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EFFICIENCY, OWNERSHIP AND FINANCIAL STRUCTURE IN EUROPEAN BANKING: A CROSS-COUNTRY COMPARISON

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Efficiency, Ownership and Financial Structure in European Banking: A Cross-Country Comparison

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Abstract

This paper investigates the efficiency in European banking organisations and the relation with corporate governance issues deriving from differences in ownership, bank type and financial structure. More specifically, we estimate the cost X-efficiency levels for a large sample of commercial, savings and co-operative banking institutions operating in the EU-15 (European Union) over 1998-2003 by using alternative parametric frontiers across bank- and market-based countries classified using the World Bank Financial Structure Database (Beck et al., 2001 and Demirguc-Kunt and Levine, 2001). In line with the main literature, it is found that cost X-inefficiencies are on average 23% and the Fourier-flexible should be the preferred functional form to model EU banks' production processes. However, while non-listed commercial institutions appear less cost efficient than the listed ones, on the whole our results reject the agency theory hypothesis that managers of privately-owned banks are more cost efficient than those of mutual banking institutions because of capital market devices. In particular, we find that mutual banks operating in the EU-15 countries are significantly more cost efficient than the commercial banks included in our sample. Furthermore, results are mixed concerning the financial structure hypothesis that in developed financial systems bank efficiency should not be statistically different across bank- versus market-based economies. Specifically, we find that while the hypothesis seems to hold for the sub-sample of commercial banks, in bank-based countries savings banks have significant cost efficiency advantages over those operating in market-based ones and over commercial banks.

Keywords: Bank Efficiency, Stochastic Frontier Analysis, Bank Ownership, Agency theory, Financial Structures.

JEL classification: G21, G32.

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1. Introduction

The relationship between firms' ownership and efficiency is of great importance in the corporate governance literature (see Berle and Means, 1932; Jensen and Meckling, 1976; Fama, 1980; Grossman and Hart, 1980; and Fama and Jensen, 1983). In the principal-agent framework, a major issue is what makes managers in different ownership types minimise production costs and maximise profits. For most European countries the banking sectors have traditionally been characterised by three main banks' types namely commercial, savings and co-operatives. Each bank type is associated with well-defined ownership and control characteristics on banks' operations. For instance, commercial banks can be either privately owned or listed; and co-operatives are typically mutual banks. While the legal form of saving banks clearly differs across countries (see sections 2 and 3.1), we analyse them as a single bank type as in Altunbas et al. (2003). Although the separation of ownership from control is common in all organisational forms, each ownership structure presents alternative property and contracting rights, thus each one imposes different restrictions on the "optimal" managerial behaviour. Agency theory postulates that managers of private institutions are forced to run their institutions efficiently and control their costs via market discipline devices; whereas managers in mutual institutions may not promote efficiency since capital market discipline devices are to some extent limited.[1]

Over the last decade or so, the financial sector in Europe has witnessed a series of fundamental changes such as deregulation and financial and technological innovation that have forced banks to modify their strategic objectives. For example, banking institutions have responded to deregulation and greater competitive pressures with a privatisation and consolidation process. As a result, European banks' managers have become increasingly demand-oriented and had to adjust their strategic goals towards cost reductions, profit and shareholder value maximisation (see, for example,

[1] If capital markets cannot provide the tools for diminishing the discretionary power of managers over firms' property rights, then managers are left free to pursue their own interests and their incentives to increase firm's efficiency are weak. For instance, the absence of a compensation package that links the managers' income with the mutual banks' performance makes managers of those banks more likely to maximise their own utility (see for instance O'Hara, 1981; and Masulis, 1987). In addition, other external corporate governance discipline devices such as board of directors', creditors' or shareholders' monitoring have limited, if not any, power to minimise the agency costs associated with behaviour of managers of mutual banks (namely expense preference behaviour, self-selection of management quality, and choice of project risk, see e.g. Williams, 2004).

Fiordelisi and Molyneux, 2006). As part of these strategic changes many banks operating in different European countries have recently engaged in transforming their ownership structures and have converted into privately owned or listed companies, while the role of the national governments in the banking sector has decreased considerably.[2] However, savings and co-operative banks still retain a relatively high market share in terms of total assets and deposits (around 15-20%) (see European Savings Banks Group, 2003 and European Association of Co-operative Banks, 2004). Although these credit institutions operating in Europe are usually smaller in terms of asset base compared with other banks' types and operate locally rather than globally, they are able to enjoy relatively high profits (see European Savings Banks Group, 2004).

The proposed relationship in the literature is that private banks are more efficient than their mutual counterparts. The motivation of this hypothesis is the alliance of managers' objectives and owners' interest in each ownership form. Although managers of private banks are expected to be cost efficient through market devices, it is possible that environmental factors may force mutual banks' managers to pursue the objective of high efficiency.[3] Finally, it is rational to assume that in each ownership form the owners are concerned about cost efficiency (see, Altunbas et al., 2001a); however, the same does not hold true for the management incentives in each ownership type. It might be that non-private banks' managers have an advantage in keeping their banks safe and maintaining good relationship with their long-term customers; whereas private banks' managers may be interested in providing additional or higher quality services that raise costs but also may drive up revenues by more than the cost increases (see Berger and Mester, 2003). From the above it is apparent that the private versus non-private ownership forms debate can only be resolved empirically. In this paper we compare the cost efficiency between commercial privately-owned and listed banks versus mutual banks.

[2] For example, the process of demutualisation started in the UK with the conversion of *building societies* into banks and was later followed in other EU countries e.g. in Italy, Austria and France. Also the direct/indirect state involvement in Finnish, French, German, Greek and Irish banking institutions has been further reduced (see European Central Bank, 2002 and Chakravarty and Williams, 2006).

[3] For instance Rasmusen (1988) shows that uninformed and risk-averse depositors prefer mutual banks because managers in these banks have a stronger incentive to choose a safe portfolio since their upside gains in compensation are limited by law and they risk losing their high lifetime income if their bank bankrupts. Similarly, Miles (1994) indicates that the owners of mutual banks, due to the right to withdraw their funds, can discipline inefficient management more effectively compared with private banks' owners who can just sell their shares in secondary markets.

Another objective of this paper is to relate European banks' efficiency with corporate governance issues deriving from differences in financial structure. This is because the effectiveness of a corporate governance system is also strongly related to the financial structure and development that prevails in a country. Indeed it is widely acknowledged in the corporate governance literature that a cross-country analysis is valid only if financial structure and financial development are controlled for (see Schmidt and Tyrell, 1997, and section 2). The related literature is vast; nonetheless, there is only one study that attempts to empirically investigate the relationship between financial structure and bank performance (Demirguc-Kunt and Huizinga, 2001).

This paper compares efficiency levels for a sample of 16,674 EU-15 bank observations over 1998-2003 estimated using alternative parametric cost frontiers, across different financial structures; namely bank- and market-based financial systems classified using the World Bank Financial Structure Database (Beck et al., 2001 and Demirguc-Kunt and Levine, 2001). The paper first attempts to resolve one of the main problems in parametric analysis that is to determine which cost function imposes the best structure on the shape of the efficient frontier. In particular, we test and compare the stochastic translog and linear spline against the Fourier-flexible cost frontier. Then we rearrange the data and estimate two frontier models: a common European and separate bank- and market based frontiers. The aim is to compare the cost X-efficiencies across bank- and market- based EU countries for the different groups of commercial, savings and co-operative banks; and between listed and non-listed banking institutions in our sample. In addition, we attempt to determine potential implications for bank efficiency originating from differences in financial structure and investigate the relationship between efficiency, bank type, ownership and financial structure. The ultimate goal is to identify the organisational and financial structures as important determinants of a sound corporate governance system in Europe. To the best of our knowledge there are no previous similar empirical works for the EU banking sector. Such a study has important policy implications especially in light of the fact that the EU banking sector is experiencing profound structural changes and a full integration has not yet been achieved (see Marquez-Ibanez and Molyneux, 2002, and Berger et al. 2001).

The next section briefly reviews the main literature. Section 3 explains the data and the methodology used to classify the sampled countries according to the World

Bank Financial Structure Index and to calculate bank efficiency. Section 4 discusses the main findings. The last section concludes and outlines the main policy implications of the research.

2. Literature review

The banking literature on X-efficiencies calculated using various forms of parametric frontiers is copious both in the US and, to a lesser extent, in Europe (see for extensive reviews, Berger and Humphrey, 1997, and Goddard et al. 2001). Nonetheless only a few studies carry out a methodological cross-checking of the results obtained using alternative parametric frontier methods. The advantages and disadvantages of using Fourier-flexible versus translog functional forms are well discussed in the literature (see Berger et al., 1997; Berger and Mester, 1997 and Altunbas and Chakravarty 2001); whereas only a handful of studies employ the linear spline function to estimate bank efficiencies in terms of scale and scope economies (see McAllister and McManus, 1993, for a US study and, more recently, Humphrey and Vale, 2004, for a study on Norwegian banks).

Focusing on the European banking sector, there are several country-specific studies that investigate the efficiency of different bank ownership structures using both parametric and/or non-parametric frontier methods (for more details on the most popular frontier methods see for example Goddard et al., 2001). Altunbas et al. (2001a) use the Fourier-flexible functional form to estimate cost and profit characteristics of the German banking market between 1989 and 1996. They estimate separate cost and alternative profit frontiers for each ownership type, namely private commercial, public savings and mutual co-operative banks; they also compare these results with those obtained from a sample combining all ownership forms. Their average cost inefficiency scores derived from the separate and the pooled stochastic frontier models (when off-balance sheet items are excluded) is 21.5% and 26.5% in commercial banks; 15.3% and 17.6% in savings banks; and 11.1% and 16.9% in mutual co-operative banks. Overall, their results do not find agency problems for non-private banks and argue that this can be explained by either their lower cost of funding due to their small and retail customer business orientation or their power of exercising local monopolies and pricing uncompetitively for moral hazard reasons. Using

Spanish data, Hasan and Lozano-Vivas (2002) employ the Fourier-flexible stochastic cost frontier for each ownership structure separately and find that mutual savings banks are 8.6% more cost inefficient than commercial banks over 1986-1995. The authors interpret their findings as a deliberate strategy of savings banks' managers to motivate employees to compete with commercial banks in the deregulated markets. Girardone et al. (2004) use a Fourier-flexible cost function to estimate cost X-efficiency and scale economies for a sample of Italian banks by size and ownership type over 1993-96. They find that on average the best performing banks are the mutual banks; in 1996 the cost efficiency of credit co-operative banks was 88.2% and that of commercial banks was 83.2%. The authors explain these results by referring to the possible greater homogeneity of the co-operative banking sector and by the fact that small co-operative banks are more likely to exploit economies of scale and other efficiencies because of possible local monopolies.

Only a handful of cross-country studies in Europe focus on the relation of bank efficiency and ownership. For instance, Carbo et al. (2002) investigates the case of European savings banks from 1989 to 1996 by employing a Fourier-flexible stochastic cost frontier approach. They find scale economies range between 7% and 10% while X-inefficiency scores reach a much higher 22%. They also distinguish between four different organisational models adopted by European savings banks, namely a 'state' model (e.g. Germany); a 'mixed' model (e.g. Spain); an 'in-transition' model (e.g. Finland); and a 'marketised' model (e.g. the UK). However, the authors do not seem to find any strong evidence that could suggest the superiority of any of these models in terms of either X-inefficiencies or economies of scale. Williams and Gardener (2003) also study the European saving banks over 1990-1998 by employing the Battese and Coelli (1995) model in which the level of firm inefficiency is determined by a vector of environmental and firm-specific variables. They find that the savings banks operating under a 'foundations' structure (Germany and France) are more cost efficient than those organised under the 'association' (Denmark and UK) and 'mixed' (Italy and Spain) models. Altunbas et al. (2003) investigate whether systematic efficiency differences can occur between a large sample of commercial, savings and co-operative banks in the US and Europe during the 1990s by employing a translog stochastic frontier approach. As far as we are aware, their's is the only study to examine the relationship between efficiency and ownership structure in a European cross-country framework. Overall, they find that commercial banks are less cost but

more profit efficient compared with mutual banks. Their cost inefficiency estimates ranges between 23.1%-37% for commercial banks; 17.8%-34.9% for savings banks; and 13.8%-36% for co-operative banks (based on the pooled ownership frontier estimations). According to the authors their findings can be explained by the fact that commercial banks offer a diverse business mix, higher quality services and better risk management procedures compared to other banks types that may increase costs but also generate higher revenues. However, they cannot exclude the possibility that commercial banks may, in some cases, exert market power.

Overall, the empirical evidence on bank efficiency and ownership structure seems to indicate that the proposed ownership hypothesis that private banks are more efficient than their non-private counterparts does not always hold true for European banks. This paper attempts to contribute to this mixed evidence of the agency theory by estimating cost efficiency measures for large samples of commercial, savings and co-operative banks in Europe over recent years and also distinguishing between commercial listed and non-listed banking institutions.

As discussed above, the effectiveness of a corporate governance system is also strongly related to the financial structure and development that prevails in a given country. Indeed it is acknowledged in the corporate governance literature that a cross-country analysis is valid only if financial structure and financial development are controlled for (see Schmidt and Tyrell, 1997, for the different role of banks and market in the context of corporate governance; Shleifer and Vishny, 1997, for a survey in corporate governance; as well as Cernat, 2004, for the major constraints on convergence of national corporate governance systems in Europe).[4] The deadlock of the bank- versus market-based systems debate (see Goldsmith, 1969, Vogel, 1979, and Porter, 1992) made researchers turn their interest to alternative views of financial structure and economic development. For instance, the *financial services view* proposed by Levine (1997) posits that the main concern for the efficient allocation of resources and economic growth should be to create an environment in which banks and markets provide "sound" financial services. Similarly, the *law and finance view* by La Porta et al. (1998) is a special case of Levine's (1997) financial services view that demonstrates that the legal system has a significant role in determining the overall

4 However, recently Allen et al. (2005) have pointed out that although the traditional classification into bank- and market-based might become less applicable due to the increased importance of pan-European developments in financial services such as the Euronext, it is still very useful as it summarises the main characteristics of a financial system.

level and quality of financial services. Therefore, based on these two views our proposed hypothesis is that after controlling for the level of financial development, financial structure does not have any independent effect on bank efficiency.

The literature focusing on financial systems' structure and development is vast; however, as far as we are aware there are no studies that attempt to directly associate the financial structure with efficiency and ownership in banking. To date we found only one study that focuses on the relationship between financial structure and bank performance by Demirguc-Kunt and Huizinga (2001). The authors present evidence on the impact of financial development and structure on bank performance for a sample that covers 44 developed and underdeveloped countries over 1990-1997. Based on the World Bank Financial Structure Index (see Section 3.1) they classify UK, Sweden, and Denmark as market-based economies and Austria, Belgium, France, Greece, Ireland, and Italy as bank-based economies. Overall, their results provide evidence that after controlling for the level of financial development, financial structure does not have an independent effect on bank profitability as they find that in developed financial systems bank profits and margins are not statistically different across bank-based and market-based systems.

None of the above studies directly link banking efficiency with different bank types and financial structures in Europe. To address these issues, the countries in our sample have been classified into bank-based and market-based using the World Bank Financial Structure database (Section 3.1). Then, the cost efficiency estimates are derived based on alternative stochastic cost frontiers which are explained in Section 3.2.

3. Data and Methodology

3.1 Banks' inputs and outputs and the World Bank Financial Structure Index

The data used for the cost frontier estimations are drawn from BankScope, an international London-based database. The sample comprises 4,177 commercial (of which 645 are listed), 4,656 savings, and 7,842 mutual co-operative bank observations across 15 European countries over 1998-2003 (see Table 1).

In our sample, commercial banks can be either privately owned or listed companies. Although the co-operative banks are all mutual, the savings banks sample

is heterogeneous in terms of legal status across European countries as pointed out among others by Carbo et al. (2002) and Williams (2004). For example, in France savings banks are organised as non-profit entities owned by their customers; in Germany they are mainly government-owned; in Italy they have a joint-stock ownership structure but are effectively owned by private foundations that have non-profit objectives. In the UK, a substantial volume of total assets of the savings banks sector has been converted and the remaining building societies maintain the mutual legal status.[5]

Table 1 EU-15 Commercial, Savings and Co-operative Bank Observations (1998-2003)

Country	*Commercial Banks*	*Savings Banks*	*Co-operative Banks*	*Total*
Austria	192	372	168	732
Belgium	114	48	48	210
Denmark	300	180	n.a.	480
Finland[a]	20	n.a.	10	30
France	738	156	372	1,266
Germany	876	2,964	4,668	8,508
Greece	61	n.a.	n.a.	60
Ireland	42	n.a.	n.a.	42
Italy	522	312	2,550	3,384
Luxembourg	450	n.a.	n.a.	450
Netherlands	60	n.a.	n.a.	60
Portugal	72	n.a.	n.a.	72
Spain	354	282	36	672
Sweden	36	24	n.a.	60
UK	360	318	n.a.	678
Total	4,177	4,656	7,842	16,674

"n.a."= not available because that particular type of banking institution either does not exist in that particular country or there are not enough observations to estimate country- and ownership-specific frontier models (see section 3.2).

[a] Due to the significantly low number of observations we could not estimate the country-specific frontier for Finland; thus it is not included in our data sample.

Source: Bankscope (2005).

Regardless of their diverse business structures and legal forms, savings banks in Europe have common objectives such as the focus on local regions and the maximisation of social welfare (see Gardener et al., 1997 and 1999; European Savings Bank Group, 2004 and Williams 2004 for details on the savings banks sector in the EU; and Casu et al., 2006 for an evaluation of the main features of the European

[5] Following Williams (2004) in this paper we consider the building societies operating in the UK as savings banks.

banking system).[6] Therefore as in Altunbas et al. (2003) we analyse them as a single bank type.[7]

Concerning the input-output definition, we use the intermediation approach originally developed by Sealey and Lindley (1977) which posits that total loans and securities are outputs, whereas deposits along with labour and physical capital are inputs (see Table A1 in the Appendix for a detailed description). Given the heterogeneity of our sample we are looking at efficiency in traditional intermediation business since many mutual banking institutions do not report off-balance sheet activities.

As noted above, one of the aims of this paper is to examine the link between the financial structure and banking efficiency. Despite the fact that there is not any widely accepted measure that determines whether the financial system of a country is bank- or market-based, one of the most common used method in the recent literature is the conglomerate index of financial structure defined by Beck et al. (2001) and Demirguc-Kunt and Levine (2001).

The financial structure index quantifies the degree of stock market orientation of a financial system. It is based on the means-removed average of relative 'size', 'activity' and 'efficiency' of the stock market and banking sub-sectors of the financial system in each country. Relative 'size' is defined as the ratio of the stock market capitalisation to total assets of deposit money banks; relative 'activity' is defined as the total value of stocks traded divided by bank credit to the private sector; and relative 'efficiency' is defined as the product of total value of stocks traded and the ratio of average overhead cost to total assets of banks in the country. (See Beck et al., 2001, for a description and intuition behind these variables and also refer to the notes to Table A2). Then from each individual value of the relative 'size', 'activity' and 'efficiency' series we subtract the mean to obtain the means-removed values and finally we take the average of these values to obtain the means-removed average.

We use aggregate data of 54 countries obtained by the World Bank Financial structure database[8] over the period 1998-2003 which coincides with the period for

[6] As recently emphasised by *The Banker* (2006), European savings banks provide "a locally focused, decentralised bank model offering 'proximity banking' to customers via the use of branches as the main distribution channels".

[7] Note that we do not include listed savings banks in our sample; thus, saving banks are generally referred as mutual to denote that are non-listed banks, (see Gardener et al., 1999). Altunbas et al. (2007) denote that the European savings sector has mutual/quasi public ownership.

[8] See http://www.worldbank.org/research/projects/finstructure/

which we estimate banks' efficiency. Countries with values of the Financial Structure Index above (below) the sample mean are classified as market-based (bank-based) (see Table A2 in the Appendix). In order to control for financial development[9] we group the 54 countries in our sample into a) developed bank-based; b) developed market-based; and c) underdeveloped (see Table A2 in the Appendix and Demirguc-Kunt and Levine, 2001, p. 21 for more details). Table 2 reports the financial structure measures for the EU-15 countries only.

Table 2 Country classification of Financial Structure and Development for Our Sample of EU countries (1998-2003)

Country Name	*Relative Size*	*Relative Activity*	*Relative Efficiency*	*Structure*
Austria	-0.869	-0.646	-0.014	-0.510
Belgium	-0.418	-0.465	-0.011	-0.298
Denmark	-0.457	-0.283	-0.001	-0.247
Germany	-0.630	-0.243	0.004	-0.290
Ireland	-0.354	-0.364	-0.012	-0.244
Italy	-0.430	-0.003	0.007	-0.142
France	-0.203	0.047	0.009	-0.049
Greece	-0.099	0.327	0.003	0.077
Luxembourg	0.320	-0.662	-0.015	-0.119
Netherlands	-0.115	0.343	0.017	0.081
Portugal	-0.643	-0.502	-0.010	-0.385
Spain	-0.373	0.742	0.028	0.132
Sweden	0.553	0.976	0.011	0.513
United Kingdom	0.239	0.255	0.027	0.174

Source: World Bank Financial Structure database, http://www.worldbank.org. See table A2 for more details.

Sweden, United Kingdom, Spain, Netherlands and Greece[10] (countries with the highest values of structure index) are defined as market-based and the rest as bank-based (see Table A2 for the classification of the full sample of the 54 countries used). For robustness, we apply the financial structure analysis to the dataset

[9] According to Demirguc-Kunt and Levine (2001) a financial system is defined as 'underdeveloped' when both bank credit/GDP and total value of the stock traded/GDP are below the sample mean.

[10] By using this method two traditionally bank-based countries, namely Greece and Spain, are classified as market-based. This could be explained by the fact that in the period under investigation these two countries had a significantly 'active' and 'efficient' stock market as reflected in the high relative 'activity' and 'efficiency' indicators. Allen et al. (2005) also find that Spain has very large stock market (as defined by the number of listed companies) over 1995-2004; this is mostly due to the fact that since 1999 the market segment of the Spanish stock exchange dedicated to Latin America (Latibex) has risen a lot. However, in order to account for the fact that this may be a temporary effect we estimated our frontier with and without the inclusion of these two countries for both the bank- and market based-groups.

comprised by the 15 European countries and we also develop alternative measures of financial structure. The main results do not change significantly.[11]

3.2 Estimating bank efficiency

In this paper we specify alternative frontier models, namely the translog; linear spline and Fourier-flexible functional forms, to analyse cost X-efficiency levels across EU-15 countries using the Battese and Coelli's (1992) time-varying stochastic frontier models. To derive our efficiency estimates, we first pool our total sample of banks for all countries and derive average efficiency scores based on a common European frontier. Then, we use the World Bank Financial Structure Index described in Section 3.1 and re-estimate two separate frontiers for bank- and market-based countries to minimise criticisms associated with potential differences in underlying technology between banking sectors in different financial structures when estimating the pan-European frontier. Finally, we cross-check the alternative common frontier results with those derived from country-specific frontiers.[12]

X-efficiency scores are estimated using the Battese and Coelli's (1992) time-varying stochastic frontier approach. The single-equation stochastic cost model is represented by $\ln TC_{it} = \ln TC^*(Q_{it}, P_{it}; B) + \varepsilon_{it}$ and $\varepsilon_{it} = u_{it} + v_{it}$ with i=1,…,N and t=1,…,T denoting the banks and years indices, respectively. The terms $\ln TC_{it}$ and $\ln TC^*$ are the natural logarithms of the observed and optimal total cost; $\ln Q_{it}$ and $\ln P_{it}$ are the vectors of the natural logarithms of output quantities and input prices; B is the vector of unknown parameters to be estimated; v_{it} is a two-sided error term capturing the effects of statistical noise, assumed to be independently and identically normal distributed with zero mean and variance σ_v^2 and independent of the $u_{it} = \{u_i \exp[-n(t-T)]\}$ where u_i is a one-sided error term capturing the effects of inefficiency and assumed to be half normally distributed with mean zero and variance

[11] In particular we used the first principal component of relative 'size', relative 'activity' and relative 'efficiency'. In addition, we used the ratio of stock market capitalisation to bank credit to define the relative 'size' and the product of stock market turnover ratio and overhead cost to define relative 'efficiency' (see Levine, 2002). The estimates are available from the authors on request.

[12] These results are available from the authors; however, they do not differ significantly from those reported in this paper.

σ_u^2 [13]; n is an unknown parameter to be estimated capturing the effect of inefficiency change over time.[14]

Moreover, in this paper we employ three different parametric frontiers to estimate bank efficiencies, namely the stochastic translog, linear spline and Fourier-flexible. In the banking literature the most common used frontier is the translog. However it has the drawback of being a local approximation which predicts average cost as a standard U-shaped quadratic curve (Greene, 1980). It is well accepted that due to the heterogeneous nature of banking technology, the global behaviour of the cost function is better analysed when global approximation estimation strategies are employed (see Mitchell and Onvural, 1996; Berger et al., 1997; and Altunbas et al., 2001b). McMallister and McManus (1993) and more recently Humphrey and Vale (2004) observe that compared to translog both the linear spline and the Fourier-flexible functional form better fit the global properties of the cost function in banking as they predict an M-shaped average cost curve.

The linear spline is a semi-parametric technique (Poirier, 1976) that approximates the unknown (minimising) cost function by a piecewise linear function. The Fourier-flexible function is also a semi-parametric technique (Gallant, 1981) that approximates the unknown cost function by a Fourier series. As a way of checking the robustness of our results this paper compares the stochastic translog, linear spline and Fourier-flexible cost frontier approaches.

The translog cost function is a second-order Taylor series expansion of any twice-differentiable cost function at a given local point. For two outputs and three inputs, it can be written as follows (we have dropped the subscripts denoting bank *i* and year *t* for notational ease):

[13] There is no consensus on which distributional assumption is the most appropriate to disentangle the composed error term in banking efficiency literature. Other distributional assumptions often employed are the truncated normal (Stevenson, 1980) and gamma distribution (Greene, 1990).

[14] If the *i-th* bank is observed in the last period of the panel, *T*, then $u_{iT} = u_i$ as the exponential function has value one when *t=T*. For earlier periods in the panel, the technical inefficiency effects are the product of the technical inefficiency effect for the *i-th* bank in the last period of the panel and the value of the exponential function which depends on the parameter *n*, and the number of period before the last period of the panel *T-t*. If *n*>0, then *–n(t-T)*>0 and *exp[-n(t-T)]*>1;thus $u_{it} \geq u_i$ i.e. efficiency decreases with time, see Coelli et al. (1998 p. 204).

$$\ln TC = \alpha_0 + \sum_{i=1}^{2} \alpha_i \ln Q_i + \sum_{j=1}^{3} \beta_j \ln P_j + \frac{1}{2}[\sum_{i=1}^{2}\sum_{j=1}^{2} \delta_{i,j} \ln Q_i \ln Q_j + \sum_{i=1}^{3}\sum_{j=1}^{3} \gamma_{ij} \ln P_i \ln P_j] +$$
$$+ \sum_{i=1}^{2}\sum_{j=1}^{3} \rho_{ij} \ln Q_i \ln P_j + \varepsilon \quad (1)$$

where TC is the normalised total cost including operating and financial costs; Q_1 and Q_2 are output quantities, total loans and total securities, respectively (with one added to avoid problems with taking the natural logarithm of zero); P_1 is the normalised price of labour; P_2 is the normalised price of deposits; α, β, δ, γ, ρ are parameters to be estimated; and ε is the two-components error term as defined above.

The general form of linear Spline function is defined as follows:

$$\ln TC = \alpha_0 + \sum_{i}^{2}\sum_{w=1}^{7} \alpha_{i,w} \ln Q_{i,n} + \sum_{j=1}^{3} \beta_j \ln P_j + \frac{1}{2}[\sum_{i\neq j}^{2} \delta_{i,j} \ln Q_i \ln Q_j + \sum_{i=1}^{3}\sum_{j=1}^{3} \gamma_{ij} \ln P_i \ln P_j] +$$
$$+ \sum_{i=1}^{2}\sum_{j=1}^{3} \rho_{ij} \ln Q_i \ln P_j + \varepsilon \quad (2)$$

where $Q_{i,w}$ are the i=1,2 outputs and w=1,…,7[15] size-classes of banks with a separate linear spline line segment. One line segment is specified for each of the seven bank size-classes for each output subject to constrain that the segments join up continuously at the knots.[16]

Finally, the Fourier-flexible function is defined as follows:

[15] Following Humphrey and Vale (2004), in this study we use seven piecewise linear segments for each output.

[16] The $\alpha_{i,1}$ represents the slope over the first interval for output *i,* and each of the remaining coefficient $\alpha_{i,w}$ (w=2,…,7) represent the change in the slope from interval *(w*-1*)* to interval *w*, respectively. Knots are specified according to the percentiles of the output series.

$$\ln TC = \alpha_0 + \sum_{i=1}^{2} \alpha_i \ln Q_i + \sum_{j=1}^{3} \beta_j \ln P_j + \frac{1}{2}[\sum_{i=1}^{2}\sum_{j=1}^{2} \delta_{i,j} \ln Q_i \ln Q_j + \sum_{i=1}^{3}\sum_{j=1}^{3} \gamma_{ij} \ln P_i \ln P_j] +$$
$$+ \sum_{i=1}^{2}\sum_{j=1}^{3} \rho_{ij} \ln Q_i \ln P_j + \sum_{i=1}^{2} [\lambda_i \cos z_i + \theta_i \sin z_i] + \sum_{i=1}^{2}\sum_{j\geq i}^{2} [\lambda_{ij} \cos(z_i + z_j) + \theta_{ij} \sin(z_i + z_j)] +$$
$$+ \sum_{i=1}^{2}\sum_{j\geq i}^{2}\sum_{\substack{k\geq j \\ k\neq i}}^{2} [\lambda_{ijk} \cos(z_i + z_j + z_k) + \theta_{ijk} \sin(z_i + z_j + z_k)] + \varepsilon \qquad (3)$$

The Fourier form is a global approximation since the respective trigonometric terms attached to the translog form are mutually orthogonal over the [0, 2π] interval.[17]

In the translog part of each cost function we apply the common restrictions of standard symmetry ($\delta_{ij} = \delta_{ji}$ and $\gamma_{ij} = \gamma_{ji}$) and of homogeneity in prices ($\sum_j^3 \beta_j = 1, \sum_i^3 \gamma_{ij} = \sum_j^3 \rho_{ij} = 0$) where *i*=1,2 and *j*=1,2,3. In accordance with the linear homogeneity in prices TC, P_1 and P_2 are normalised by the price of capital P_3. We do not consider input share equations embodying Shephard's Lemma restrictions in order to allow for the possibility of allocative inefficiency (Berger and Mester, 1997).

In order to determine which of the functional forms better fits our data we carry out a set of structural tests and comparisons. First we use the likelihood-ratio to test if the translog cost function is an adequate representation of the data given the Fourier-flexible cost specification. Then, we employ the Akaike information criterion to determine which of the three cost specifications is the most informative. The linear spline and the translog are not nested models; hence, the likelihood-ratio cannot be used. With non-nested models, the ones with the largest number of parameters often have advantages over those with less number of parameters. However, this violates the parsimony principle that the model which has the least number of parameters is preferable. Therefore the benefit of the Akaike information criterion is that by

[17] In order to reduce the problems arising near the end points we restrict z_i - the 'adjusted' values of $\ln Q_i$ - to span over [.1x2π, .9x2π] interval (Gallant, 1981). The formula for z_i is $(.2\pi - \mu \times a + \mu \times \ln Q_i)$ where [a b] is the range of $\ln Q_i$ and $\mu = \frac{(.9 \times 2\pi - .1 \times 2\pi)}{(b-a)}$.

penalising models with a large number of parameters it avoids the problem of choosing too often the less parsimonious one.

Finally, we check whether the alternative cost functions as well as the various frontier modelling applied in this study satisfy the consistency conditions set out by Bauer et al. (1998). According to these authors, to ensure accuracy of results when comparing estimates derived from different methodologies it is important to check whether different cost specifications and frontiers modelling rank the institutions in approximately the same order. We employ the Spearman rank-order correlation coefficient that shows how close the ranking of banks among each of the six frontier specifications is.[18] The ranking for each model is based on the average efficiency value for each bank over the six year period. Another condition is to make sure the different methods used identify mostly the same institutions as best practice and worst practice. Specifically, for each pair of frontier models we check if the 25% best (worst) practice banks identified by one model are also identified in the top (bottom) quarter by the other model.

4. Results

The likelihood-ratio test and Akaike information criterion are undertaken to check which functional form best fits our data and they indicate that the Fourier-flexible should be preferred to the translog and linear spline specifications (see Table A3 in the Appendix for the tests results). In addition, Table A4 shows that the alternative cost functions and frontier models applied in this study generally satisfy the consistency conditions set out by Bauer et al. (1998).

Table 3 illustrates the cost efficiency scores over the period 1998-2003 for the common European and the separate bank- and market-based frontiers by bank types and ownership based on the Fourier-flexible cost function.[19] It reports our findings by country (grouped according to their financial structures). The alternative frontier

[18] For each frontier modelling we derive efficiency scores based on the three alternative cost functions. The efficiency scores derived from the bank- and market-based frontiers are pooled in order to compare the ranking for the full sample of banks.

[19] As discussed in Section 3.1 our financial structure calculations allocate two traditionally bank-based countries, namely Greece and Spain, to the market-based group. To account for the fact that this may be a temporary effect we calculate the cost efficiency estimates with and without the inclusion of these two countries in both the bank- and market based- groups. Unless it is reported, the results do not change significantly.

models identify the same best and worst practices banking sectors within the bank-based financial system's group. Indeed countries are ranked in the same order and overall the most cost efficient banking sectors are those of Italy (with efficiency scores of about 89%) and Denmark (with average scores of 84%); in contrast, Luxembourg and Ireland seem to present the lowest efficiency levels of around 56%.[20] The market-based estimations yield only slightly different results according to whether the cost efficiency scores are derived from the European common frontier or the separate market-based frontier. Nevertheless, in both cases the UK and Sweden seem to show relatively high average cost efficiency scores for commercial banks (over 75% on average). However, it also appears that in various countries the banking sector as a whole tends to be less efficient when savings and mutual banks are not included in the sample, as in the case of Ireland, Luxembourg and Portugal.[21]

Focusing on bank ownership, Table 3 confirms that commercial banks are found on average less cost efficient than savings banks in all countries except France, Sweden and the UK. In addition, with only one exception (namely Belgium) commercial banking institutions are significantly less cost efficient than co-operative banks.

[20] Results for Luxembourg are often found extreme in the literature. This could be due to the large proportion of foreign banks in the sample for this country.

[21] Our total sample in each country was constrained by the requirement that the available observations in each bank type are sufficient to estimate separate country- and ownership-specific frontiers. Therefore, although for some countries saving or co-operative banks do exist they are not included in our sample.

Table 3 Fourier-Flexible Cost Efficiency Estimates: Common European versus Bank- and Market- Based Frontiers (1998-2003)

	European Common Frontier				*Separate Bank- and Market- Based Frontiers*			
Country	Commercial	Savings	Co-op	All	Commercial	Savings	Co-op	All
Bank-based countries:								
Austria	78.79%	83.60%	79.80%	80.73%	78.00%	82.82%	78.97%	79.93%
Belgium	72.33%	78.23%	70.88%	73.81%	70.63%	79.09%	71.80%	73.84%
Denmark	83.56%	86.02%	n.a.	84.79%	81.64%	84.76%	n.a.	83.20%
France	80.89%$^{+}$	78.08%$^{+}$	80.42%$^{+}$	79.79%	80.52%	76.00%	81.35%	79.29%
Germany	75.69%$^{+}$	79.01%$^{+}$	77.87%$^{+}$	77.53%	75.21%	78.81%	77.41%	77.14%
Ireland	54.38%	n.a.	n.a.	54.38%	57.63%	n.a.	n.a.	57.63%
Italy	82.38%	94.31%	90.67%	89.12%	82.05%	93.84%	90.78%	88.89%
Luxembourg	55.97%	n.a.	n.a.	55.97%	56.06%	n.a.	n.a.	56.06%
Portugal	64.95%	n.a.	n.a.	64.95%	65.30%	n.a.	n.a.	65.30%
Market-based countries:								
Greece	63.26%	n.a.	n.a.	63.26%	60.18%	n.a.	n.a.	60.18%
Netherlands	57.43%	n.a.	n.a.	57.43%	60.61%	n.a.	n.a.	60.61%
Spain	75.66%	79.84%	78.79%	78.10%	79.29%$^{+}$	83.46%$^{+}$	82.38%$^{+}$	81.71%
Sweden	80.06%	75.52%	n.a.	77.79%	74.43%$^{++}$	74.24%$^{++}$	n.a.	74.34%
UK	76.84%	57.99%	n.a.	67.41%	82.18%	55.10%	n.a.	68.64%
Total (All banks)	71.59%	79.18%	79.74%	76.83%	71.61%	76.74%	81.22%	76.53%

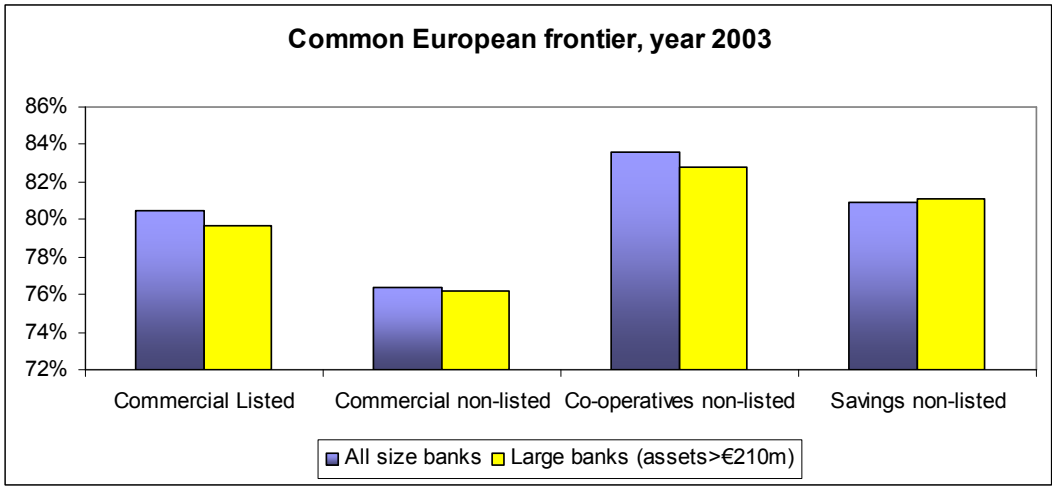
Notes:
a. All figures are mean cost efficiencies for the period 1998-2003. Other descriptive statistics and year-by-year estimations are available from the authors upon request.
b. The non-parametric Kruskal-Wallis tests employed to check for the hypothesis H_0 of equality of means cost efficiencies across ownership structure in each country. The $^{+}$,$^{++}$ denotes statistical insignificant at 1% and 10% significance level, respectively.
c. "n.a."= not available because that particular type of banking institution either does not exist in that particular country or there are not enough observations to estimate country- and ownership-specific frontier models.
d. The translog and linear spline estimates are available from the authors upon request.
e. Finland is dropped from our sample because we could not estimate the country-specific frontier due to low number of observations.

To further investigate the ownership hypothesis we also test the relationship between commercial listed banks versus mutual banks. Figure 1 reports the average cost efficiencies estimated using the common EU frontier for the listed versus non-listed banks in our sample for the year 2003.

Results show that while commercial listed institutions appear more cost efficient than their non-listed counterparts, on the whole our results reject the agency theory

hypothesis that managers of privately-owned banks are more cost efficient than those of mutual banking institutions because of capital market devices.

Figure 1: Cost efficiency of listed versus non-listed institutions by size, 2003



Notes:
The non-parametric Kruskal-Wallis tests employed to check for the hypothesis H_0 of equality of means cost efficiencies across listed and non-listed institutions. All the results are statistical different at 1%.

In particular, we find that mutual banks operating in the EU-15 countries are significantly more cost efficient over the other bank types in our sample. As shown in Figure 1, these results are also confirmed for large banks only (assets > €210m that represents the first quartile of the total asset series) and, although not reported in the figure, for each of the years under study.

Overall these results imply that the ownership structure hypothesis described in Section 1 is not supported by our empirical results. Our findings are in the line for example with Altunbas et al. (2003) who also find that on average commercial banks operating in Europe and the US are less cost efficient than their mutual counterparts over 1990-2000. One explanation for these results could be that the agency costs in mutual banks are to some extent limited due to their mainly retail and small customers' business orientation (see Altunbas et al., 2001a). The managers of local banks are interested in establishing long-term relationships with their clients and promoting cost efficiency in order to signal the credibility and safety of their banking institutions (Rasmusen, 1988). However, the possibility that mutual co-operative and

savings banks exert local monopoly power cannot be excluded since the lower cost of funding may imply that these institutions have market power in pricing their inputs and outputs. For instance, the savings and co-operative banks have the reputation of being safer as the deposit protection schemes operated in these banks are designed to reduce the bankruptcy risk; hence, depositors might be willing to accept a lower interest rate on their deposits in order to reduce the risk of bank insolvency.[22]

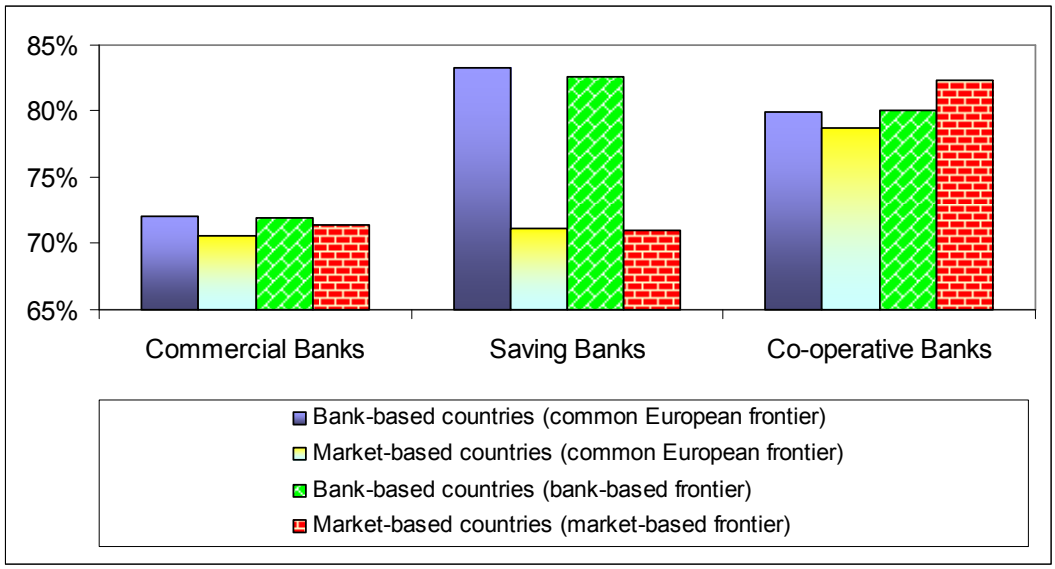
Another aim of this paper is to test the financial structure hypothesis that posits that after controlling for the level of financial development financial structure does not have any independent effect on bank efficiency. In order to control for the fact that the inclusion of Greece and Spain in the market-based group may be just a temporary effect, we also calculate the cost efficiency estimates without the inclusion of these two countries in both the bank- and market-based groups.

As shown in Figure 2, the estimates of the common European and separate bank- and market-based frontiers reveal that commercial banks operating in bank- and market-based economies have average efficiency scores of just above 70%; and according to the non-parametric Kruskal-Wallis test the differences in average efficiency level are not significant at the 5% level. The same holds true when we exclude Greece and Spain from the market-based group, although these results are not reported here. Looking at the average results for savings banks in Figure 2, the estimates show that market-based savings banks are about 12% less cost efficient than bank-based ones. The same hold true when we exclude Greece and Spain from the market-based group; however, in this case the average of the overall market-based savings banks sector drops by 6.5%, from 71.12% to 66.76%. Finally, the co-operative banking sector shows similar efficiency scores (around 80%) in bank- and market-based countries; however we need to interpret this with caution, as only the Spanish banks comprise our market-based co-operative sample.

These results suggest that at least for the commercial banking sector the financial structure hypothesis holds (see Levine 1997 and La Porta et al. 1998's view, and later confirmed by Demirguc-Kunt and Huizinga, 2001). Nonetheless, the estimates clearly show that market-based savings banks are significantly less cost efficient than bank-based ones.

[22] For instance, until May 2002 savings banks in Germany enjoyed the support of government or local authorities. The European Commission has also begun investigations in Austria into whether the state guarantee for the regional mortgage banks and certain savings banks would qualify as illegal state aid (see European Central Bank, 2002).

Figure 2 Average cost X-efficiency by financial structure for commercial, savings and co-operative banks (1998-2003)[a,b]



Notes:
a. The non-parametric Kruskal-Wallis test was employed to check for the hypothesis H_0 of equality of means cost efficiencies across financial systems in each ownership structure. The results for all frontier models are significant at the 1% level within the savings sector; whereas the null hypothesis is accepted at least at the 5% level for the commercial and co-operative banks' sector.
b. The non-parametric Kruskal-Wallis test was employed to check for the hypothesis H_0 of equality of means cost efficiencies across ownership structures in each financial system. The results for all frontier models are significant at the 1% level within the bank-based countries; whereas the null hypothesis is accepted at 10% level within the market-based countries.

This mixed evidence can be explained by the fact that the prevailing corporate governance mechanisms in bank-based financial systems, such as the reputation factor, may force managers in these economies to be more cost efficiency disciplined. Typically savings and co-operative banks are regionally restricted and therefore do not compete against one another, e.g. savings banks do not compete against savings banks but compete against commercial and co-operative banks; similarly, co-operative banks do not compete against other co-operative banks but do compete against savings and commercial banks. This, on the one hand, may encourage them to be less efficient, but on the other hand they have strong incentives to maintain their brand and reputation in their own particular region or local markets.

In contrast, the corporate governance mechanisms in market-based economies such as takeover threats and managerial compensation schemes do not have the same power in threatening the managers of savings and co-operative banks (see Caprio and Levine, 2002; and Levine, 2003, for a description of the problems of governing banks

and Tadesse, 2002; Levine, 2002 Beck and Levine, 2002 on how the effectiveness of the financial structure depends on the strength of the contractual environments and agency costs in each economy).

Therefore, we provide some evidence that differences in cost efficiency across financial systems can be explained by bank type specific characteristics. This evidence can be useful to policy-makers who are interested in designing corporate governance principles at international level, as they need to take into consideration the special features of each institutional structure of the banking system (see also Altunbas and Chakravarty, 1998).[23]

It is also meaningful to compare cost efficiencies across different bank types within each financial structure. This comparison provides useful insights for any potential links between bank efficiency, financial structure and bank types. We focus only on commercial and savings banks, as only the Spanish banks comprise our market-based co-operative sample. Figure 2 shows that on average bank-based savings banks are significantly more efficient than their commercial counterparts. In contrast, the alternative common frontiers show that market-based commercial and savings banks have similar average cost efficiency (around 71%). However, when we exclude Greece and Spain from the market-based sample we find that the market-based commercial banks are more cost efficient than savings banks (by more than 4.6% points).

On one hand, the fact that commercial banks are less efficient than mutual banks in bank-based economies might be evidence of lower agency costs in savings banks due to their business orientation or local monopoly power. However, it is also possible that the commercial sector includes all the recently converted mutual banks in bank-based economies and that they may have not yet realised the full benefits of conversion.[24] On the other hand, the complementary effect between bank and stock market development can explain why on average commercial banks are found to have the same (or greater) efficiency levels compared with savings within market-based economies. With high stock market development there is a lot of available

[23] It is also worth mentioning that any inference based on the savings banks of market-based economies should be treated with caution since the number of market-based countries with an active savings sectors is relatively small compared to the bank-based economies.

[24] See Ruozi and Anderloni (1999) for a description of differences in banks' privatisation process across European countries.

information on stock-traded firms that help banks evaluate better their credit risk and thus reduce the risk of loan default.

Overall our analysis suggests that differences in cost efficiency across bank types can be explained by the prevailing financial system in each economy. This evidence illustrates the national diversity of corporate governance systems in Europe and can be of importance for the policy-makers who are concerned with the full integration of the European financial system. This is in line with Cernat (2004) who demonstrates that the poor EU decision-making procedures and the diversity of national corporate governance models across Europe are the two major constraints on the convergence of a harmonised corporate governance model in Europe.

5. Conclusion

This paper seeks to extend the established literature on efficiency in banking organisations by providing European cross-country evidence on the relative efficiency across ownership, bank type and financial structures. In particular, we estimate the cost X-efficiency levels for a large sample of commercial, savings and co-operative banking institutions over 1998-2003 by employing alternative parametric frontiers across bank- and market-based EU-15 countries classified using the World Bank Financial Structure Database (see Beck et al., 2001 and Demirguc-Kunt and Levine, 2001).

The paper shows that, in line with previous literature, the Fourier-flexible is clearly preferable over the linear spline and the translog cost specifications. Moreover, it seems that despite the tremendous efforts that have been made in European banking with respect to deregulation, liberalisation and harmonisation of the regulatory framework there are still considerable cost efficiency differences across alternative bank types, ownership and financial structures. The various frontier models tested in this paper provide evidence of cost inefficiencies of around 23%; hence, there are still significant cost savings that can be obtained by eliminating managerial inefficiencies across the European banking systems.

Most importantly, while non-listed commercial institutions appear less cost efficient than the listed ones, on the whole our results reject the agency theory hypothesis that managers of privately-owned banks are more cost efficient than those

of mutual banking institutions because of capital market devices. In particular, we find that mutual banks operating in the EU-15 countries are significantly more cost efficient over the other bank types included in our sample. Furthermore, results are mixed concerning the financial structure hypothesis that in developed financial systems bank efficiency should not be statistically different across bank- versus market-based economies. Specifically, we find that while the hypothesis seems to hold for the sub-sample of commercial banks, in bank-based countries savings banks appear to have significant cost efficiency advantages over those operating in market-based countries and over commercial banks. Finally, there is some evidence that in market-based economies, commercial and savings banks have similar average cost efficiency scores; however, this relationship is not confirmed when we exclude Spain and Greece from the market-based sample so it needs further empirical testing.

There are three main policy implications arising from this paper. First it is possible that the cost savings from bank demutualisation can be realised only in the medium/long run; hence, this study could give important indications to policy-makers in the context of banking markets restructuring and the effects of demutualisation of non-private banking institutions. Second, it is clear that bank type characteristics have an important role in explaining the differences in cost efficiency across financial systems, an issue that should be of fundamental importance to policy-makers who are interested in the corporate governance principles at the international level (e.g. the Basel Committee). Finally, the national diversity of corporate governance systems seems to be a major constraint on the convergence to a single corporate governance system in Europe, an issue that will likely affect the progress towards the full integration of the European financial sector.

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Appendix

Table A1: Variable Description

Variable	Symbol	Description
Total Cost	TC	Personnel Expenses + Interest Expenses + Other Administrative Expenses
Output 1	Q1	Total Customer Loans
Output 2	Q2	Total Other Earning Assets
Input price 1	P1	Personnel Expenses/Total Assets
Input price 2	P2	Interest Expenses/Total Deposits
Input price 3 [a]	P3	Other Administrative Expenses/Total Fixed Assets

[a] For Greek banks we replaced the item 'Other Administrative Expenses' for 'Other Operating Expenses' due to missing data.

Table A2 Country classification of Financial Structure and Development based on a sample of 54 countries (1998-2003)

Financial Developed economies					Financial Underdeveloped economies				
Country Name	*Relative Size*	*Relative Activity*	*Relative Efficiency*	*Structure*	*Country Name*	*Relative Size*	*Relative Activity*	*Relative Efficiency*	*Structure*
Bank-based economies					**Bank-based economies**				
Austria	-0.869	-0.646	-0.014	-0.510	Czech Republic	-0.659	-0.514	-0.013	-0.396
Portugal	-0.643	-0.502	-0.010	-0.385	Colombia	-0.429	-0.660	-0.015	-0.368
New Zealand	-0.593	-0.539	-0.013	-0.382	Poland	-0.581	-0.486	-0.014	-0.360
Belgium	-0.418	-0.465	-0.011	-0.298	Mexico	-0.473	-0.333	-0.011	-0.273
Germany	-0.630	-0.243	0.004	-0.290	Estonia	-0.294	-0.472	-0.013	-0.260
Japan	-0.512	-0.312	-0.006	-0.277	Peru	-0.164	-0.578	-0.014	-0.252
Israel	-0.443	-0.370	-0.009	-0.274	Moldova	-0.075	-0.489	-0.014	-0.193
Cyprus	-0.411	-0.352	-0.004	-0.256	Brazil	-0.223	-0.190	-0.005	-0.139
Denmark	-0.457	-0.283	-0.001	-0.247	Hungary	-0.381	-0.026	-0.006	-0.137
Norway	-0.489	-0.243	-0.005	-0.246	Philippines	0.039	-0.419	-0.012	-0.131
Ireland	-0.354	-0.364	-0.012	-0.244	Kuwait	-0.306	-0.046	-0.012	-0.121
Iceland	-0.350	-0.358	-0.009	-0.239	Botswana	0.319	-0.621	-0.015	-0.106
Jordan	-0.099	-0.524	-0.013	-0.212	Jamaica	0.358	-0.633	-0.015	-0.097
Italy	-0.430	-0.003	0.007	-0.142	Barbados	0.365	-0.561	-0.013	-0.070
Luxembourg	0.320	-0.662	-0.015	-0.119	Chile	0.387	-0.573	-0.013	-0.066
France	-0.203	0.047	0.009	-0.049	Argentina	0.481	-0.558	-0.013	-0.030
					Trinidad and Tobago	0.620	-0.621	-0.015	-0.005
					Saudi Arabia	-0.140	0.149	-0.012	-0.001
Cat. Av.	**-0.411**	**-0.364**	**-0.007**	**-0.260**	**Cat. Av.**	**-0.064**	**-0.424**	**-0.013**	**-0.167**
Market-based economies					**Market-based economies**				
Australia	0.081	-0.001	-0.002	0.026	Pakistan	-0.667	1.046	-0.004	0.125
Malaysia	0.334	-0.238	-0.009	0.029	Zimbabwe	1.114	-0.173	-0.008	0.311
Greece	-0.099	0.327	0.003	0.077	El Salvador	1.946	-0.655	-0.016	0.425
Netherlands	-0.115	0.343	0.017	0.081					
Singapore	0.176	0.103	-0.003	0.092	**Cat. Av.**	0.798	0.073	-0.009	0.287
Spain	-0.373	0.742	0.028	0.132					
United Kingdom	0.239	0.255	0.027	0.174					
Canada	0.327	0.255	0.010	0.197					
Korea, Rep.	-0.444	1.128	0.016	0.233					
India	-0.292	1.447	-0.002	0.384					
Switzerland	0.450	0.622	0.086	0.386					
Hong Kong	0.832	0.309	0.037	0.393					
South Africa	1.076	0.152	0.029	0.419					
Sweden	0.553	0.976	0.011	0.513					
Turkey	-0.200	2.343	0.020	0.721					
Finland	1.673	1.401	0.019	1.031					
United States	1.126	3.070	0.070	1.422					
Cat. Av.	**0.314**	**0.778**	**0.021**	**0.371**					
Developed econ.	**-0.037**	**0.225**	**0.008**	**0.065**	**Underdeveloped econ.**	**0.059**	**-0.353**	**-0.012**	**-0.102**
Overall mean	*0.000*	*0.000*	*0.000*	*0.000*					

Notes:

a. Financial Structure Index is the means-removed average of relative 'size', 'activity' and 'efficiency' measures. Relative 'size' is defined as the ratio of the stock market capitalisation to total assets of deposit money banks; the relative 'activity' is defined as the ratio of total value of stocks traded divided by bank credit to the private sector; and relative 'efficiency' is defined as the product of total value of stocks traded and the ratio of average overhead cost to total assets of banks in the country. Countries with values of Financial Structure Index above (below) the sample mean are classified as market-based (bank-based). A financial system is characterised as underdeveloped when both bank credit to the private sector/GDP and the total value of the stock traded/GDP are below the sample mean.

b. The non-parametric Kruskal-Wallis tests were employed to check for the hypothesis H_0 of equality of means Structure indexes across financial systems. The null hypotheses have been rejected at 1% significance level.

Source: World Bank Financial Structure database, http://www.worldbank.org. Beck et al. (2001) describe the sources, the construction and the intuitions behind all the variables used for the financial structure and development index.

Table A3 Structural tests: Likelihood-ratio and Akaike Information Criterion

	H_0: Translog form versus H_1: Fourier-flexible		Translog	Spline	Fourier Flexible	Max [AIC_i]
	LR-Test Statistics [a] (Critical value $X^2_{0.01}$)	***Outcome***	***AIC[b]***	***AIC[b]***	***AIC[b]***	***Outcome***
European frontier	1226.48 (29.14)	do not accept	9607.27	8458.73	10206.51	Fourier-flexible
Bank-based frontier	1296.39 (29.14)	do not accept	10918.78	10067.69	11552.97	Fourier-flexible
Market-based frontier	155.24 (29.14)	do not accept	90.07	44.89	153.69	Fourier-flexible

Notes:
a. Likelihood-ratio tests H_0: Translog form versus H_1: Fourier-flexible form. The likelihood ratio statistic, LR, is calculated as $-2\{\ln[L(H_0)]-\ln[L(H_1)]\}$ where $L(H_0)$ and $L(H_1)$ are the values of the likelihood function under the null and alternative hypotheses, H_0 and H_1,respectively. The critical values of $X^2_{0.01}$ with 14 degrees of freedom are presented in parenthesis.
b. We define the Akaike information criterion as $AIC_i=\ln[L(H_i)]-k_i$, where i=translog, linear spline and Fourier-flexible cost function specification and k_i is the number of parameters in each model. The model that maximises AIC_i is the most informative model.

Table A4 Bauer et al.'s (1998) Consistency Conditions

Condition 1: Spearman rank-order correlations among the efficiency scores estimated by the alternative frontier models						
	EU-T	***EU-S***	***EU-F***	***MB&BB-T***	***MB&BB-S***	***MB&BB-F***
EU-T	1.000	0.893	0.970	0.208	0.193	0.179
EU-S		1.000	0.875	0.201	0.189	0.172
EU-F			1.000	0.200	0.184	0.177
MB&BB-T				1.000	0.891	0.939
MB&BB-S					1.000	0.899
MB&BB-F						1.000
Condition 2: Correspondence of "Best Practice" and "Worst Practice" banks across the various frontier models						
EU-T		0.847	0.932	0.888	0.770	0.868
EU-S	0.827		0.822	0.806	0.871	0.807
EU-F	0.921	0.810		0.859	0.761	0.912
MB&BB-T	0.886	0.783	0.856		0.807	0.866
MB&BB-S	0.820	0.863	0.816	0.820		0.819
MB&BB-F	0.896	0.793	0.915	0.871	0.849	

Notes:
Condition 1: According to Bauer et al. (1998) in order to reduce the effects of noise, the rank-order correlations are based on the average efficiency value for each bank over the six year period. All the Spearman rank-order correlations are statistical significant at 1% level using two-sided *t*-test.
Condition 2: Each number in the upper (lower) triangle depicts the proportion of banks that are identified by one model as having efficiency scores in the 25% of the most (least) efficient banks that are also identified in the most (least) efficient 25% by the other model. In all cases the correspondence is statistically greater than 0.250 at the 5% and 1% using an asymptotic Normal test for proportions in ordered data. Under the null hypothesis of the independence of the two categorisations, the number of banks in the top 25% of both has a hypergeometric distribution. Exact p-values can be obtained using Fisher's test but given the large number of observations, these p-values are well approximated by using a normal distribution.

EU-T = European frontier based on the translog cost function; EU-S = European frontier based on the linear spline cost function; EU-F = European frontier based on the Fourier-flexible cost function; MB&BB-T = market-based and bank-based frontiers based on the translog cost function.; MB&BB-S = market-based and bank-based frontiers based on the linear spline cost function; MB&BB-F = market-based and bank-based frontiers based on the Fourier-flexible cost function.