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# *Efficiency and integration in European banking markets*

WP 08/2011/DE/UECE

WORKING PAPERS

ISSN Nº 0874-4548

# Efficiency and integration in European banking markets

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**Abstract**

This paper seeks to contribute to the relatively scarce published research on the relationship between bank efficiency and European integration in the wake of the recent financial crisis. Using Stochastic Frontier Analysis and Data Envelopment Analysis approaches, the study estimates bank efficiency for different panels of European Union countries during the time period 1994-2008. The main conclusions point to the persistence of inefficiencies, which decreased with the implementation of the European Monetary Union (in the time period 2000-2008) but then increased slightly in the most recent phase (2004-2008), during which the EU had to adapt to the new universe of 27 member-states. On the other hand, there is evidence of a convergence process, although this is very slow and not strong enough to avoid the differences in the country efficiency scores.

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# Efficiency and integration in European banking markets

## 1. Introduction

The European banking institutions play a unique role in the context of the European Monetary Union, as the increase of competition in all financial-product market segments is expected to contribute to price and cost reductions and benefit the exploitation of scale economies.

In recent years, financial systems have been experiencing the consequences of the strong imbalances and turbulence caused by the US sub-prime mortgage market, which affected different segments of the international money and credit markets and revealed the fragility of many financial institutions, including some EU banking institutions and markets.

The ensuing crisis drew attention to the importance of studies seeking to identify the factors explaining the weaknesses in the financial systems at national and international levels. There is already a large strand of literature on the analysis of the determinants of efficiency and particularly on the empirical measurement of the profit and cost efficiency in banking (among others, Altunbas *et al.*, 2001; Goddard *et al.* 2001, 2007; Williams and Nguyen, 2005; Kasman and Yildirim, 2006; Barros *et al.* 2007; Berger, 2007; Hughes and Mester, 2008; Sturm and Williams, 2010).

Nevertheless, in Europe there is no clear consensus on the evidence of increasing consolidation and integration of the European markets. Some empirical studies conclude that there is evidence of integration, particularly of the European money market, but also to some extent of the bond and equity markets (Cabral *et al*., 2002; Hartmann *et al.*, 2003; Guiso *et al*., 2004; Manna, 2004; Cappiello *et al*., 2006; Bos and Schmiedel, 2007). Other empirical contributions have concluded that the European financial markets are as yet far from achieving integration (Gardener *et al*., 2002; Schure *et al*., 2004; Dermine, 2006; European Central Bank, 2007, 2008; Gropp and Kashyap, 2008; Affinito and Farabullini, 2009). However, there are not many references to studies that have clearly addressed the relationship between banking efficiency and European integration. The main examples are to be found in Tortosa-Ausina (2002), Murinde *et al*., (2004), Holló and Nagy (2006), Weill (2004, 2009) and Casu and Girardone (2009, 2010).

This paper follows this latter strand of literature and tests banking efficiency across EU countries in the wake of the recent crisis, using both Stochastic Frontier Analysis (SFA) and Data Envelopment Analysis (DEA) estimates and comparing the results obtained for a panel comprising the "old" EU-15 countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and UK) and another panel comprising all of the current EU-27 members. The main conclusions point to the existence of statistically important technical inefficiencies that increased slightly after 2004 with the inclusion of the 12 new member-states. The obtained country efficiency rankings also allow us to conclude that countries that performed well in the EU-15 panel maintain their strong positions in the enlarged EU-27 panel. Furthermore, the analysis of the convergence process with the estimation of a *beta*-convergence model clearly shows that while there is convergence in banking efficiency across EU countries, it is a very slow process and not only the new member-states but also some of the "old" EU countries are still facing difficulties in adapting to the new market conditions.

The paper is structured as follows: Section 2 presents the theoretical framework and a brief literature review; the methodology and the data are presented in Section 3; Section 4 reports the obtained results; Section 5 discusses these results and concludes.

## 2. Theoretical framework and brief literature review

Whilst European research on bank efficiency has not yet matched the record of the US contributions, it has increased enormously over recent years, following the dynamic changes in the structure of European banking.

There is a strand of literature that focuses on the heterogeneities across banks, explaining them by such differences in the performance conditions as technological progress (Wheelock and Wilson, 1999; Berger, 2003; Casu *et al*., 2004), bank size (Altunbas *et al*., 2001; Molyneux, 2003; Bikker *et al*., 2006; Schaeck and Cihak, 2007), bank ownership (Bonin *et al*., 2005; Kasman and Yildirim, 2006; Lensink *et al*., 2008), bank mergers (Diaz *et al*., 2004; Campa and Hernando, 2006; Altunbas and Marquês, 2007), financial deregulation (Kumbhakar *et al*., 2001; Vives, 2001; Goddard *et al.*, 2007) and legal tradition (Berger *et al*. 2001; Beck *et al*., 2003-a, 2003-b; Barros *et al.,* 2007).

The study of bank efficiency is usually based on the assumption that the performance of each individual bank can be described by a production function that links banking outputs to the necessary banking inputs. However, there is no consensus concerning the definition of these banking outputs and inputs. The discussion is mainly on the specific role of deposits, since they may be considered either as inputs or as outputs of the production function.

According to the *production approach,* banks provide services related to loans and deposits and, like the other producers, they use labour and capital as inputs of a given production function (see among others, Berger and Humphrey, 1991; Resti, 1997; Rossi *et al*., 2005).

The *intermediation approach c*onsiders that banks are mainly intermediaries between those economic agents with excess financing capacity and those that need support for their investments. Banks attract deposits and other funds and, using labour and other types of inputs such as buildings, equipment, or technology, they transform these funds into loans and investment securities. This approach has been used, for instance, by Sealey and Lindley (1977), Berger and Mester (1997), Altunbas *et al*. (2001), Bos and Kool (2006) and Barros *et al*. (2007).

The research into efficiency, either by the production approach or by the intermediation approach, is based on the estimation of an efficiency frontier with the best combinations of the different inputs and outputs of the production process and then on the analysis of the deviations from the frontier that correspond to the losses of efficiency. Most of the empirical studies on the measurement of bank efficiencies adopt either parametric methods, like the Stochastic Frontier Analysis (SFA), or non-parametric methods, particularly the Data Envelopment Analysis (DEA).

The SFA estimates efficiency based on economic optimisation (maximisation of profits or minimisation of costs), given the assumption of a stochastic optimal frontier. It follows the pioneering contribution of Farrel (1957) and has been further developed by such authors as Aigner *et al*. (1977), Meeusen and van den Broeck (1977), Stevenson (1980), Battese and Coelli (1988, 1992, 1995), Frerier and Lowell (1990), Coelli *et al*. (1998), Kumbhakar and Lovell (2000) and Altunbas *et al*. (2001).

According to Altunbas *et al*. (2001), the single equation stochastic cost function model can be represented with the following expression: $TC = TC(Q_i, P_j) + \varepsilon$; where *TC* is the total cost, *Q* is the vector of outputs, *P* is the input-price vector and ε is the error (a formal presentation of the cost function for panel data models is presented in Appendix I).

The error of this cost function can be decomposed into $\varepsilon = u + v$; where *u* and *v* are independently distributed. The first part of this sum, *u*, is assumed to be a positive disturbance, capturing the effects of the inefficiency or the weaknesses in managerial performance. It is distributed as half-normal and is truncated at zero, $\left[u \sim \mathrm{N}^+\left(\mu, \sigma_u^2\right)\right]$, with non-zero $\mu$ mean, as each unit´s production must lie on or below its production frontier, but above zero. The second part of the error, $v$, is assumed to be distributed as two-sided normal, with zero mean and variance $\sigma_v^2$ and it represents the random disturbances.

As the estimation of the presented cost function provides only the value of the error term, ε, the value of the inefficient term, $u$, has to be obtained indirectly. Following Jondrow *et al*. (1982) and Greene (1993, 2003), the total variance can be expressed as $\sigma^2 = \sigma_u^2 + \sigma_v^2$ where the contribution of the inefficient term is $\sigma_u^2 = \frac{\sigma^2 \lambda^2}{1+\lambda^2}$; $\sigma_v^2 = \frac{\sigma^2}{1+\lambda^2}$ is the contribution of the noise and $\lambda = \frac{\sigma_u}{\sigma_v}$ is a measure of the relative contribution of the inefficient term.

The variance ratio parameter γ, which relates the variability of $u$ to total variability $\sigma^2$, can be formulated as $\gamma = \frac{\lambda^2}{1+\lambda^2}$ or $\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$ ; $0 \leq \gamma \leq 1$. If γ is close to zero, the differences in the cost will be entirely related to statistical noise, while a γ close to one reveals the presence of technical inefficiency.

One important advantage of SFA is that in the event of our including a variable that is not relevant, this variable will have a very low weighting in the calculation of the efficiency scores, so its impact will be negligible. This is an important difference from DEA, where the weights for a variable are usually unconstrained. Another advantage of the econometric frontier is that it allows the decomposition of deviations from efficient levels between the stochastic shocks or the noise ($v$) and pure inefficiency ($u$), whereas DEA classifies the whole deviation as inefficiency.

Again following the proposals of Farrel (1957), the non-parametric approach was developed by Charnes *et al*. (1978), who first used the term DEA, and continues to be used by many authors, as is well-documented in the detailed reviews provided by Thanassoulis *et al*. (2008) and Cook and Seiford (2009).

Fundamentally, DEA is a mathematical programming approach which is based on the microeconomic concept of efficiency and the microeconomic view of production functions (see Appendix II for a more formal presentation). In DEA, the production function is, however, generated from the actual data for the evaluated units and not determined by any specific functional form.

Taking the available data, the DEA frontier will be defined by the piecewise linear segments that represent the combinations of the best-practice observations, the measurement of efficiency being relative to the particular frontier obtained. If the actual production of one decision-making unit (DMU) lies on the frontier, this production unit will be considered perfectly efficient, whereas if it is situated below the frontier, the DMU will be inefficient; the ratio of the actual to the potential level of production will define the level of efficiency of any individual DMU.

Thus, with the DEA approach, the efficiency score for any DMU is not defined absolutely in comparison with a universal efficiency standard; rather, it is always defined as the distance to the particular production frontier, that is, in relation to the other DMUs that are included in the specific data set. As a consequence, DEA provides efficiency scores even in the presence of relatively few observations, which represents a great advantage of DEA in comparison with the parametric approaches (like the SFA), as these require the availability of sufficient observations to allow the estimation of specific production functions.

Solving a linear optimisation problem (see Appendix II), the DEA approach provides, for every *i* DMU, a scalar efficiency score ($\theta_i \leq 1$). If $\theta_i = 1$, the DMU lies on the efficient frontier and will be considered an efficient unit. On the contrary, if $\theta_i < 1$, the DMU lies below the efficient frontier and will be considered an inefficient unit; moreover, ($1- \theta_i$) will always be the measure of its inefficiency.

## 3. Methodology and used data

Considering the aims of European integration to increase competition in all financial-product segments, to contribute to price and cost reductions and to benefit bank efficiency, we will use both SFA and DEA techniques to test the existence of bank inefficiency across EU countries. We will also investigate whether there any remarkable differences in the bank efficiency patterns of the "old" EU-15 members in comparison with the universe of all EU-27 countries. We will follow the intermediation approach and specify a Stochastic Cost Frontier (SCF) model, using a linear cost function with three outputs (loans, securities and other earning assets) and the price of three inputs (borrowed funds, physical capital and labour) to estimate the following translog form of a cost function:

$$\ln C_{it} = \sum_h \beta_{w_h} \ln w_h + \sum_r \beta_{y_r} \ln y_r + \frac{1}{2}\sum_h \sum_k \beta_{w_{h,k}} \ln w_h \ln w_k + \frac{1}{2}\sum_r \sum_s \beta_{y_{r,s}} \ln y_r \ln y_s + $$
$$+ \sum_r \sum_h \beta_{y_r w_h} \ln w_h \ln y_r + \sum_m \beta_{z_m} \ln z_m + \varepsilon_{it} \qquad [1]$$

Where:

C = total cost (i = 1,..., N = number of the countries included in each panel; t = 1,...,T = time period)

w = inputs (h,k = 1, ..., H)

y = outputs (r,s = 1, ..., R)

Our data are sourced from the Bankscope database. The sample comprises annual data from the consolidated accounts of the commercial and savings banks of all EU countries between 1994 and 2008. In Appendix III, we present the number of banks of each country in 1994, 2000 and 2008 and also the average number of the entire period (1994-2008).

We define the input prices and the outputs (quantities) of the cost function using the following variables:

- **Dependent variable = Total cost (TC)** = natural logarithm of the sum of the interest expenses plus the total operating expenses

- **Outputs**:
    - $Y_1$ **= Total loans** = natural logarithm of the loans
    - $Y_2$ **= Total securities =** natural logarithm of the total securities
    - $Y_3$ **= Other earning assets =** natural logarithm of the difference between the total earning assets and the total loans

- **Inputs:**
    - $W_1$ **= Price of borrowed funds** = natural logarithm of the ratio interest expenses over the sum of deposits
    - $W_2$ **= Price of physical capital** = natural logarithm of the ratio non-interest expenses over fixed assets
    - $W_3$ **= Price of labour** = natural logarithm of the ratio personnel expenses over the number of employees

- **Other variables**:
    - $Z_1$ **= Number of banks =** natural logarithm of the number of banks included in the panels
    - $Z_2$ **= Equity ratio** = natural logarithm of the ratio equity over total assets
    - $Z_3$ **= Ratio revenue over expenses =** natural logarithm of the ratio of the total revenue over the total expenses

In our estimations, we consider two sets of EU countries:

- **EU-15** – comprising the 15 "old" EU member-states: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and UK.

- **EU-27** – all current EU member-states.

In order to test the degrees of convergence among each of the two panels of countries, we use the predicted values of efficiency obtained with the estimated stochastic cost frontier model and, borrowing from economic growth theory, we estimate the following *beta*-convergence model:

$$\Delta BE = \alpha + \beta BE_{i,t-1} + \sum_{i=1}^{n} D_i + \varepsilon_{i,t} \qquad [2]$$

Where: $BE_{i,t}$ = bank efficiency in country i (i = 1, ...n) in year t (t = 1, ... T)

$\Delta BE = BE_{i,t} - BE_{i,t-1}$

$D_i$ = country dummies

Finally, being aware that during the last decade, the EU's structural changes were due both to the historically remarkable enlargement process and to the implementation of the EMU, we also use the DEA approach to test the cross-country differences and compare the average DEA input-oriented efficiency measures for the EU-15 and the EU-27 panels during three specific time intervals: 1994-2008, 2000-2008 and 2004-2008.

## 4. Empirical results

Appendix IV presents the results obtained with SFA, more precisely with stochastic cost frontier (SCF) functions for both the EU-15 and the EU-27 panels during the time period 1994-2008. We report the results of two estimated models[1]: one following the cost model presented above and the other being a simplified cost model, in which we include only the statistically important variables.

The provided information on the Wald tests and the log of the likelihood allow us to conclude that in all panels, the specified cost function fits the data well and the null hypothesis that there is no inefficiency component is rejected. Furthermore, in all situations the frontier parameters are statistically significant (see the bottom lines of Appendix IV).

The high values of the mean, $\mu$, of the first part of the cost function's error, capturing the effects of the inefficiency, as defined above, indicates that in all circumstances (see Table 1, below, with values taken from Appendix IV), technical inefficiencies exist and they are always statistically important. This means that the use of a traditional cost function with no technical inefficiency effects would not be an adequate representation of the data.

A more careful observation of the values provided in Table 1 allows us to conclude that inefficiencies increased with the inclusion of the new EU member-states, reflecting some possible difficulties of the EU banking institutions in the process of adaptation to the new conditions of the enlarged market.

**TABLE 1 – Summary of the obtained results for the mean, μ**

| Variable | EU-15 | | EU-27 | |
|---|---|---|---|---|
| | **Model I** | **Model II** | **Model I** | **Model II** |
| **mu** | | | | |
| **coefficient** | 2.952165 | 2.8636 | 3.533474 | 3.254799 |
| **z** | 6.50 | 7.00 | 8.85 | 9.40 |
| **P>\|z\|** | 0.000 | 0.000 | 0.000 | 0.001 |

The presence of inefficiency is also confirmed by the high values of the contribution of the inefficiency ($u$) to the total error. The obtained values of the $\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$, reported in Table 2, reveal that in all panels the inefficient error term amounts to around 98%. This implies that the variation of the total cost among the different EU countries was almost solely due to the differences in their cost inefficiencies.

**TABLE 2 – Summary of the obtained results for the contribution of the inefficient error term to total variance, γ**

| Variable | EU-15 | | EU-27 | |
|---|---|---|---|---|
| | **Model I** | **Model II** | **Model I** | **Model II** |
| **gamma** | | | | |
| Coefficient | .9743051 | .9769977 | .9803236 | .9796408 |
| Standard error | .0118859 | 0.0102856 | .0057757 | .0059013 |

The previous results are confirmed by the comparison of the values of the variances of the inefficient error term ($\sigma_u$) and the random disturbances ($\sigma_v$), which are presented in Table 3.

[1] Other models were estimated to check the validity of these results. They include different combinations of the outputs, inputs and their products and the obtained results will be provided on request.

In all situations, the variance is mostly due to the inefficient term and the EU-15 panel is revealed to be much more homogeneous than the EU-27 panel.

**TABLE 3 – Summary of the obtained results for the variance of the inefficient error term ($\sigma_u$) and the noise ($\sigma_v$)**

| Variable | EU-15 | | EU-27 | |
|---|---|---|---|---|
| | **Model I** | **Model II** | **Model I** | **Model II** |
| **sigma_u2** | | | | |
| Coefficient | **.1665279** | **.1873025** | **.3809868** | **.3708549** |
| Standard error | .0754535 | .0819444 | .1097962 | .105689 |
| | | | | |
| **sigma_v2** | | | | |
| Coefficient | **.0043918** | **.0044098** | **.0076469** | **.0077072** |
| Standard error | .0004367 | .0004369 | .0005586 | .0005625 |

According to the estimation results of the cost function, also displayed in Appendix IV, we can see that in all situations, the total cost (more precisely, the sum of interest expenses plus the operating expenses) increases mostly with the price of the borrowed funds ($W_1$, here represented by the ratio interest expenses over the sum of the deposits). However, the contrary appears likely to have occurred with the other two inputs: the price of capital ($W_2$, with the proxy ratio of the non-interest expenses over fixed assets) and the price of labour ($W_3$, the ratio personnel expenses over the number of employees). This may be due either to the chosen proxies or to the decreasing importance of the traditional production factors in bank activities.

On the other hand, as expected, the total cost always increases with the provided securities ($Y_2$) and the other earning assets ($Y_3$, here the difference between the earning assets and the total loans). As for the other output, total loans ($Y_1$), they clearly also increase the total cost, but only in the EU-27 panel.

With regard to the other explanatory variables, the results are statistically significant only for the equity ratio ($Z_2$, equity over total assets) and for the ratio revenue over expenses ($Z_3$), thereby confirming our expectations: total cost clearly increases with the equity ratio and decreases with the revenue over expenses ratio.

From the residuals of the estimated cost frontier functions (Model I of Appendix IV), we also obtain the country efficiency scores, which are presented in Appendix V. For each panel, the 100% result is obtained by the country with the best practice, that is, the country with least waste in its production process. All the other countries are classified in relation to each panel´s benchmark.

Again according to the results reported in Appendix V, we see that the inclusion of the new EU member-states produces a very small decrease in the mean score and the median of cost efficiency and slightly increases the standard deviation. Regarding the country efficiency scores, the results for the EU-27 panel clearly show that the all of the 12 "new" member-states are situated below the mean efficiency. However, there are also three "old" members (specifically, Austria, Portugal and Greece) which not only have the worst scores in the EU-15 panel, but also occupy low positions in the EU-27 ranking, indeed obtaining worse results than some of the "new" member-states.

In order to test the degrees of convergence within the two panels of countries, we use the predicted values of efficiency obtained with the estimated cost model (Model II of Appendix IV) to estimate the previously-presented *beta*-convergence model (see equation [2]).

Borrowing from economic growth theory, we know that a negative value of the estimated *betas* reveals convergence and that the higher is *beta,* the faster will the convergence process be.

The results obtained with our model are reported in Table 4 (we have omitted the results for the country dummies, but they will be provided on request).

**Table 4 – $\beta$-Convergence estimates**

| | PANEL 1 - 15 EU countries | PANEL 2 - 27 EU countries |
|---|---|---|
| **Constant:** | | |
| coefficient | 0.3084647 | 0.3128859 |
| t | 3.85 | 6.12 |
| P>\|t\| | 0.000 | 0.000 |
| $\beta$: | | |
| coefficient | -0.1335495 | -0.141474 |
| t | -3.70 | -5.95 |
| P>\|t\| | 0.000 | 0.000 |
| | | |
| R-squared | 0.1147 | 0.1638 |
| N | 210 | 378 |

From the results reported in Table 4, we can conclude that there is a convergence process across EU countries in both panels, since the values of the estimated *betas* are statistically significant and negative but they are relatively small, revealing that this convergence is not a very fast process.

Appendix VI presents the results obtained with the input-oriented Data Envelopment Analysis (DEA) which, as was mentioned earlier, does not require the specification of a functional form. In our estimations, we use the same three inputs (borrowed funds, physical capital and labour, as defined previously) and the same three outputs (total loans, total securities and other earning assets). In this case, a perfectly efficient country will be situated on the efficient frontier, which is defined, for each panel, with the combinations of the best-practice observations of the panel. In addition, the relative measure of any country´s inefficiency will be its distance from the efficient frontier.

As expected, the DEA efficiency scores are lower than those obtained with the estimation of the Stochastic Cost Frontier (SCF), since DEA does not allow for the decomposition between "pure" technical inefficiency and "noise". Now there is a clearer decrease of the average efficiency score in the EU-27 panel, compared to the EU-15 panel (from 80% to 74%). The median also declines from 78% to 75%, while the standard deviation increases from 16.2% to 22.7%.

Table 5 below allows the comparison between the country efficiency rankings which were obtained with both the estimated SCF and DEA estimations. In spite of the methodological differences, there are only few remarkable changes in the countries' ranking positions. For instance, Finland is very well classified with the SCF, but falls dramatically with the DEA estimations. However, it is worth noting that according to the data presented in Appendix III, the Finnish banks represent, on average, only around 0.5% of all considered banks. Generally speaking, Table 5 shows that for some of the more representative countries, even when the ranking position is not exactly the same, a good score with the SCF is almost always confirmed with a similarly good position with DEA (and *vice versa*).

**Table 5 – SCF and DEA country efficiency rankings**

| | EU-15 | | EU-27 | |
|---|---|---|---|---|
| | **SCF** | **DEA** | **SCF** | **DEA** |
| 1 | Ireland | Ireland | Finland | Estonia |
| 2 | Finland | Portugal | Ireland | Ireland |
| 3 | Denmark | Spain | Denmark | Malta |
| 4 | Netherlands | UK | Sweden | Slovakia |
| 5 | Sweden | Italy | Netherlands | Spain |
| 6 | UK | Greece | UK | Slovenia |
| 7 | Spain | Belgium | Luxembourg | Romania |
| 8 | Luxembourg | Austria | Belgium | UK |
| 9 | Belgium | Netherlands | Spain | Italy |
| 10 | Italy | Denmark | France | Cyprus |
| 11 | France | Germany | Italy | Czech Rep. |
| 12 | Germany | Luxembourg | Germany | Belgium |
| 13 | Austria | France | Malta | Portugal |
| 14 | Portugal | Sweden | Cyprus | Netherlands |
| 15 | Greece | Finland | Austria | Denmark |
| 16 | | | Slovenia | Germany |
| 17 | | | Slovakia | Luxembourg |
| 18 | | | Estonia | France |
| 19 | | | Latvia | Greece |
| 20 | | | Lithuania | Austria |
| 21 | | | Czech Rep. | Poland |
| 22 | | | Portugal | Sweden |
| 23 | | | Bulgaria | Finland |
| 24 | | | Hungary | Latvia |
| 25 | | | Greece | Lithuania |

| | | | | |
|---|---|---|---|---|
| 26 | | | Poland | Hungary |
| 27 | | | Romania | Bulgaria |
| **average** | **98.825** | **79.853** | **98.616** | **74.174** |
| **median** | **98.778** | **77.500** | **98.479** | **74.900** |
| **stand.dev.** | **0.364** | **16.172** | **0.365** | **22.660** |

Finally, in order to test the differences in the efficiency results in two specific periods that coincide both with the implementation of the EMU and with the last EU enlargement, we apply the DEA estimates for the two panels of countries (EU-15 and EU-27) during two time sub-periods: 2000-2008 and 2004-2008. The average results[2] are presented below in Table 6, where we also include the average results for the entire time period (1994-2008). These results allow us to conclude that the EU enlargement not only increased heterogeneity (the standard deviations are always greater in the EU-27 panels), but also contributed to the decrease of the average and the median of the efficiency scores.

Furthermore, and again according to the results reported in Table 6, for both panels (EU-15 and EU-27), there has been an increase in efficiency since the implementation of the EMU (the results for the time period 2000-2008 are always higher than those for the entire period, 1994-2008). However, efficiency decreased slightly after the most recent EU enlargement process (the results for the period 2004-2008 are inferior to those obtained for 2000-2008).

**Table 6 –DEA average efficiency by panels and time periods**

| | **1994-2008** | | **2000-2008** | | **2004-2008** | |
|---|---|---|---|---|---|---|
| | **EU-15** | **EU-27** | **EU-15** | **EU-27** | **EU-15** | **EU-27** |
| **Average** | 79.853 | 74.174 | 82.953 | 81.033 | 82.013 | 80.589 |
| **Median** | 77.500 | 74.900 | 82.600 | 82.400 | 82.200 | 83.300 |
| **stand.dev.** | 16.172 | 22.660 | 17.109 | 16.262 | 17.039 | 18.458 |

[2] In order to save space, the country-specific results are not presented in this paper, but will be provided on request.

## 5. Discussion and conclusions

The two approaches to efficiency measurement, SFA and DEA, rely on the concept of efficiency that relates, in a production function, the allocation of scarce resources or inputs to the obtained results or outputs defining the production possibility frontier. Thus, with both approaches, technical efficiency is always a relative measure of the distance to the frontier and depends on the specific inputs and outputs and the definition of the production function.

The SFA approach is a parametric method that requires the econometric estimation of the (cost or profit) function. One of its main advantages is to allow the decomposition of the deviations from the efficient frontier between the stochastic error and pure inefficiency. Another important advantage of this approach is the guarantee that if we include an irrelevant variable in the function, the method will detect this irrelevance and the variable will have a very low or even zero weight in the definition of the efficiency results.

On the other hand, the DEA approach may be more flexible, as it does not require the estimation of any econometric function. One of its main advantages is to provide efficiency scores even in the presence of relatively few observations, since for each situation, DEA will take the available data to define the efficiency frontier with the combinations of the best-practice observations. All production units are situated either on or below the defined efficiency frontier and the efficiency measure is simply the distance of each production unit to the frontier.

So, the natures of these two approaches are very different and even when they are estimating the underlying efficiency values of the same production units, using the same inputs to produce the same outputs, SFA and DEA can provide different efficiency scores for some or even all the units under analysis. As each method has its own advantages, neither of them provides results that can be considered, for all data sets, much better than the results obtained with the other one.

In this paper, we chose to use both the SFA and DEA approaches and, when possible, we compare their results. Following the intermediation approach, we take into account the available data and the specific character of the bank production activities and consider three inputs (total loans, total securities and other earning assets) and the prices of three outputs (borrowed funds, physical capital and labour). For the application of the SFA, we opt to estimate stochastic cost frontier (SCF) functions and suppose that the total cost depends on three other explanatory variables: the number of banks, the equity ratio and the ratio revenue over expenses.

We took our data from the Bankscope database, which is universally recognised as one of the most appropriate banking data sources as it guarantees standardisation and comparability and provides data on banks accounting for 90% of total bank assets. Nevertheless, in spite of its recognised advantages, Bankscope data can still be very unbalanced, at least insofar as the number of included banks is concerned. In this paper, we use the available data from the consolidated accounts of the commercial and savings banks of all EU countries for the time period 1994-2008. Approximately 30% of the included banks are from one country (Germany), while the banks of four countries (Germany, France, Italy and UK) account for half of all the banks considered (see Appendix III). The main argument is that this reflects the reality of European banking, with the dominant power of the rich, large countries. On the other hand, even when we recognise that the number of banks can be important, we should also take into account their weight and the degree of concentration in the specific bank market.

Another important issue concerns the variables used. As Bankscope does not directly provide the prices of the production inputs, we consider proxies of these prices. For the price of the borrowed funds, we took the ratio interest expense over the sum of deposits; for physical capital, the ratio of the non-interest expenses over fixed assets; and for the price of labour, the ratio personnel expenses over the number of employees. This may be one of the explanations for the unexpected signals that we obtained for the influence of the labour and capital in the total cost in the estimated cost frontier functions. Another possible reason stems from the specificity of the banking production process, which actually depends much more on the borrowed funds that on the traditional production factors.

The estimated SCF function also confirms that the total cost depends on the chosen outputs. It mostly increases with the provided securities and the other earning assets, as well as with the total loans, although less clearly. As for the other explanatory variables included in the cost function, the results confirm that total cost clearly increases with the equity ratio and decreases with the ratio revenue over expenses.

Furthermore, the results obtained with the SCF function confirm the existence of statistically important technical inefficiencies and that these inefficiencies increase with the inclusion of the new EU member-states, since all of the countries have had to adapt to the new competitive conditions of the enlarged market.

These results are also confirmed by the DEA approach, which clearly shows that efficiency decreased with the inclusion of the new EU member-states. Furthermore, the DEA results allow us to analyse the evolution of the efficiency scores after the implementation of EMU (2000-2008) and in the years after the recent EU enlargement (2004-2008). Concentrating on the average levels of efficiency, we may conclude that while the implementation of the EMU has contributed to an increase of bank efficiency, the contrary appears to have happened more recently with the enlargement process. In line with these conclusions, the country ranking positions obtained with SCF estimates clearly show that most of the new member-states are situated below the average efficiency scores, together with some “old” EU members which have faced difficulties in the process of adaptation to the new, enlarged market conditions.

Moreover, the comparison of the results obtained with SCF and DEA country efficiency rankings allows us to conclude that, in spite of the different methodologies, and with few exceptions, countries that are well-classified with one approach are also in a good position with the other approach, and *vice versa*.

Thus, even if it is true that European integration may contribute to the increase of the average efficiency scores, some EU members are still facing difficulties to catch up with the levels of the best performers. Nevertheless, our convergence estimates confirm that there is a clear convergence process among EU members, although the pace continues to be very slow, with no guarantee that full integration will be achieved in the near future.

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## APPENDIX I – Panel stochastic frontier models

For panel data models, and particularly with stochastic frontier models, it is necessary not only to suppose the normality for the noise error term (*v*) and half- or truncated normality for the inefficiency error term (*u*), but also to assume that the firm-specific level of inefficiency is uncorrelated with the input levels. This type of model also addresses the fundamental question of whether and how inefficiencies vary over time.

Following Battese and Coelli (2008) and Battese et al. (1989), a general panel stochastic frontier model, with $T_i$ time observations of *i* units, can be represented as:

$$Y_{it} = \alpha + \beta^T x_{it} + v_{it} - u_{it}$$
$$u_i \sim \left|N\left[\mu_i, \sigma_u^2\right]\right|$$
$$v_{it} \sim N\left[0, \sigma_v^2\right]$$

Using the Greene (2003) reparameterisation and the truncated normal distribution of $u_i$, we have:

$$E\left[u_i \middle| \varepsilon_{i,1}, \varepsilon_{i,2}, \ldots, \varepsilon_{i,T_i}\right] = \mu_i * + \sigma_{i*}\left[\frac{\phi\left(\mu_i * / \sigma_i *\right)}{\Phi\left(-\mu_i * / \sigma_i *\right)}\right]$$
$$\mu_i * = \gamma_i \mu + (1-\gamma_i)(-\bar{\varepsilon}_i)$$
$$\varepsilon_{it} = y_{it} - \alpha\beta^T x_{it}$$
$$\gamma_i = 1 / 1 + \lambda T_i$$
$$\lambda = \sigma_u^2 / \sigma_v^2$$
$$\sigma_{i*}^2 = \gamma_i \sigma_u^2$$

So, as $T_i$ increases, $\gamma_i$ will decrease. If $T_i \to \infty$ , $\gamma_i \to 0$, so $-\bar{\varepsilon}_i \to u_i$ and there are clear advantages of having observed $u_i$ several times with panel data models.

## APPENDIX II – Data Envelopment Analysis (DEA)

DEA was originally presented in the paper of Charles et al. (1978), assuming constant returns to scale, which can be accepted as optimal but only in the long run. Later, Banker et al. (1984) introduced an additional convexity constraint (λ) and allowed for variable returns to scale.

Following Banker et al. (1984), we can assume that at any time t, there are N decision-making units (DMUs) that use a set of X inputs ($X = x_1, x_2, ..., x_k$) to produce a set of Y outputs ($Y = y_1, y_2, ..., y_m$), thus obtaining the DEA input-oriented efficiency measure of every *i* DMU, solving the following optimisation problem:

$$\min_{\theta,\lambda} \theta_i$$

$$s.t. \quad \sum_{r=1}^{N} y_{mr}^{t} \lambda_r^t \geq y_{mi}^t$$

$$\sum_{r=1}^{N} x_{kr}^{t} \lambda_r^t \leq \theta_i x_{ki}^t$$

$$\lambda_r^t \geq 0$$

$$\sum_{r=1}^{N} \lambda_r^t = 1$$

## APPENDIX III – Number of banks (and %) by country

| Country | 1994 | 2000 | 2008 | Average (1994-2008) |
|---|---|---|---|---|
| Austria | 54 (**2.34**) | 129 (**4.92**) | 147 (**6.92**) | 127 (**4.90**) |
| Belgium | 88 (**3.82**) | 68 (**2.60**) | 34 (**1.60**) | 72 (**2.78**) |
| Bulgaria | 10 (**0.43**) | 25 (**0.95**) | 21 (**0.99**) | 23 (**0.89**) |
| Cyprus | 12 (**0.52**) | 23 (**0.88**) | 9 (**0.42**) | 18 (**0.69**) |
| Czech Rep. | 24 (**1.04**) | 27 (**1.03**) | 20 (**0.94**) | 26 (**1.00**) |
| Denmark | 98 (**4.25**) | 123 (**4.69**) | 109 (**5.13**) | 116 (**4.48**) |
| Estonia | 9 (**0.39**) | 10 (**0.38**) | 10 (**0.47**) | 11 (**0.42**) |
| Finland | 11 (**0.48**) | 14 (**0.53**) | 12 (**0.56**) | 13 (**0.50**) |
| France | 350 (**15.18**) | 308 (**11.76**) | 204 (**9.60**) | 297 (**11.46**) |
| Germany | 786 (**34.08**) | 771 (**29.43**) | 593 (**27.92**) | 738 (**28.48**) |
| Greece | 25 (**1.08**) | 26 (**0.99**) | 29 (**1.37**) | 32 (**1.24**) |
| Hungary | 30 (**1.30**) | 39 (**1.49**) | 26 (**1.22**) | 34 (**1.31**) |
| Ireland | 24 (**1.04**) | 42 (**1.60**) | 40 (**1.88**) | 42 (**1.62**) |
| Italy | 177 (**7.68**) | 216 (**8 .24**) | 199 (**9.37**) | 231 (**8.92**) |
| Latvia | 16 (**0.69**) | 25 (**0.95**) | 33 (**1.55**) | 27 (**1.04**) |
| Lithuania | 7 (**0.30**) | 16 (**0.61**) | 15 (**0.71**) | 14 (**0.54**) |
| Luxembourg | 118 (**5.12**) | 112 (**4.27**) | 80 (**3.77**) | 106 (**4.09**) |
| Malta | 8 (**0.35**) | 10 (**0.38**) | 14 (**0.66**) | 12 (**0.46**) |
| Netherlands | 50 (**2.17**) | 50 (**1.91**) | 41 (**1.93**) | 57 (**2.20**) |
| Poland | 33 (**1.43**) | 50 (**1.91**) | 37 (**1.74**) | 48 (**1.85**) |
| Portugal | 34 (**1.47**) | 37 (**1.41**) | 25 (**1.18**) | 36 (**1.39**) |
| Romania | 3 (**0.13**) | 31 (**1.18**) | 27 (**1.27**) | 23 (**0.89**) |
| Slovakia | 11 (**0.48**) | 22 (**0.84**) | 16 (**0.75**) | 19 (**0.73**) |
| Slovenia | 14 (**0.61**) | 25 (**0.95**) | 21 (**0.99**) | 23 (**0.89**) |
| Spain | 172 (**7.46**) | 204 (**7.79**) | 136 (**6.40**) | 196 (**7.56**) |
| Sweden | 14 (**0.61**) | 22 (**0.84**) | 78 (**3.67**) | 60 (**2.32**) |
| UK | 128 (**5.55**) | 195 (**7.44**) | 148 (**6.97**) | 190 (**7.33**) |
| **TOTAL** | **2306** | **2620** | **2124** | **2591** |

# APPENDIX IV – Estimates with Cost Frontier Function

| PANEL 1 - 15 EU countries (1994 – 2008) | | | PANEL 2 - 27 EU countries (1994 – 2008) | | |
|---|---|---|---|---|---|
| **Variable** | **Model I** | **Model II** | **Variable** | **Model I** | **Model II** |
| **$W_1$:** | | | **$W_1$:** | | |
| coefficient | .7978371 | .7182306 | coefficient | .8743844 | .8159698 |
| z | 5.99 | 6.59 | z | 8.33 | 8.72 |
| P>\|z\| | 0.000 | 0.000 | P>\|z\| | 0.000 | 0.000 |
| **$W_2$:** | | | **$W_2$:** | | |
| coefficient | -.4135728 | -.3531588 | coefficient | -6.864385 | -.7367332 |
| z | -3.45 | -4.08 | z | -6.18 | -7.13 |
| P>\|z\| | 0.001 | 0.000 | P>\|z\| | 0.000 | 0.000 |
| **$W_3$:** | | | **$W_3$:** | | |
| coefficient | -.1162695 | -.0858007 | coefficient | -.1191528 | -.1065062 |
| z | -2.43 | -2.00 | z | -3.33 | -3.46 |
| P>\|z\| | 0.015 | 0.045 | P>\|z\| | 0.001 | 0.001 |
| **$Y_1$:** | | | **$Y_1$:** | | |
| coefficient | -.1072872 | | coefficient | .3433489 | .3308214 |
| z | -0.89 | | z | 5.65 | 10.66 |
| P>\|z\| | 0.376 | | P>\|z\| | 0.000 | 0.000 |
| **$Y_2$:** | | | **$Y_2$:** | | |
| coefficient | .1749893 | | coefficient | .103594 | |
| z | 0.81 | | z | 1.42 | |
| P>\|z\| | 0.418 | | P>\|z\| | 0.157 | |
| **$Y_3$:** | | | **$Y_3$:** | | |
| coefficient | .7515762 | .08218408 | coefficient | .3294587 | .457603 |
| z | 3.03 | 30.54 | z | 3.24 | 17.01 |
| P>\|z\| | 0.002 | 0.000 | P>\|z\| | 0.001 | 0.000 |
| **$P_1$:** | | | **$P_1$:** | | |
| coefficient | -.2089033 | -.1765455 | coefficient | -.0447659 | -.0470006 |
| z | -5.15 | -25.26 | z | -2.39 | -5.66 |
| P>\|z\| | 0.000 | 0.000 | P>\|z\| | 0.017 | 0.000 |
| **$P_2$:** | | | **$P_2$:** | | |
| coefficient | .0894457 | .0313571 | coefficient | .0566359 | .0308515 |
| z | 1.21 | 2.48 | z | 2.71 | 5.77 |
| P>\|z\| | 0.228 | 0.013 | P>\|z\| | 0.007 | 0.000 |
| **$P_3$:** | | | **$P_3$:** | | |
| coefficient | .1058051 | .1342023 | coefficient | -0.304238 | |
| z | 1.25 | 7.23 | z | -1.06 | |
| P>\|z\| | 0.212 | 0.000 | P>\|z\| | 0.288 | |
| **$P_4$:** | | | **$P_4$:** | | |
| coefficient | .0753658 | .09093 | coefficient | .000928 | |
| z | 2.21 | 3.76 | z | 0.05 | |
| P>\|z\| | 0.027 | 0.000 | P>\|z\| | .964 | |
| **$P_5$:** | | | **$P_5$:** | | |
| coefficient | -.1099221 | -.0777023 | coefficient | -.1232773 | -.1395303 |
| z | -2.25 | -3.05 | z | -3.73 | -5.03 |
| P>\|z\| | 0.025 | 0.002 | P>\|z\| | 0.000 | 0.000 |
| **$P_6$:** | | | **$P_6$:** | | |
| coefficient | .0505409 | | coefficient | .1639128 | .1834019 |
| z | 0.74 | | z | 3.96 | 6.12 |
| P>\|z\| | 0.461 | | P>\|z\| | 0.000 | 0.000 |
| **$P_7$:** | | | **$P_7$:** | | |
| coefficient | -.0054226 | | coefficient | -.011956 | -.0106709 |
| z | -0.80 | | z | -2.24 | -2.06 |
| P>\|z\| | 0.461 | | P>\|z\| | 0.025 | 0.040 |
| **$P_8$:** | | | **$P_8$:** | | |
| coefficient | -.0342686 | -.0344847 | coefficient | -.005493 | |
| z | -2.82 | -2.95 | z | -0.68 | |
| P>\|z\| | 0.005 | 0.003 | P>\|z\| | 0.495 | |
| **$P_9$:** | | | **$P_9$:** | | |
| coefficient | .0455189 | .0379471 | coefficient | .02441 | .0170957 |

| | | | | | |
|---|---|---|---|---|---|
| z | 3.10 | 3.02 | z | 2.21 | 3.06 |
| P>\|z\| | 0.002 | 0.002 | P>\|z\| | 0.027 | 0.002 |
| **$Z_1$:** | | | **$O_1$:** | | |
| coefficient | -.0316589 | -.0329478 | coefficient | -.0006337 | |
| z | -1.61 | -1.80 | z | -0.03 | |
| P>\|z\| | 0.107 | 0.071 | P>\|z\| | 0.974 | |
| **$Z_2$:** | | | **$O_2$:** | | |
| coefficient | .1961499 | .2154676 | coefficient | .0854296 | .0819597 |
| z | 4.78 | 5.77 | z | 3.77 | 3.64 |
| P>\|z\| | 0.000 | 0.000 | P>\|z\| | 0.000 | 0.000 |
| **$Z_3$:** | | | **$O_3$:** | | |
| coefficient | -1.010373 | -.9939596 | coefficient | -.7982632 | -.7986451 |
| z | -8.27 | -8.19 | z | -12.15 | -12.17 |
| P>\|z\| | 0.000 | 0.000 | P>\|z\| | 0.000 | 0.000 |
| | | | | | |
| **mu** | | | **mu** | | |
| **coefficient** | **2.952165** | **2.8636** | **coefficient** | **3.533474** | **3.254799** |
| **z** | **6.50** | **7.00** | **z** | **8.85** | **9.40** |
| **P>\|z\|** | **0.000** | **0.000** | **P>\|z\|** | **0.000** | **0.001** |
| | | | | | |
| **lnsigma2** | | | **lnsigma2** | | |
| **coefficient** | **-1.766562** | **-1.65176** | **coefficient** | **-.945118** | **-.9713751** |
| **z** | **-4.00** | **-3.87** | **z** | **-3.35** | **-3.48** |
| **P>\|z\|** | **0.000** | **0.000** | **P>\|z\|** | **0.001** | **0.001** |
| | | | | | |
| **ilgtgamma** | | | **ilgtgamma** | | |
| **Coefficient** | **3.635433** | **3.748892** | **Coefficient** | **3.908464** | **3.873654** |
| **z** | **7.66** | **8.19** | **z** | **13.05** | **13.09** |
| **P>\|z\|** | **0.000** | **0.000** | **P>\|z\|** | **0.000** | **0.000** |
| | | | | | |
| **sigma2** | | | **sigma2** | | |
| Coefficient | **.1709196** | **.1917123** | Coefficient | **.3886337** | **.3785621** |
| Standard error | .0754052 | .0819039 | Standard error | .1097808 | .1056769 |
| | | | | | |
| **gamma** | | | **gamma** | | |
| Coefficient | **.9743051** | **.9769977** | Coefficient | **.9803236** | **.9796408** |
| Standard error | .0118859 | 0.0102856 | Standard error | .0057757 | .0059013 |
| | | | | | |
| **sigma_u2** | | | **sigma_u2** | | |
| Coefficient | **.1665279** | **.1873025** | Coefficient | **.3809868** | **.3708549** |
| Standard error | .0754535 | .0819444 | Standard error | .1097962 | .105689 |
| | | | | | |
| **sigma_v2** | | | **sigma_v2** | | |
| Coefficient | **.0043918** | **.0044098** | Coefficient | **.0076469** | **.0077072** |
| Standard error | .0004367 | .0004369 | Standard error | .0005586 | .0005625 |
| | | | | | |
| **Wald chi2** | 6653.75 | 6642.71 | **Wald chi2** | 13032.10 | 12927.96 |
| Prob > chi2 | 0.0000 | 0.0000 | Prob > chi2 | 0.0000 | 0.0000 |
| | | | | | |
| **Log likelihood** | 243.80243 | 242.49131 | **Log likelihood** | 322.8634 | 321.74196 |
| **N** | 225 | 225 | **N** | 405 | 405 |

(*) **TC** = **Total cost** (dependent variable) = natural logarithm of the sum of the interest expenses plus the total operating expenses

**Inputs: $W_1$ = Price of the borrowed funds** = natural logarithm of the ratio interest expenses over the sum of deposits;
**$W_2$ = Price of physical capital** = natural logarithm of the ratio noninterest expenses over fixed assets
**$W_3$ = Price of labour** = natural logarithm of the ratio personnel expenses over the number of employees

**Outputs: $Y_1$ = Total loans** = natural logarithm of the loans
**$Y_2$ = Total securities =** natural logarithm of the total securities
**$Y_3$ = Other earning assets =** natural logarithm of the difference between the total earning assets and the total loans

**Products of Inputs and Outputs:** $\mathbf{P_1} = W_1 * Y_1$; $\mathbf{P_2} = W_1 * Y_2$ ; $\mathbf{P_3} = W_1 * Y_2$ ; $\mathbf{P_4} = W_2 * Y_1$ ; $\mathbf{P_5} = W_2 * Y_2$ ; $\mathbf{P_6} = W_2 * Y_3$ ; $\mathbf{P_7} = W_3 * Y_1$ ; $\mathbf{P_8} = W_3 * Y_2$ ; $\mathbf{P_9} = W_3 * Y_3$

**Other variables:** $\mathbf{Z_1}$ **= Number of companies =** natural logarithm of the number of companies included
$\mathbf{Z_2}$ **= Equity ratio =** natural logarithm of the ratio equity over total assets
$\mathbf{Z_3}$ **= Ratio revenue over expenses =** natural logarithm of the ratio of the total revenue over the total expenses

## APPENDIX V – Cost efficiency rankings obtained from SCF estimations

| | **EU-15 (1994-2008)** | | **EU-27 (1994-2008)** | |
|---|---|---|---|---|
| | **Country** | **Efficiency Ranking** | **Country** | **Efficiency Ranking** |
| 1 | Ireland | 100.000 | Finland | 100.000 |
| 2 | Finland | 98.990 | Ireland | 98.987 |
| 3 | Denmark | 98.952 | Denmark | 98.971 |
| 4 | Netherlands | 98.874 | Sweden | 98.905 |
| 5 | Sweden | 98.867 | Netherlands | 98.869 |
| 6 | UK | 98.801 | UK | 98.785 |
| 7 | Spain | 98.786 | Luxembourg | 98.784 |
| 8 | Luxembourg | 98.778 | Belgium | 98.777 |
| 9 | Belgium | 98.768 | Spain | 98.760 |
| 10 | Italy | 98.736 | France | 98.733 |
| 11 | France | 98.712 | Italy | 98.729 |
| 12 | Germany | 98.678 | Germany | 98.720 |
| 13 | Austria | 98.573 | Malta | 98.559 |
| 14 | Portugal | 98.445 | Cyprus | 98.479 |
| 15 | Greece | 98.409 | Austria | 98.474 |
| 16 | | | Slovenia | 98.446 |
| 17 | | | Slovakia | 98.411 |
| 18 | | | Estonia | 98.402 |
| 19 | | | Latvia | 98.394 |
| 20 | | | Lithuania | 98.378 |
| 21 | | | Czech Rep. | 98.348 |
| 22 | | | Portugal | 98.331 |
| 23 | | | Bulgaria | 98.329 |
| 24 | | | Hungary | 98.286 |
| 25 | | | Greece | 98.284 |
| 26 | | | Poland | 98.274 |
| 27 | | | Romania | 98.211 |
| **average** | | **98.825** | | **98.616** |
| **median** | | **98.778** | | **98.479** |
| **stand.dev.** | | **0.364** | | **0.365** |

## Appendix VI – Estimates with input-oriented Data Envelopment Analysis (DEA): EU-15 and EU-27 for the time period 1994-2008

| | EU-15 (1994-2008) | | EU-27 (1994-2008) | |
|---|---|---|---|---|
| | **Country** | **Efficiency Ranking** | **Country** | **Efficiency Ranking** |
| 1 | Ireland | 100.00 | Estonia | 100.00 |
| 2 | Portugal | 100.00 | Ireland | 100.00 |
| 3 | Spain | 100.00 | Malta | 100.00 |
| 4 | UK | 100.00 | Slovakia | 100.00 |
| 5 | Italy | 95.80 | Spain | 100.00 |
| 6 | Greece | 84.40 | Slovenia | 97.60 |
| 7 | Belgium | 81.60 | Romania | 97.40 |
| 8 | Austria | 77.50 | UK | 96.40 |
| 9 | Netherlands | 75.50 | Italy | 95.80 |
| 10 | Denmark | 73.70 | Cyprus | 88.70 |
| 11 | Germany | 70.50 | Czech Rep. | 87.40 |
| 12 | Luxembourg | 68.80 | Belgium | 81.50 |
| 13 | France | 66.20 | Portugal | 76.40 |
| 14 | Sweden | 52.00 | Netherlands | 74.90 |
| 15 | Finland | 51.80 | Denmark | 73.50 |
| 16 | | | Germany | 70.40 |
| 17 | | | Luxembourg | 68.20 |
| 18 | | | France | 66.20 |
| 19 | | | Greece | 64.20 |
| 20 | | | Austria | 63.80 |
| 21 | | | Poland | 58.70 |
| 22 | | | Sweden | 52.00 |
| 23 | | | Finland | 49.30 |
| 24 | | | Latvia | 43.00 |
| 25 | | | Lithuania | 40.30 |
| 26 | | | Hungary | 34.50 |
| 27 | | | Bulgaria | 22.50 |
| **average** | | **79.853** | | **74.174** |
| **median** | | **77.500** | | **74.900** |
| **stand.dev.** | | **16.172** | | **22.660** |