Contribution of ICT to efficiency

As explained in section 4.1, we can obtain the predictions of technical efficiency by using the conditional expectation defined in equation (5). Table 8 presents average efficiency measures for each sector across the nine European countries, over the entire period 1995-2005.

According to table 8, the most efficient countries in the sector of wholesale & retail trade are the northern European countries such as Netherlands and Denmark, with average efficiency scores above 95%. On the other hand, the least efficient countries are Italy and Spain with average efficiency scores at 69% and 51%, respectively. In the sector of hotels & restaurants, Denmark and Spain are the most efficient countries with efficiency measures above 90%, while Italy and Austria are the most inefficient ones with scores slightly above 80%.

In the sector of financial intermediation, Finland and Denmark are the most efficient countries with average efficiency at 98% and 89.5%, respectively, while the least efficient countries in this sector are Netherlands and Austria with scores below 60%. Finally, the most efficient countries in real estate, renting & business activities are Denmark, UK and Netherlands with average efficiency scores above 90%. On the

contrary, the least efficient country in this sector is Spain with an average efficiency score slightly above 60%.

Furthermore, significant disparities exist in the levels of technical efficiencies across sectors. It seems that the most efficient sectors are those of hotels & restaurants, as well as real estate, renting & business activities, with average efficiency scores close to 85%. The sectors of wholesale & retail trade and financial intermediation follow with average efficiency scores at 81.5% and 71.5%, respectively,

The predicted technical efficiencies in equation (5) are gross measures which include the impact of ICT along with the impact of the other factors considered in the technical inefficiency equation (3). An interesting question that arises is whether we can decompose these predicted efficiencies by factor. Such attempts can be found in the microeconomic literature (Gathon and Pestieau, 1995; Coelli et al., 1999). Based on these ideas, we wish to calculate to which extent ICT contributes to the improvement of technical efficiency across sectors.

First we need to evaluate the efficiency levels after we clear out the influences from the ICT factor. To obtain such measures of net technical efficiency (net of ICT influences), we replace the term $\sum_{j=1}^{n}\delta_j z_{j,it}$ in eq. (5) with $\min\left[\sum_{j=1}^{n}\delta_j z_{j,it} - \delta_{ICT} ICT\right]$ and recalculate efficiency predictions (Coelli et al., 1999). These predictions may be interpreted as net efficiency scores because they involve predictions of efficiency when all countries are assumed to face identical effects of ICT (Coelli et al., 1999). The differences between gross and net efficiency scores represent the contribution of ICT to efficiency for each country.

We calculate contributions of ICT, the results of which are presented in table 9. These results show that ICT in general contributed positively in the increase of technical efficiencies across sectors of the European economy. The highest contribution is observed in financial intermediation in the countries of Finland and Denmark.

6.3 Discussion

The empirical evidence of this paper provides us with strong evidence that there exist significant benefits from the use of ICT capital, associated with higher technical efficiency of EU service sectors. However, the results of table 8 indicate that there are significant differences amongst EU service sectors, with respect to technical efficiency levels. Overall, it seems that northern European service sectors operate closer to the frontier, as compared to the service sectors of southern countries, like Spain and Italy.

Another important element is that there exist noteworthy differences among EU service sectors, with respect to the diffusion of ICT capital. In general, the service sectors of north EU countries seem to devote more resources in ICT investment spending, as opposed to the service sectors of southern Europe. As discussed in Uppenberg and Strauss (2010), there exist important differences across EU countries in terms of the composition of investment by asset type. Countries likes Denmark, Sweden and UK spend around 30%-40% of their fixed investment in the service sector to ICT equipment, as compared to 20% for the EU, as a whole. These two elements together confirm the empirical evidence of table 8, that the service industries of north EU countries have already registered a noteworthy contribution from ICT in their economies. Timmer and Van Ark (2005) show that there exist several disparities

within European countries, with respect to the benefits from the use of ICT. They argue that northern EU countries, like Ireland and Finland, have benefited more from ICT use, as opposed to the rest of the EU, where benefits from ICT are much smaller.

Furthermore, there is strong evidence in the relevant literature that the ICT productivity gains arise only when ICT investment is accompanied with organizational changes and knowledge capital investment, in the form of human capital or R&D (Oliner at al., 2007; Uppenberg and Strauss, 2010). Therefore, the significant impact of ICT on technical efficiency levels of EU services might partly reflect its complementary relationship with such kind of investments and organizational changes.

In summary, the positive association between ICT capital and lower inefficiency at the sector level of the EU economy suggests that higher aggregate productivity is more likely to be achieved through investment in ICT. This is an important observation for EU policy makers, given the willingness of EU countries to achieve higher growth and reduce the growth gap vis-à-vis the US.

7. Conclusion

In this paper we explored the idea that technologies associated with information and communications may have a contribution in reducing technical inefficiency. A stochastic production frontier was simultaneously estimated with a technical inefficiency model using panel data from service sectors of European countries, for the period 1995-2005. The results provided us with strong evidence in favour of a negative impact of ICT in reducing inefficiencies at the sector level. The most efficient countries are the Netherlands in the sector of wholesale & retail trade,

Finland in financial intermediation, and Denmark in hotels & restaurants, as well as in real estate, renting & business activities.

Several questions remain to be addressed by future research. Given that ICT is considered as complementary to other forms of intangible investment, an important issue would include the examination of the impact of knowledge capital on productivity growth and efficiency improvement of the service sector. Such forms of knowledge capital include R&D, as well as, human capital in the form of education and training.

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Tables

Table 1 ICT capital as a share of total capital

	1995	2000	2005	Average 1995-2005
WHOLESALE & RETAIL TRADE				
AUSTRIA	3.12%	9.85%	19.57%	10.85%
CZECH	4.93%	14.24%	13.31%	10.83%
DENMARK	9.53%	21.61%	33.46%	21.53%
FINLAND	7.02%	15.93%	21.10%	14.68%
GERMANY	9.41%	15.49%	19.52%	14.81%
ITALY	3.37%	7.38%	10.21%	6.99%
NETHERLANDS	5.92%	12.89%	19.97%	12.93%
SPAIN	2.24%	4.73%	6.52%	4.50%
UK	10.91%	16.74%	26.14%	17.93%
AVERAGE	**6.27%**	**13.21%**	**18.87%**	**12.78%**
HOTELS & RESTAURANTS				
AUSTRIA	1.19%	3.16%	8.11%	4.15%
CZECH	2.25%	1.92%	4.43%	2.87%
DENMARK	7.98%	15.35%	13.32%	12.22%
FINLAND	2.42%	5.85%	8.34%	5.54%
GERMANY	5.35%	6.26%	7.74%	6.45%
ITALY	1.14%	3.06%	4.58%	2.93%
NETHERLANDS	1.37%	3.56%	7.47%	4.13%
SPAIN	1.73%	2.73%	3.89%	2.78%
UK	2.37%	4.90%	10.59%	5.95%
AVERAGE	**2.87%**	**5.20%**	**7.61%**	**5.22%**
FINANCIAL INTERMEDIATION				
AUSTRIA	6.95%	15.77%	23.82%	15.51%
CZECH	18.77%	25.16%	37.98%	27.30%
DENMARK	13.94%	33.74%	68.48%	38.72%
FINLAND	37.19%	66.36%	89.54%	64.36%
GERMANY	9.90%	16.07%	21.98%	15.98%
ITALY	10.97%	25.22%	33.69%	23.29%
NETHERLANDS	9.15%	21.01%	36.81%	22.32%
SPAIN	20.08%	30.41%	40.24%	30.24%
UK	17.05%	27.95%	46.09%	30.36%
AVERAGE	**16.00%**	**29.08%**	**44.29%**	**29.79%**
REAL ESTATE, RENTING & BUSINESS ACTIVITIES				
AUSTRIA	0.34%	1.21%	2.95%	1.50%
CZECH	1.00%	1.66%	4.18%	2.28%
DENMARK	0.80%	2.40%	4.78%	2.66%
FINLAND	0.46%	1.09%	1.61%	1.05%
GERMANY	0.69%	1.72%	2.77%	1.73%
ITALY	0.32%	0.79%	1.57%	0.89%
NETHERLANDS	0.55%	1.60%	2.53%	1.56%
SPAIN	0.35%	0.79%	1.10%	0.75%
UK	1.00%	3.27%	5.35%	3.21%
AVERAGE	**0.61%**	**1.61%**	**2.98%**	**1.74%**

Source: EU KLEMS (2007)

Table 2 Definition of variables

VARIABLE NAME	DEFINITION
Y	Gross Value Added (expressed in 2000 prices)
K	Capital Stock (expressed in 2000 prices)
L	Employment (number of persons employed, in full time equivalents)
ICT	ICT capital (% of total capital)
INV	Investment intensity (investment as % of value added)
VA	Value added share in total economy

Table 3 Descriptive statistics of variables

Variable*	Obs.	Mean	Std. Dev.	Min	Max
WHOLESALE & RETAIL TRADE					
Y*	99	25.05	0.99	22.88	26.69
K*	99	25.72	1.01	23.91	27.49
L*	99	14.09	1.08	12.41	15.62
ICT	99	12.56	6.71	2.24	33.46
INV	99	13.49	4.59	7.92	33.81
VA	99	11.96	1.20	9.52	13.94
HOTELS & RESTAURANTS					
Y*	99	23.50	1.07	20.96	24.99
K*	99	24.35	1.26	21.69	26.27
L*	99	12.83	1.24	11.00	14.49
ICT	99	5.24	3.75	1.14	17.60
INV	99	12.77	4.27	6.28	26.59
VA	99	2.98	1.81	1.33	7.61
FINANCIAL INTERMEDIATION					
Y*	99	24.08	0.89	22.12	25.11
K*	99	24.84	1.15	22.12	26.20
L*	99	12.37	1.17	10.56	14.06
ICT	99	29.79	17.91	6.95	89.54
INV	99	15.05	9.72	-1.27	62.99
VA	99	4.90	1.14	2.45	7.69
REAL ESTATE, RENTING & BUSINESS ACTIVITIES					
Y*	99	25.44	1.00	23.41	26.90
K*	99	28.09	0.97	26.23	29.40
L*	99	13.70	1.15	11.94	15.45
ICT	99	1.66	1.16	0.32	5.35
INV	99	47.18	14.09	24.02	87.39
VA	99	18.11	3.33	11.73	24.60

* Variables in logs.

Table 4: Panel data ML estimates in Wholesale & retail trade

Production Function						
	(1)		**(2)**		**(3)**	
	coef.	t-stat	coef.	t-stat	coef.	t-stat
c	0.71*	2.03	0.52**	1.65	0.58	0.58
K†	0.85*	60.88	0.84*	70.69	0.85*	3.94
L	0.19*	14.61	0.21*	17.85	0.19	0.46
t	0.00	0.70	0.01*	3.63	0.01	0.18
Inefficiency Function						
c	0.53*	3.98	0.21	1.37	0.00	0.00
ICT	-0.06*	-2.22	-0.07*	-3.39	-0.07	-0.16
t			0.09*	3.20	0.07	0.18
INV					0.04	0.10
VA					-0.03	-0.03
σ^2	0.11**	1.78	0.08*	2.63	0.10	0.35
γ	0.11*	92.60	0.99*	111.73	0.98	1.38
Log likelihood	50.15		60.94		58.89	
Observations	99		99		99	

† See table 2 for the definitions of variables.
* Significant at the 5% level.
** Significant at the 10% level

Table 5: Panel data ML estimates in Hotels & restaurants

Production Function						
	(1)		**(2)**		**(3)**	
	coef.	t-stat	coef.	t-stat	coef.	t-stat
c	3.69*	6.19	3.95*	7.13	4.29*	8.98
K†	0.71*	33.13	0.71*	31.92	0.75*	27.89
L	0.21*	9.14	0.21*	9.27	0.15*	15.16
t	-0.02*	-2.28	-0.04**	-1.72	-0.07*	-3.62
Inefficiency Function						
c	0.14	0.34	0.36	1.19	1.03*	6.22
ICT	0.00	-0.34	-0.01	-0.63	-0.02*	-8.53
t			-0.04	-1.01	-0.04**	-1.87
INV					0.02*	2.58
VA					-0.08*	-6.60
σ^2	0.05*	5.15	0.06*	3.22	0.04*	6.58
γ	0.09	0.28	0.29	1.08	1.00*	81.71
Log likelihood	5.39		5.93		27.30	
Observations	99		99		99	

† See table 2 for the definitions of variables.
* Significant at the 5% level.
** Significant at the 10% level.

Table 6: Panel data ML estimates in Financial intermediation

Production Function						
	(1)		**(2)**		**(3)**	
	coef.	t-stat	coef.	t-stat	coef.	t-stat
c	3.93*	10.57	3.91*	10.15	4.16*	15.30
K†	0.79*	42.08	0.77*	39.28	0.76*	58.08
L	0.11*	6.80	0.11*	6.94	0.09*	5.71
t	-0.02*	-4.13	0.03*	2.47	0.03*	4.92
Inefficiency Function						
c	1.08*	9.51	0.61*	4.89	0.17**	1.64
ICT	-0.02*	-9.60	-0.02*	-9.51	-0.02*	-10.32
t			0.06*	4.57	0.07*	7.15
INV					0.01*	5.48
VA					0.03*	2.64
σ^2	0.02*	6.57	0.02*	6.28	0.01*	7.80
γ	0.20	0.34	0.48	1.46	0.43*	3.73
Log likelihood	51.96		56.39		72.70	
Observations	99		99		99	

† See table 2 for the definitions of variables.
* Significant at the 5% level.
** Significant at the 10% level.

Table 7: Panel data ML estimates in Real estate, renting & business activities

Production Function						
	(1)		**(2)**		**(3)**	
	coef.	t-stat	coef.	coef.	t-stat	coef.
c	-1.08*	-2.85	-1.19*	-2.97	-0.69*	-2.98
K†	0.85*	66.50	0.85*	59.65	0.87*	89.15
L	0.23*	25.94	0.22*	26.68	0.14*	19.34
t	-0.02*	-3.91	0.00	-0.32	0.03*	4.38
Inefficiency Function						
c	0.44*	8.99	0.25*	3.42	0.43*	7.27
ICT	-0.14*	-6.07	-0.18*	-4.55	-0.06*	-4.97
t			0.03*	3.32	0.05*	4.42
INV					0.00*	5.02
VA					-0.03*	-7.26
σ^2	0.01*	5.53	0.01*	4.63	0.00*	4.89
γ	0.93*	13.31	0.98*	33.04	1.00*	114.88
Log likelihood	92.97		98.58		151.00	
Observations	99		99		99	

† See table 2 for the definitions of variables.
* Significant at the 5% level.
** Significant at the 10% level.

Table 8: Average efficiency scores (1995-2005)

WHOLESALE & RETAIL TRADE		HOTELS & RESTAURANTS		FINANCIAL INTERMEDIATION		REAL ESTATE, RENTING, & BUSINESS ACTIVITIES	
NETHERLANDS	96.52%	DENMARK	91.38%	FINLAND	98.80%	DENMARK	96.93%
DENMARK	95.09%	SPAIN	91.14%	DENMARK	89.53%	UK	92.43%
GERMANY	93.11%	NETHERLANDS	89.12%	SPAIN	83.03%	NETHERLANDS	91.19%
AUSTRIA	90.75%	CZECH	85.84%	ITALY	70.39%	ITALY	85.60%
CZECH	89.60%	UK	85.35%	UK	67.82%	CZECH	83.44%
UK	74.58%	GERMANY	85.09%	CZECH	63.28%	GERMANY	82.97%
FINLAND	73.29%	FINLAND	83.52%	GERMANY	60.42%	FINLAND	80.53%
ITALY	69.34%	ITALY	83.37%	NETHERLANDS	57.14%	AUSTRIA	75.82%
SPAIN	51.52%	AUSTRIA	82.46%	AUSTRIA	53.22%	SPAIN	62.84%
AVERAGE	**81.53%**	**AVERAGE**	**86.36%**	**AVERAGE**	**71.51%**	**AVERAGE**	**83.53%**

* Countries are sorted in descending order according to their average efficiency scores.

Table 9: Contribution of ICT to technical efficiency (average 1995-2005)

Wholesale & retail trade				**Hotels & restaurants**			
	GROSS EFFICIENCY	**NET EFFICIENCY**	**CONTRIBUTION OF ICT**		**GROSS EFFICIENCY**	**NET EFFICIENCY**	**CONTRIBUTION OF ICT**
DENMARK	95.09%	94.49%	0.59%	DENMARK	91.38%	92.66%	-1.28%
UK	74.58%	74.14%	0.45%	SPAIN	91.14%	94.55%	-3.42%
GERMANY	93.11%	92.78%	0.33%	NETHERLANDS	89.12%	93.51%	-4.39%
FINLAND	73.29%	72.97%	0.32%	GERMANY	85.09%	89.92%	-4.83%
CZECH	89.60%	89.37%	0.23%	UK	85.35%	90.46%	-5.11%
AUSTRIA	90.75%	90.55%	0.20%	CZECH	85.84%	91.07%	-5.23%
NETHERLANDS	96.52%	96.32%	0.19%	FINLAND	83.52%	89.39%	-5.87%
ITALY	69.34%	69.32%	0.01%	ITALY	83.37%	89.81%	-6.45%
SPAIN	51.52%	51.57%	-0.06%	AUSTRIA	82.46%	89.11%	-6.65%
Financial intermediation				**Real estate, renting & business activities**			
	GROSS EFFICIENCY	**NET EFFICIENCY**	**CONTRIBUTION OF ICT**		**GROSS EFFICIENCY**	**NET EFFICIENCY**	**CONTRIBUTION OF ICT**
FINLAND	98.80%	79.99%	18.81%	UK	92.43%	91.82%	0.62%
DENMARK	89.53%	79.00%	10.53%	DENMARK	96.93%	96.43%	0.50%
SPAIN	83.03%	77.32%	5.71%	CZECH	83.44%	82.98%	0.46%
UK	67.82%	66.65%	1.17%	GERMANY	82.97%	82.69%	0.28%
ITALY	70.39%	70.10%	0.29%	NETHERLANDS	91.19%	90.94%	0.25%
CZECH	63.28%	65.35%	-2.07%	AUSTRIA	75.82%	75.65%	0.17%
GERMANY	60.42%	65.47%	-5.05%	FINLAND	80.53%	80.48%	0.05%
NETHERLANDS	57.14%	64.72%	-7.58%	ITALY	85.60%	85.61%	0.00%
AUSTRIA	53.22%	61.24%	-8.02%	SPAIN	62.84%	62.88%	-0.04%

* Countries are sorted in descending order according to the average contribution of ICT.