School of Economics and Management
TECHNICAL UNIVERSITY OF LISBON

Department of Economics

Cândida Ferreira

European integration and banking efficiency: a panel cost frontier approach

WP 03/2011/DE/UECE

WORKING PAPERS

ISSN Nº 0874-4548

European integration and banking efficiency: a panel cost frontier approach

Cândida Ferreira[1]

Abstract

The aim of this paper is to contribute to the relatively scarce published research on the relationship between European integration and banking efficiency. Estimating cost translog frontier functions for different panels of European Union countries for the time period 1994-2008 we conclude that there is always technical inefficiency. Additionally, although country inefficiencies have decreased in recent years (2000-2008), there are no remarkable changes in the countries' ranking positions. Our results also point to the existence of a quite slow convergence process across EU countries during the period analysed, as well as its acceleration after the establishment of the European Monetary Union.

Keywords: Bank efficiency; European integration; convergence; cost frontier approach.

JEL Classification: G15; G21; F36; C58.

[1] ISEG-UTL - *Instituto Superior de Economia e Gestão – Technical University of Lisbon and UECE – Research Unit on Complexity and Economics*
Rua Miguel Lupi, 20, 1249-078 - LISBOA, PORTUGAL
tel: +351 21 392 58 00
fax: +351 21 397 41 53
(candidaf@iseg.utl.pt)

European integration and banking efficiency: a panel cost frontier approach

1. Introduction

In recent years, financial systems have been experiencing the consequences of the strong imbalances and turbulence of 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.

The ensuing crisis has raised attention to the importance of studies aiming to identify the factors explaining the weaknesses in the financial systems at national and international levels. It has also intensified the questioning of the role of the financial authorities and their policy responses in order to detect the symptoms of fragility and prevent further crisis and instability.

It remains true that the European Union (EU) financial and credit systems are bank-dominated and among EU regulators, there is a strong belief that a well-integrated financial system is a necessary precondition for the enhancement of financial stability and the increased efficiency of the entire EU economy.

Moreover, the process of financial integration is often presented as a necessary pre-requisite for the adoption of the euro and the implementation of the single monetary policy, with the predominance of the banking intermediation in the context of the EU (Cabral *et al.,* 2002; European Central Bank, 2003; Hartmann *et al.*, 2003; Baele *et al.*, 2004; Sørensen and Gutiérrez, 2006; Arghyrou *et al.,* 2009).

The establishment of the European Monetary Union was supposed to accelerate the process of consolidation and economic and financial integration. However, 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 far from being integrated (Gardener *et al.,* 2002; Schure *et al.* 2004; Dermine, 2006; European Central Bank, 2007; European Central Bank, 2008; Affinito and Farabullini, 2009; Gropp and Kashyap, 2010).

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

There is 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).

Nonetheless, few studies have clearly addressed the relationship between European integration and banking efficiency. 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 tests banking efficiency across European Union countries in the wake of the recent crisis, estimating translog cost frontier functions and comparing the results for different samples of EU countries: all European Union members (EU-27), the "old" members (EU-15) and those that joined the Union during the last decade (EU-12) for the time period 1994-2008 and for the years after the introduction of the single currency (2000-2008). The conclusions point to the existence of statistically relevant technical inefficiencies, although these have tended to decrease during the last decade. Furthermore, the analysis of the convergence process with the estimation of β-convergence models allows us to conclude that there is clear convergence in banking efficiency across EU countries and that the pace of convergence increased slightly after the implementation of the EMU.

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

Over recent years, the research into the role and performance of the banking industry has paid particular attention to the estimation of bank efficiency, explaining the variations in efficiencies across banks and countries. Although European research on bank efficiency has not yet matched the record of the US contributions, it has increased enormously since the dynamic changes were introduced into the structure of European banking.

There is a strand of literature that focuses on the heterogeneities across banks, explaining them by the differences in the performance conditions, such as 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, 2008), technological progress (Wheelock and Wilson, 1999; Berger, 2003; Casu *et al*., 2004) 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 analysis of bank cost efficiency is 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 the banking outputs. The discussion is mainly on the specific role of deposits, since they may be considered both as inputs and outputs of the production function.

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

The *intermediation approach* considers that banks are mainly intermediaries between the economic agents with excess financing capacity and those economic agents that need financial 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 deviation from the frontier that corresponds to the losses of efficiency.

Most of the empirical studies on the measurement of bank efficiencies adopt either non-parametric methods, particularly the Data Envelopment Analysis (DEA), or parametric methods, like the Stochastic Frontier Analysis (SFA), which estimate efficiency based on economic optimisation (maximisation of profits or minimisation of costs), given the assumption of a stochastic optimal frontier.

Following the pioneering contribution of Farrel (1957), the SFA has been 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), Kumbhakar and Lovell (2000), Altunbas *et al.* (2001) and Coelli *et al*. (2005).

According to Altunbas *et al*. (2001), the single equation stochastic cost function model can be represented by 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 to be found 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 the managerial performance, and 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 μ 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 σ_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 inefficient term, *u*, must be obtained indirectly. Following Jondrow *et al*. (1982) and Greene (1990, 2003, 2008) the total variance can be expressed as $\sigma^2 = \sigma_u^2 + \sigma_v^2$, where the contribution of the inefficient term is $\sigma_u^2 = \dfrac{\sigma^2 \lambda^2}{1+\lambda^2}$; $\sigma_v^2 = \dfrac{\sigma^2}{1+\lambda^2}$ is the contribution of the noise and $\lambda = \dfrac{\sigma_u}{\sigma_v}$ 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 σ^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.

The theoretical background to financial integration can be found in the large strand of literature that analyses price convergence, particularly in the different versions of the Law of One Price.
The Law of One Price simply states that "identical goods must have identical prices". It is a fundamental and intuitive proposition and it is usually considered as one of the most basic laws in economics (Lamont and Thaler, 2003). This law is based on the assumption that price differences would provide an opportunity for arbitrage and, in the absence of transaction costs, the arbitrageurs would lead to price convergence.
Some authors (e.g. Baele *et al*., 2004; European Central Bank, 2007, 2008; Casu and Girardone, 2009, 2010) consider that full integration in the financial markets means that all potential agents in these markets, facing a single set of financial instruments and/or services, follow a single set of decision rules, have equal access to these financial instruments and/or services and are treated equally when acting in these markets.
This concept of financial integration, which is closely related to the Law of One Price, supposes that financial integration is independent of the financial structures within countries or regions. Several works have discussed and empirically tested the validity of this law, recognising the existence of some caveats, since markets may be incomplete, in which case financial integration will not benefit all agents acting in these markets (e.g. Allen and Gale, 1997; Baele *et al*., 2004). For different euro-area countries, Hartmann e*t al*. (2003) find that there is no support for the argument that financial integration leads to convergence in the financial structures. Baele et al.

(2004) consider five key euro-area markets (money, government bonds, corporate bonds, banking/credit and equity markets) and conclude that these distinct market sectors have attained different levels of integration. Casu and Girardone (2009, 2010) also state that despite the regulatory emphasis, the process of integration of the EU financial services sector has been slower than in other sectors and there still remain real obstacles to the integration.

Borrowing the concepts σ-convergence and β-convergence from the economic growth theory and the contributions of authors like Barro and Sala-i-Martin (1992), Quah (1996) or, specifically for panel data, Weill (2009), a *β*-convergence test to access the speed of integration can be performed through the estimation of the following linear equation:

$$\ln BPerf_{i,t} - \ln BPerf_{i,t-1} = \alpha + \beta \ln BPerf_{i,t-1} + \sum_{i=1}^{n} D_i + \varepsilon_{i,t}$$

Where: $BPerf_{i,t}$ = bank performance in country i (i = 1, ...n) in year t (t = 1, ... T)
D_i = country dummies
ε = error term

A negative value of the parameter β implies convergence, and this convergence will be as fast as β is high.

3. Methodology and data used

In this paper, we follow the intermediation approach and we specify 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).

The general translog form of the cost function to be estimated is:

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

Where:

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

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

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

z = other explaining variables (m = 1, ..., M)

t = time trend

Our data are sourced from the BankScope database. The sample comprises annual data from consolidated accounts of the commercial and saving banks of all EU countries between 1994 and 2008. In Appendix II, 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 and we use 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
  - **t = Time trend**

In our estimations we consider three sets of EU countries:

- **EU-27** – all EU member-states.

- **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-12** – comprising the 12 member-states that have joined the union since 2004: Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia and Slovenia.

In order to analyse the possible influences of the implementation of the EMU in our estimations, we define two time periods: 1994-2008 and 2000-2008.

The convergence in banking efficiency across the different panels will be tested through the estimation of the following β-convergence model:

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

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

4. Empirical results

The results obtained with the translog cost frontier function are presented in Appendix III. The information provided on the Wald tests and the log of the likelihood allows us to conclude that in all considered 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 III).

The high values of the mean, μ, of the first part of the cost function's error, capturing the effects of the inefficiency, as we defined above, indicates that in all circumstances (see Table 1 below, with the values taken from Appendix III), technical inefficiencies exist and they are statistically important, so 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 z values provided in Table 1 allows us to conclude that according to the statistical significance of this mean, the existence of technical inefficiencies is particularly clear for the time period 2000-2008 and also for the panels that include all EU countries (EU-27) for both time periods (1994-2008 and 2000-2008).

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

Variable	1994 – 2008			2000 – 2008		
	EU27	EU15	EU12	EU27	EU15	EU12
mu						
coefficient	.9236	.2838	.2703	.6571	.3868	.5147
z	4.06	1.04	2.63	4.39	3.24	4.34
P>|z|	0.000	0.296	0.009	0.000	0.001	0.000

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 $\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$, which are reported in Table 2, reveal that in almost all panels, the inefficient error term amounts to more than 97%. This implies that in almost all situations, the variation of the total cost among the different EU countries was due to the differences in their cost inefficiencies. The only exception is the panel including the newest EU member states (EU-12) for the time period 1994-2000, but the differences in the cost inefficiency still contributes to 85% of the variation of the total cost.

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

Variable	1994 – 2008			2000 – 2008		
	EU27	EU15	EU12	EU27	EU15	EU12
gamma						
Coefficient	.9875	.9801	.8492	.9846	.9741	.9689
Standard error	.0056	.0199	.0827	.0082	.0167	.0175

These results are confirmed by the comparison of the values of the variances of the inefficient error term (σ_u) and the random disturbances (σ_v) which are shown in Table 3. The comparison of the different columns allows us to conclude that for the EU-27 and EU-15 panels, the heterogeneity in the entire period (1994-2008) clearly diminishes in the more recent years (2000-2008). Moreover, in both periods, the EU-12 panel is more homogeneous than the EU-15, the latter being much more homogeneous than the EU-27 panel.

TABLE 3 – Summary of the results obtained for the variance of the inefficient error term (σ_u) and the noise (σ_v)

Variable	1994 – 2008			2000 – 2008		
	EU27	EU15	EU12	EU27	EU15	EU12
sigma_u2						
Coefficient	.4973	.1641	.0302	.1957	.0729	.0688
Standard error	.2205	.1632	.0191	.0995	.0462713	.0379
sigma_v2						
Coefficient	.0063	.0033	.0054	.0031	.0019	.0022
Standard error	.0005	.0003	.0006	.0003	.0003	.0003

According to the estimation results of the cost function, which are also presented in Appendix III, we can see that, as expected, the number of the included banks (Z_1) increases the total cost. The same happens with the equity ratio (Z_2), while the ratio revenue over expenses decreases the total cost.

In all situations, the total cost decreases with the trend (t) and increases with the total provided loans (Y_1) and total securities (Y_2). With reference to the third output, the "other earning assets" (Y_3), the influence in the total cost is not so clear. Particularly since 2000, the total cost decreases with these earning assets, but not with its squares (Y_3Y_3).

On the other hand, the total cost clearly increases with the price of the borrowed funds (W_1), but almost always decreases with the other two inputs, the price of physical capital (W_2) and the price of labour (W_3), but not with their products. In order to check this mixed influence of the inputs in the total cost, we also estimated a simplified model[1], in which we include only the outputs, the inputs and the time trend as explanatory variables. The results obtained are reported in Appendix IV and they reveal the importance of these variables to the total cost, confirming the strong and statistically valid positive influence of the price of the borrowed funds on the total cost and the much clearer positive influence of the price of the physical capital, while the price of labour still reveals mixed results.

From the residuals of the estimated more complete model (see Appendix III), we also obtain the country efficiency scores, which are presented in Appendix V. For each panel, the best 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 the panel´s benchmark. Table 4 below reports the country efficiency rankings by panel and clearly shows that there are very few changes in the countries' ranking positions in the different panels.

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

TABLE 4 –Efficiency rankings

EU27 1994-2008	EU27 2000-2008	EU15 1994-2008	EU15 2000-2008	EU12 1994-2008	EU12 2000-2008
Finland	Finland	Finland	Finland	Estonia	Bulgaria
Sweden	Sweden	Sweden	Luxembourg	Lithuania	Malta
Luxembourg	Luxembourg	Luxembourg	Sweden	Malta	Lithuania
Ireland	Ireland	Ireland	Ireland	Bulgaria	Estonia
Denmark	Denmark	Denmark	Denmark	Slovakia	Slovakia
Netherlands	Netherlands	Netherlands	Netherlands	Latvia	Latvia
Belgium	Belgium	Belgium	Belgium	Slovenia	Slovenia
Italy	Italy	Italy	Italy	Romania	Cyprus
Spain	Spain	Spain	Spain	Cyprus	Romania
UK	UK	UK	UK	Czech Rep.	Czech Rep.
Germany	Germany	Germany	Germany	Hungary	Poland
France	France	France	France	Poland	Hungary
Estonia	Bulgaria	Greece	Greece		
Bulgaria	Lithuania	Portugal	Portugal		
Lithuania	Malta	Austria	Austria		
Malta	Estonia				
Slovakia	Slovakia				
Latvia	Latvia				
Romania	Slovenia				
Slovenia	Romania				
Cyprus	Cyprus				
Czech Rep.	Czech Rep.				
Hungary	Hungary				
Poland	Poland				
Greece	Greece				
Portugal	Portugal				
Austria	Austria				

The results obtained with the β-Convergence test are presented in Appendix VI and the values of the estimated β are also reported in Table 5. For almost all panels (the only exception is the EU-12 panel for the time period 2000-2008), the estimated β are statistically significant and negative, revealing convergence processes, although these are not very fast, since the values are relatively small. Nevertheless, the acceleration of the convergence process is very clear during the last decade (here the period 2000-2008) for all EU-27 countries and particularly for the EU-15 group, in which most countries are also EMU members.

Table 5 – β-Convergence

Variable	1994 – 2008			2000 – 2008		
	EU27	EU15	EU12	EU27	EU15	EU12
β:						
coefficient	-.0123885	-.1426132	-.1623192	-.1167656	-.3616606	.0794333
p	-4.31	-3.95	-3.21	-2.03	-3.75	1.60
P>|p|	0.000	0.000	0.002	0.044	0.000	0.114

5. Discussion and conclusions

Efficiency is always a concept that relates, in a production function, the allocation of scarce resources or inputs, with the obtained outputs defining the production possibility frontier. Thus, technical efficiency will always be a relative measurement of the distance to the frontier, depending on the definition of the production function and the specific inputs and outputs included in this function.

One of the advantages of the use of the method of econometric frontiers is that it allows the decomposition of the deviations from the efficient frontier (the error, ε) between the stochastic error (the noise, v) and the pure inefficiency (u). Another important advantage is the guarantee that if we include an irrelevant variable in the function, the econometric frontier method will detect this irrelevance and the variable will have a very low, or even zero, weight in the definition of the efficiency results.

However, in spite of these technical advantages, the analysis of bank efficiency always raises some specific concerns over the definition of the appropriate inputs and outputs to be included in the production function.

In this paper, we opt to use the intermediation approach and, taking into account the specific character of the bank production activities and the available data, we define a cost frontier function considering three outputs (total loans, total securities and other earning assets) and the prices of three inputs (borrowed funds, physical capital and labour). We also include three other variables that may influence the efficiency results, namely, the number of banks, the equity ratio and the ratio revenue over expenses.

Our data are taken from the Bankscope database, which is recognised as one of the best sources, since it includes data for all EU countries and guarantees standardisation and comparability, providing data on banks accounting for around 90% of total assets. Nevertheless, Bankscope data can still be very unbalanced, at least in the number of included banks. Our Appendix I clearly shows that around 30% of the included banks are from one country (Germany) and the banks of four countries (Germany, France, Italy and UK) account for half of the banks considered. On the other hand, while it is true 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.

With regard to the variables, Bankscope does not directly provide the prices of the production inputs. Therefore, we consider proxies of these prices; specifically, 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.

For all panels, our estimations point to the dominance of the borrowed funds to explain the evolution of the total cost and the relatively low weight of the other two inputs (physical capital and labour), which reveal a mixed and unclear influence on the cost. This confirms the intermediation approach and the very specific characteristics of the banks' production process, since it depends much more on the borrowed funds than on the traditional production factors.

On the other hand, with regard to the influence of the considered outputs in the total cost, the validation of the intermediation approach is reinforced as total cost clearly always grows in line with the provided total loans. Generally speaking, we can also accept that an increase of provided total securities will contribute to the growth of the total cost, while the influence of the other earning assets (here, the difference between the total earning assets and the total loans) is not so clear. However, taking into particular account the results obtained with the simplified model (Appendix IV), we can also conclude that total cost positively depends on the increase of the other earning assets.

As expected, the total cost always increases with the growth of the considered banks and the equity ratio (a possible proxy for the accepted risk) and decreases with the ratio revenue over expenses. Furthermore, in all situations the time trend variable, which can be interpreted as the neutral technological changes, clearly contributes to the decrease of the total cost.

Our results also very clearly point to the existence of statistically important technical inefficiency in all panels, although this appears to decline in recent years (2000-2008), once again in all panels. Regarding the obtained ranking positions, there are very few changes in the efficiency rankings of the EU countries.

Moreover, the obtained results confirm the existence of a convergence process, but in spite of the clear acceleration of this process during the last decade (2000-2008), it is still quite slow and does not raise any credible prospects of full integration being achieved in the near future.

These results do not allow us to support the validity of the Law of One Price in the European bank markets. In an increasingly competitive environment, the ability to create differentiated products is crucial and financial products have become increasingly complex, so that market and country segmentation may continue to be a reality.

References

Affinito, M. and Farabullini, F. (2009) "Does the Law of One Price hold in Euro-Area Retail Banking? An Empirical Analysis of Interest Rate Differentials across the Monetary Union" *International Journal of Central Banking*, **5**, pp. 5-37.

Aigner, D., Lovell C.A.K. and Schmidt, P. (1977) "Formulation and estimation of stochastic frontier production function models", *Journal of Econometrics*, **6**, pp. 21-37.

Allen, F. and Gale, D. (1997) "Financial Markets, Intermediaries and Inter-temporal Smoothing" *Journal of Political Economy*, **105**, pp. 523-546.

Altunbas, Y., Gardener, E.P.M., Molyneux, P. and Moore, B. (2001) "Efficiency in European banking" *European Economic Review*, **45**, pp. 1931-1955.

Altunbas, Y. and Marquês, D. (2008) "Mergers and acquisitions and bank performance in Europe. The role of strategic similarities", *Journal of Economics and Business*, **60**, pp. 204-222.

Arghyrou, M.G., Gregoriou, A. and Kontonikas, A. (2009) "Do real interest rates converge? Evidence from the European union", *Journal of International Financial Markets, Institutions & Money*, **19**, pp. 447-460.

Baele, L., Ferrando, A., Hordahl, P., Krylova, E. and Monnet, C. (2004) "Measuring European Financial Integration", *Oxford Review of Economic Policy*, **20**, pp. 509-530.

Barro, R. J. and Sala-i-Martin, X. (1992) "Convergence" *Journal of Political Economy*, **100**, pp. 223-251.

Barros, C., Ferreira, C. and Williams, J. (2007) "Analysing the determinants of performance of best and worse European banks: A mixed logit approach", *Journal of Banking and Finance*, **31**, pp. 2189-2203.

Battese, G. E. and Coelli, T. J. (1988) "Prediction of firm-level technical efficiencies with a generalized frontier production function and panel data", *Journal of Econometrics*, **38**, pp. 387-399.

Battese, G. E. and Coelli, T. J. (1992) "Frontier Production Functions, Technical Efficiency and Panel Data: With Application to Paddy Farmers in India", *Journal of Productivity Analysis*, **3**, pp. 153-169.

Battese, G. E. and Coelli, T. J.(1995) "A Model for Technical Inefficiency Effects in a Stochastic Frontier Production Function for Panel data", *Empirical Economics*, **20**, pp. 325-332.

Battese, G., Coelli, T. J. and Colby, T. (1989) "Estimation of Frontier Production Functions and the Efficiencies of Indian Farms Using Panel Data from ICRISTAT's Village Level Studies," *Journal of Quantitative Economics*, **5**, pp. 327-348.

Beck, T., Demirguç-Kunt, A. and Levine, R. (2003-a) "Law, endowments, and finance", *Journal of Financial Economics*, **70**, 137–181.

Beck, T., Demirguç-Kunt, A. and Levine, R. (2003-b) "Law and finance. Why does legal origin matter?" *Journal of Comparative Economics*, **31**, 653–675.

Berger, A. N. (2003) "The economic effects of technological progress: Evidence from the banking industry", *Journal of Money, Credit and Banking*, **35**, pp. 141-176.

Berger, A. N. (2007) "International Comparisons of Banking Efficiency", *Financial Markets, Institutions and Instruments*, **16**, pp. 119-144.

Berger, A.N., DeYoung, R. and Udell, G.F. (2001) "Efficiency barriers to the consolidation of the European Financial services industry" *European Financial Management*, **7,** pp. 117-130.

Berger, A.N. and Humphrey, D. B. (1991) "The dominance of inefficiencies over scale and product mix economies in banking", *Journal of Monetary Economics*, **28**, pp. 117-148.

Berger, A.N. and Mester, L. J. (1997) "Inside the black box: What explains differences in inefficiencies of financial institutions?", *Journal of Banking and Finance*, **21**, pp. 895-947.

Bikker, J.A., Spierdijk, L. and Finnie, P. (2006) *The impact of bank size on market power*, Netherlands Central Bank, Research Department, DNB Working Paper No. 120,

Bonin, J.P., Hasan, I. and Wachtel, P. (2005) "Bank performance, efficiency and ownership in transition countries" *Journal of Banking and Finance*, **29**, pp. 31-53.

Bos, J. W. B. and Kool, C. J. M. (2006) "Bank efficiency: The role of bank strategy and local market conditions" *Journal of Banking and Finance*, **30**, pp. 1953-1974.

Bos, J. W. B. and Schmiedel, H. (2007) "Is there a single frontier in a single European banking market?" *Journal of Banking and Finance*, **31**, pp. 2081-2102.

Cabral I., Dierick, F. and Vesala, J. (2002) *Banking Integration in the Euro Area*, ECB Occasional Paper Series No. 6.

Campa, J.M. and Hernando, I. (2006) "M&As performance in the European financial industry", *Journal of Banking and Finance*, **30**, pp. 3367-3392.

Cappiello, L., Hodahl, P., Kadareja, A. and Manganelli, S. (2006) *The impact of the euro on financial markets*, ECB Working Paper Series No. 598.

Casu, B., Girardone, C. and Molyneux, P. (2004) "Productivity change in European banking: A comparision of parametric and non-parametric approaches", *Journal of Banking and Finance*, **28**, pp. 2521-2540.

Casu, B. and Girardone, C. (2009) "Competition issues in European banking" *Journal of Financial Regulation and Compliance*, **17**, pp. 119-133.

Casu, B. and Girardone, C. (2010) "Integration and efficiency convergence in EU banking markets" *Omega*, **38**, pp. 260-267.

Coelli, T., D., Rao, D. S. P. , O'Donnell, C. J. and Battese, G. E. (2005) *An introduction to efficiency and productivity analysis*, 2nd. Ed. Springer Science+Business Media, Inc., New York.

Dermine, J. (2006) "European banking integration: Don't put the cart before the horse", *Financial Markets, Institutions and Instrum*ents, **15**, pp. 57-106.

Diaz, B. D.,. Olalla, M. G. and Azofra, S. S. (2004) "Bank acquisitions and performance: evidence from a panel of European credit entities" *Journal of Economics and Business*, **56**, pp. 377-404.

European Central Bank (2003) "The integration of Europe's financial markets" in *ECB Monthly Bulletin*, October 2003, pp. 53-66.

European Central Bank (2007) *Financial integration in Europe,* ECB, Frankfurt.

European Central Bank (2008) *Financial integration in Europe,* ECB, Frankfurt.

Farrell, M.J. (1957) "The Measurement of Productive Efficiency" *Journal of the Royal Statistical Society*, **120**, pp. 253-290.

Frerier, G.D. and Lowell, C.A.K. (1990)" Measuring cost efficiency in banking: Econometric and linear programming evidence", *Journal of Econometrics* **46**, pp. 229-245.

Gardener, E.P.M., Molyneux, P. and Moore, B. (ed.) (2002) - *Banking in the New Europe – The Impact of the Single Market Program and EMU on the European Banking Sector*, Palgrave, Macmillan.

Greene, W.M. (1990) "A gamma-distributed stochastic frontier model", *Journal of Econometrics*, **46**, pp. 141-163.

Greene, W.H. (2003) *Econometric Analysis*, 5th ed., Upper Saddle River, NJ: Prentice Hall

Greene, W.M. (2008)"The econometric approach to efficiency analysis". In: Fried, H.O., Lovell, C.A.K. and Schmidt, P. (Eds.), *The Measurement of Productive Efficiency: Techniques and Applications*, Oxford University Press, Oxford, pp. 92-251.

Goddard, J.A., Molyneux, P. and Wilson, J. O. S. (2001) *European banking efficiency, technology and growth*, John Willey and Sons.

Goddard, J.A., Molyneux, P., and Wilson, J. O. S. (2007) "European banking: an overview", *Journal of Banking and Finance*, **31**, pp. 1911-1935.

Gropp, R. and Kashyap, A. K. (2010) "A New Metric for Banking Integration in Europe", in Alesina, A. and Giavazzi, F. (ed.) *Europe and the Euro*, NBER Books, National Bureau of Economic Research, pp. 219-246.

Guiso, L., Jappelli, T., Padula, M. and Pagano, M. (2004) "Financial market integration and economic growth in the EU", *Economic Policy*, **40**, pp. 523-577.

Hartmann P., Maddaloni, A. and Manganelli, S. (2003) "The euro area financial system: structure integration and policy initiatives" *Oxford Review of Economic Policy,* **19**, pp. 180-213.

Holló, D. and Nagy, M. (2006) "Bank Efficiency in the enlarged European Union" in *The banking system in emerging economies: how much progress has been made?*, BIS Papers, N. 28, Bank of International Settlements Papers, Monetary and Economic Department, pp. 217-235.

Hughes, J. P. and Mester, L. J. (2008) *Efficiency in banking: theory, practice and evidence*, Federal Reserve Bank of Philadelphia, Working Paper 08-1.

Jondrow, J., Lovell, C.A.K., Materov, I.S. and Schmidt, P. (1982) "On estimation of technical inefficiency in the stochastic frontier production function model", *Journal of Econometrics*, **19**, pp. 233-238.

Kasman, A. and Yildirim, C. (2006) "Cost and profit efficiencies in transition banking: the case of new EU members", *Applied Economics*, **38** pp. 1079-1090.

Kumbhakar, S.C. and Lovell, C.A.K. (2000) *Stochastic Frontier Analysis*, Cambridge University Press, Cambridge.

Kumbhakar, S.C., Lozano-Vivas, A., Lovell, C.A.K. and Hasan, I. (2001) "The effects of deregulation on the performance of financial institutions: The case of Spanish savings banks", *Journal of Money, Credit and Banking*, **33**, pp. 101-120.

Lamont, O. A. and Thaler, R. H. (2003) "Anomalies: The Law of One Price in Financial Markets", *Journal of Economic Perspectives*, **17**, pp. 191-202.

Lensink, R., Meesters, A. and Naaborg, I. (2008) "Bank efficiency and foreign ownership: Do good institutions matter" *Journal of Banking and Finance*, **32**, pp. 834-844.

Manna, M. (2004) *Developing statistical indicators of the integration of the euro area banking system*, ECB Working Paper Series No.300.

Meeusen, W. and van den Broeck, J. (1977) "Efficiency estimation from a Cobb-Douglas production function with composed error" *International Economic Review*, **18**, pp. 435-444.

Molyneux, P. (2003) *"Does size matter?" Financial restructuring under EMU*, United Nations Universiy, Institute for New Technologies, Working Paper No. 03-30.

Murinde, V., Agung, J. and Mullineux, A. W. (2004) "Patterns of corporate financing and financial system convergence in Europe", *Review of International Economics*, **12**, pp. 693-705.

Quah, D. (1996) "Twin peaks: growth and convergence in models of distribution dynamics", *Economic Journal*, **106**, pp. 1045-1055.

Resti, A. (1997) “Evaluating the cost-efficiency of the Italian banking system: what can be learn from the joint application of parametric and non-parametric techniques”, *Journal of Banking and Finance*, **21**, pp. 221-250.

Rossi, S., M. Schwaiger and G. Winkler (2005) *Managerial Behaviour and Cost/Profit Efficiency in the Banking Sectors of Central and Eastern European Countries*, Oesterreichische Nationalbank (Austrian Central Bank) Working Paper 96.

Schaeck, K. and Cihak, M. (2007) *Bank competition and capital ratio*, IMF Working Paper WP/07/216.

Schure, P., Wagenvoort, R. and O'Brien, D. (2004) “The efficiency and the conduct of European banks: Developments after 1992” *Review of Financial Economics*, **13**, pp.371–396.

Sealey, C.W. Jr. and Lindley, J. T. (1977) “Inputs, outputs and a theory of production and cost at depository financial institution” *Journal of Finance*, **32**, pp. 1251–1266.

Sørensen, C. K. and Gutiérrez, J. M. P. (2006) *Euro area banking sector integration using hierarchical cluster analysis technique*s, ECB Working Paper Series No. 627.

Stevenson, R. F. (1980) “Likelihood Functions for Generalized Stochastic Frontier Estimation”, *Journal of Econometrics*, **13**, pp. 57-66.

Sturm, J-E and Williams, B. (2010) “What determines differences in foreign bank efficiency? Australian evidence”, *Journal of International Financial Markets, Institutions and Money*, **20**, pp. 284-309.

Tortosa-Ausina, E. (2002) “Exploring efficiency differences over time in the Spanish banking industry”, *European Journal of Operational Research*, **139**, pp. 643-664.

Vives, X. (2001) – “Restructuring Financial Regulation in the European Monetary Union”, *Journal of Financial Services Research*, **19**, pp. 57-82.

Weill L. (2004), “Measuring Cost Efficiency in European Banking: A comparison of frontier techniques”, *Journal of Productivity Analysis*, **21**, 133-152.

Weill, L. (2009) “Convergence in banking efficiency across European countries”, *Journal of International Financial Markets Institutions and Money*, **19**, pp. 818-833.

Wheelock, D.C. and Wilson, P. W. (1999) “Technical progress, inefficiency and productivity change in US banking, 1984-1993” *Journal of Money, Credit and Banking*, **31**, pp. 213-234.

Williams, J. and Nguyen, N. (2005) “Financial liberalisation, crisis and restructuring: A comparative study of bank performance and bank governance in South East Asia”, *Journal of Banking and Finance*, **29**, pp. 2119-2154.

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 how and whether inefficiencies vary over time.

Following Battese and Coelli (1988) 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

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

So, as T_i increases γ_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 – 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 III – Estimates with Cost Frontier Function

Variable	1994 – 2008			2000 – 2008		
	EU27	EU15	EU12	EU27	EU15	EU12
Constant:						
coefficient	4.5533	4.7331	7.9005	10.641	1.4500	8.2714
z	6.20	4.60	5.17	6.16	0.48	2.12
P>|z|	0.000	0.000	0.000	0.000	0.634	0.034
Y_1:						
coefficient	.3304	.3279	.0447	.1061	1.0492	.6560
z	2.13	1.08	0.16	0.42	1.63	1.63
P>|z|	0.033	0.279	0.874	0.671	0.104	0.102
Y_2:						
coefficient	.0444	.3906	.0245	1.1363	1.6670	.7928
z	0.26	0.82	0.10	3.15	2.14	1.41
P>|z|	0.796	0.412	0.917	0.002	0.032	0.158
Y_3:						
coefficient	.0493	-.1399	.0639	-1.3520	-1.6713	-1.3663
z	0.21	-0.24	0.18	-2.77	-1.63	-1.87
P>|z|	0.836	0.807	0.856	0.006	0.103	0.062
W_1:						
coefficient	.6541	1.4086	.0269	1.6380	1.8361	.3792
z	4.64	4.95	0.11	6.12	4.66	0.61
P>|z|	0.000	0.000	0.913	0.000	0.000	0.541
W_2:						
coefficient	-.1577	-.7262	-.3029	-.9761	.0604	1.4043
z	-0.97	-2.71	-1.09	-3.59	0.12	-1.81
P>|z|	0.331	0.007	0.278	0.000	0.906	0.071

W_3:						
coefficient	-.0496	-.1763	-.6446	.5571	-.5339	.1188
z	-0.95	-2.70	-3.67	4.60	-1.88	0.29
P>|z|	0.343	0.007	0.000	0.000	0.060	0.773
Y_1Y_1:						
coefficient	.0431	.0253	.0373	.0673	.0597	.0715
z	2.62	0.81	1.85	3.46	1.74	2.60
P>|z|	0.009	0.418	0.064	0.001	0.082	0.009
Y_1Y_2:						
coefficient	.0633	.1055	.0533	.0030	-.0139	-.0687
z	2.57	1.51	1.94	0.09	-0.13	-2.02
P>|z|	0.010	0.132	0.053	0.927	0.898	0.044
Y_1Y_3:						
coefficient	-.1438	-.1737	-.1076	-.1076	-.1498	-.0934
z	-3.74	-1.95	-2.27	-2.23	-1.15	-1.65
P>|z|	0.000	0.052	0.023	0.026	0.252	0.099
Y_2Y_2:						
coefficient	.0025	-.1381	.0107	.0265	.2420	.0540
z	0.22	-1.62	0.84	1.47	2.08	2.91
P>|z|	0.828	0.106	0.402	0.141	0.037	0.004
Y_2Y_3:						
coefficient	-.0714	.1515	-.0660	-.1079	-.5395	-.0681
z	-2.27	0.85	-1.76	-2.39	-2.04	-1.32
P>|z|	0.023	0.393	0.078	0.017	0.042	0.188
Y_3Y_3:						
coefficient	.1201	.0368	.0959	.1486	.3938	.1291
z	3.81	0.33	2.40	3.34	2.18	2.53
P>|z|	0.000	0.739	0.016	0.001	0.029	0.012
W_1W_1:						
coefficient	.0056	.0384	.0386	.0955	.0702	.0534
z	0.40	1.07	2.38	4.95	1.90	1.94
P>|z|	0.688	0.285	0.017	0.000	0.057	0.053
W_1W_2:						
coefficient	.0441	.0655	-.0118	.0804	.0446	-.0112
z	2.15	2.18	-0.39	3.09	1.24	-0.18
P>|z|	0.031	0.029	0.698	0.002	0.217	0.859
W_1W_3:						
coefficient	.0029	.0225	.0112	.0064	.0331	.0160
z	0.45	1.71	0.78	0.61	1.65	0.48
P>|z|	0.650	0.088	0.436	0.543	0.099	0.632
W_2W_2:						
coefficient	-.0393	-.1110	.0099	-.0157	-.0482	-.0021
z	-2.60	-5.64	0.41	-0.72	-1.50	-0.04
P>|z|	0.009	0.000	0.682	0.472	0.133	0.971
W_2W_3:						
coefficient	.0070	-.0446	.0280	-.0305	.0006	-.0252
z	0.80	-2.80	1.74	-2.24	0.02	-0.46
P>|z|	0.423	0.005	0.082	0.025	0.983	0.643
W_3W_3:						
coefficient	-.0030	-.0062	-.0075	.0082	-.0182	-.0106
z	-1.73	-2.26	-1.23	2.66	-2.38	-0.95
P>|z|	0.083	0.024	0.220	0.008	0.017	0.341
Y_1W_1:						
coefficient	-.0283	-.1721	.0145	-.0045	-.1058	.0465
z	-1.41	-4.02	0.59	-0.17	-2.28	1.07
P>|z|	0.157	0.000	0.558	0.866	0.023	0.285
Y_1W_2:						
coefficient	-.0114	.0825	-.0796	.0597	.1085	.0129
z	-0.49	2.54	-2.32	2.04	2.99	0.22
P>|z|	0.625	0.011	0.020	0.041	0.003	0.828
Y_1W_3:						
coefficient	-.0050	.0178	.0600	-.0158	.0472	.0444
z	-0.68	1.29	3.75	-1.47	1.55	1.32
P>|z|	0.500	0.198	0.000	0.142	0.120	0.186
Y_2W_1:						
coefficient	.0118	.1485	-.0206	.1290	.1155	.0270
z	0.52	2.03	-0.77	2.82	1.45	0.39
P>|z|	0.603	0.043	0.442	0.005	0.148	0.697
Y_2W_2:						
coefficient	-.1061	-.2465	-.0587	-.1443	-.0379	-.1133

z	-3.15	-4.47	-1.13	-3.68	-0.42	-1.82
P>|z|	0.002	0.000	0.258	0.000	0.672	0.069
Y_2W_3:						
coefficient	-.0050	-.0298	-.0776	.0482	.0328	-.0190
z	-0.52	-1.32	-3.40	2.82	0.80	-0.31
P>|z|	0.606	0.188	0.001	0.005	0.421	0.754
Y_3W_1:						
coefficient	.0128	-.0102	.0517	-.1496	-.0589	-.0431
z	0.42	-0.12	1.35	-2.92	-0.63	-0.54
P>|z|	0.671	0.904	0.176	0.003	0.527	0.591
Y_3W_2:						
coefficient	.1327	.2113	.1555	.1609	-.0633	.1874
z	3.07	2.85	2.45	3.04	-0.54	2.36
P>|z|	0.002	0.004	0.014	0.002	0.593	0.018
Y_3W_3:						
coefficient	.0128	.0258	.0565	-.0649	-.0395	-.0268
z	0.93	1.09	1.91	-3.05	-0.76	-0.40
P>|z|	0.350	0.276	0.057	0.002	0.450	0.692
Z_1:						
coefficient	.0082	.0127	.1095	.0101	.0162	.0486
z	0.44	0.70	3.16	0.46	0.58	1.23
P>|z|	0.662	0.485	0.002	0.643	0.563	0.218
Z_2:						
coefficient	.0647	.1703	.0343	.1589	.1265	-.0256
z	2.76	3.85	1.11	4.06	2.41	-0.46
P>|z|	0.006	0.000	0.266	0.000	0.016	0.648
Z_3:						
coefficient	-.7141	-.9609	-.4682	-.5947	-.6249	-.3441
z	-10.37	-7.83	-5.88	-7.47	-5.10	-3.39
P>|z|	0.000	0.000	0.000	0.000	0.000	0.001
t:						
coefficient	-.0048	-.0081	-.0050	-.0224	-.0212	-.0010
z	-1.80	-2.21	-0.98	-5.95	-6.35	-0.48
P>|z|	0.072	0.027	0.329	0.000	0.000	0.633
mu						
coefficient	.9236	.2838	.2703	.6571	.3868	.5147
z	4.06	1.04	2.63	4.39	3.24	4.34
P>|z|	0.000	0.296	0.009	0.000	0.001	0.000
lnsigma2						
coefficient	-.6859	-1.7873	-3.3358	-1.6154	-2.5925	-2.6451
z	-1.57	-1.83	-6.23	-3.23	-4.20	-4.96
P>|z|	0.117	0.067	0.000	0.001	0.000	0.000
ilgtgamma						
coefficient	4.3682	3.8951	1.7286	4.1601	3.6285	3.4378
z	9.67	3.83	2.68	7.70	5.47	5.94
P>|z|	0.000	0.000	0.007	0.000	0.000	0.000
sigma2						
Coefficient	.5036	.1674	.0356	.1988	.0748	.0710
Standard error	.2205	.1631	.0191	.0994	.0462	.0379
gamma						
Coefficient	.9875	.9801	.8492	.9846	.9741	.9689
Standard error	.0056	.0199	.0827	.0082	.0167	.0175
sigma_u2						
Coefficient	.4973	.1641	.0302	.1957	.0729	.0688
Standard error	.2205	.1632	.0191	.0995	.0462713	.0379
sigma_v2						
Coefficient	.0063	.0033	.0054	.0031	.0019	.0022
Standard error	.0005	.0003	.0006	.0003	.0003	.0003
Wald chi2(31)	15874.87	8992.55	13427.32	9552.96	5852.91	8504.17
Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Log likelihood	361.60132	278.76336	190.12184	277.52094	189.10569	144.04883
N	405	225	180	243	135	108

(*) **TC** = **Total cost** (dependent variable) = 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 difference between the total earning assets and the total loans

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 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
t = time trend

APPENDIX IV – Estimates with Cost Frontier Function (simplified model)

Variable	1994 – 2008			2000 – 2008		
	EU27	**EU15**	**EU12**	**EU27**	**EU15**	**EU12**
Constant:						
coefficient	1.704008	1.436849	3.725444	1.508172	-.4157846	4.894205
z	8.93	5.47	10.23	4.93	-1.05	11.22
P>|z|	0.000	0.000	0.000	0.000	0.295	0.000
Y_1:						
coefficient	.4575199	.5483316	.3794408	.5693051	.7773747	.4458871
z	28.35	20.18	16.27	30.25	19.68	19.60
P>|z|	0.000	0.000	0.000	0.000	0.000	0.000
Y_2:						
coefficient	.0231095	.0334319	.0276436	-.0117959	-.1326427	.0379789
z	1.31	0.73	1.37	-0.54	-2.61	1.72
P>|z|	0.190	0.463	0.172	0.590	0.009	0.085
Y_3:						
coefficient	.3180318	.2530069	.3485391	.254392	.3151639	.1929269
z	11.80	4.50	10.09	7.39	4.16	4.64
P>|z|	0.000	0.000	0.000	0.000	0.000	0.000
W_1:						
coefficient	.5813181	.5953075	.6232564	.5896733	.6100655	.5941992
z	35.40	26.52	25.73	33.46	26.12	26.56
P>|z|	0.000	0.000	0.000	0.000	0.000	0.000
W_2:						
coefficient	.0371296	-.0254601	.1145439	.0708342	.0877214	.1673463
z	1.82	-1.01	3.67	2.74	2.71	4.00
P>|z|	0.069	0.313	0.000	0.006	0.007	0.000
W_3:						
coefficient	-.008435	.0031862	-.0315724	.0157908	-.0229858	.0270339
z	-1.10	0.38	-2.76	1.34	-1.52	1.85
P>|z|	0.270	0.705	0.006	0.179	0.128	0.065
t:						
coefficient	-.0042361	-.009332	.0120695	-.0194313	-.0258149	.0003669
z	-1.45	-2.49	2.18	-4.94	-5.53	0.13

P>|z|	0.146	0.013	0.029	0.000	0.000	0.896
mu						
coefficient	1.114109	-.0998493	.5355472	1.181618	.4111179	.4174215
z	4.93	-0.08	4.03	6.19	1.58	1.99
P>|z|	0.000	0.935	0.000	0.000	0.114	0.047
lnsigma2						
Coefficient	-.5008453	-.3119287	-2.592984	-.8834989	-1.615981	-1.942696
z	-1.23	-0.27	-6.22	-2.27	-2.17	-2.74
P>|z|	0.219	0.787	0.000	0.023	0.030	0.006
ilgtgamma						
coefficient	3.905836	4.640099	1.504086	4.208388	3.778475	3.321973
z	9.21	3.95	2.87	10.08	4.75	4.41
P>|z|	0.000	0.000	0.004	0.000	0.000	0.000
sigma2						
Coefficient	.6060182	.7320337	.0747966	.4133341	.1986957	.1433171
Standard error	.2469018	.8460565	.0312009	.160907	.148247	.1016942
gamma						
Coefficient	.9802729	.9904356	.8181831	.9853476	.9776533	.965175
Standard error	.0082009	.0111318	.0779999	.006028	.0173842	.025325
sigma_u2						
Coefficient	.5940632	.7250323	.0611973	.4072778	.1942555	.1383261
Standard error	.2469252	.8460843	.031205	.1609701	.1483371	.1017123
sigma_v2						
Coefficient	.011955	.0070015	.0135993	.0060564	.0044402	.004991
Standard error	.0008738	.0006908	.0014871	.0005977	.0006059	.0007217
Wald chi2(31)	8183.79	4101.42	5143.74	4559.79	2142.34	3690.80
Prob > chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Log likelihood	237.26571	194.54221	106.63578	191.7829	134.0707	102.92957
N	405	225	180	243	135	108

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

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

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

t = time trend

APPENDIX V – Cost efficiency rankings

A – EU-27

	EU27	1994 - 2008	EU27	2000 - 2008
1	Finland	100.000	Finland	100.000
2	Sweden	98.947	Sweden	98.917
3	Luxembourg	98.935	Luxembourg	98.913
4	Ireland	98.924	Ireland	98.892
5	Denmark	98.886	Denmark	98.848
6	Netherlands	98.838	Netherlands	98.801
7	Belgium	98.830	Belgium	98.785
8	Italy	98.818	Italy	98.763
9	Spain	98.792	Spain	98.746
10	UK	98.774	UK	98.731
11	Germany	98.772	Germany	98.728
12	France	98.715	France	98.668
13	Estonia	98.699	Bulgaria	98.581
14	Bulgaria	98.684	Lithuania	98.579
15	Lithuania	98.681	Malta	98.578
16	Malta	98.662	Estonia	98.572
17	Slovakia	98.642	Slovakia	98.563
18	Latvia	98.618	Latvia	98.526
19	Romania	98.599	Slovenia	98.502
20	Slovenia	98.594	Romania	98.491
21	Cyprus	98.580	Cyprus	98.490
22	Czech Rep.	98.535	Czech Rep.	98.446
23	Hungary	98.503	Hungary	98.392
24	Poland	98.491	Poland	98.390
25	Greece	98.397	Greece	98.303
26	Portugal	98.389	Portugal	98.286
27	Austria	98.351	Austria	98.262
average		**98.728**		**98.658**
median		**98.684**		**98.579**
stand. dev.		**0.299**		**0.324**

B – EU-15

	EU15	1994 - 2008	EU15	2000 - 2008
1	Finland	100.000	Finland	100.000
2	Sweden	98.933	Luxembourg	98.944
3	Luxembourg	98.911	Sweden	98.924
4	Ireland	98.899	Ireland	98.914
5	Denmark	98.858	Denmark	98.858
6	Netherlands	98.819	Netherlands	98.826
7	Belgium	98.795	Belgium	98.806
8	Italy	98.779	Italy	98.781
9	Spain	98.773	Spain	98.768
10	UK	98.751	UK	98.752
11	Germany	98.744	Germany	98.748
12	France	98.678	France	98.687
13	Greece	98.324	Greece	98.286
14	Portugal	98.323	Portugal	98.277

15	Austria	98.271	Austria	98.240
average		**98.791**		**98.787**
median		**98.779**		**98.781**
stand. dev.		**0.386**		**0.397**

C – EU-12

	EU12	1994 - 2008	EU12	2000 - 2008
1	Estonia	100.000	Bulgaria	100.000
2	Lithuania	98.999	Malta	98.998
3	Malta	98.997	Lithuania	98.997
4	Bulgaria	98.996	Estonia	98.989
5	Slovakia	98.975	Slovakia	98.982
6	Latvia	98.951	Latvia	98.962
7	Slovenia	98.936	Slovenia	98.947
8	Romania	98.934	Cyprus	98.944
9	Cyprus	98.930	Romania	98.938
10	Czech Rep.	98.892	Czech Rep.	98.908
11	Hungary	98.860	Poland	98.880
12	Poland	98.859	Hungary	98.876
average		**99.027**		**99.035**
median		**98.943**		**98.955**
stand. dev.		**0.297**		**0.294**

APPENDIX VI – β-Convergence estimates

Variable (*)	1994 – 2008			2000 – 2008		
	EU27	EU15	EU12	EU27	EU15	EU12
Constant:						
coefficient	.1217614	.35908	.4342104	.2965211	1.020656	-.2046035
p	4.48	4.09	3.24	2.06	3.76	-1.55
P>|p|	0.000	0.000	0.001	0.041	0.000	0.126
β:						
coefficient	-.0123885	-.1426132	-.1623192	-.1167656	-.3616606	.0794333
p	-4.31	-3.95	-3.21	-2.03	-3.75	1.60
P>|p|	0.000	0.000	0.002	0.044	0.000	0.114
R-squared	0.1615	0.1173	0.1849	0.0973	0.1623	0.1542
N	378	210	168	216	210	96

(*) Country dummies were also included in the estimated equations and the results obtained will be provided on request