

Measuring Cost Efficiency in European Banking

A Comparison of Frontier Techniques

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Abstract:

Our aim here is to provide new evidence about the consistency of efficiency frontier methods on European banking samples. We measure the cost efficiency of banks from five European countries (France, Germany, Italy, Spain, Switzerland) with three approaches: stochastic frontier approach, distribution-free approach, data envelopment analysis.

We compare the means, the correlations, the diagnosis about two public policy issues, and the correlation with standard measures of performance. We broadly conclude in favor of the lack of robustness between approaches, even if there are some similarities in particular between parametric approaches. However we observe the correlation of all efficiency scores with standard cost measures.

Keywords: banking, efficiency, stochastic frontier approach, distribution-free approach, data envelopment analysis.

JEL Classification: G21

1. Introduction

Our aim here is to provide evidence about the consistency of efficiency frontier methods on European banking samples. It looks indeed deeply necessary to have more results about this issue with the increasing volume of studies on efficiency in European banking, using indifferently parametric and non-parametric techniques. In particular, these works might suggest some public policy recommendations based on non-robust results, such as privatization issues of the public banking sector (Altunbas, Evans & Molyneux (2001)) or the allowance of bank mergers to allow the consolidation of the banking sector (Vander Venet (1996)). Is it neutral on the results to use any frontier technique on European data? We undertake a large work here to provide new evidence on this question.

Several techniques have been suggested in the literature to measure banking efficiency, based either on econometric techniques (stochastic frontier approach (SFA), distribution-free approach (DFA), thick frontier approach (TFA)) or linear programming tools (data envelopment analysis (DEA), free disposal hull (FDH)). A few studies have then been performed to test the robustness of the results generated by these approaches. Bauer, Berger, Ferrier and Humphrey (1997) used four approaches on the same data set of US banks. They concluded that parametric techniques provide consistent results according to efficiency means and rankings, which are also consistent with standard nonfrontier measures of performance. However they provide evidence in favor of the lack of consistency of DEA efficiency scores with parametric approaches' results. In their former comparison of SFA and DEA results on US data, Ferrier and Lovell (1990) concluded in a similar way with a very weak rank-order correlation of scores estimated with both approaches.

However two papers on European data both concluded to high rank-order correlation between SFA and DEA (Drake and Weyman-Jones (1996) on UK building societies, Resti (1997) on Italian banks). Consequently, the diagnosis of the lack of consistency between parametric and non-parametric approaches may be invalidated for European banking data. Nonetheless this evidence remains scarce and limited.

We measure the cost efficiency of banks from five European countries (France, Germany, Italy, Spain and Switzerland) for the period 1992-1998. We use the three most applied approaches to measure banking efficiency: stochastic frontier approach (SFA), distribution-free approach (DFA), data envelopment analysis (DEA). We estimate national frontiers rather than one common frontier. National samples are large enough to allow us to estimate national frontiers instead of a common frontier on the whole sample, this latter approach generally performed in comparative European works presents the drawback of assuming similar technologies in all countries. Furthermore, we then present new evidence on the consistency of the efficiency frontier techniques in five different frameworks.

This application of three frontier efficiency techniques on European banking data raises four fundamental questions.

Q1: Do frontier efficiency approaches provide similar efficiency levels?

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More precisely, we aim to know if frontier efficiency methods generate similar means of efficiency scores. This question is of the highest interest to evaluate the relevance of the estimated inefficiency in a banking sector.

Q2: Are orderings of efficiency scores correlated across approaches?

Even if the approaches provide quantitatively different results because of different assumptions, they can generate similar rankings of efficiency scores and consequently give consistent results in terms of ordering. We measure the correlations between the efficiency scores to answer this question.

Q3: Are public policy conclusions similar across approaches?

A key motivation to use the methods for the estimation of efficiency frontiers is to provide some diagnosis useable for the regulatory analysis. In this aim, we analyze here the answers provided by the three approaches to two main issues in European banking. First, is there a link between cost efficiency and size? Second, do cooperative and savings banks outperform commercial banks?

Q4: Are efficiency scores consistent with standard measures of performance?

Here the motivation is not the consistency across approaches of the results. We test here if there is a connection between the efficiency estimates and two standard measures of cost performance. This step is required to evaluate if the efficiency estimates are not too dependent of the assumptions needed for the frontier efficiency technique.

The paper is organized so as to answer each question in turn. Namely, after a short survey of the literature devoted to efficiency to European banking and earlier efficiency comparisons in section 2, we present data in section 3. Section 4 outlines the methodologies. Then, section 5 answers questions Q1 and Q2, while sections 6 and 7 respectively answer questions Q3 and Q4. Section 8 concludes.

2. Related literature

2.1 Efficiency in European Banking

In comparison with literature on US banking, empirical research on efficiency in European banking appears relatively scarce. There is a number of country-specific studies in national European markets, in particular for France, Germany, Spain and

United Kingdom. However, the number of cross-country comparisons remains very low. Our aim here is to survey most studies on efficiency in European banking to summarize the major results. We include both country-specific papers and cross-country comparisons. Among these international comparisons, some estimate a common frontier for all countries of the sample (Allen and Rai (1996), Pastor, Perez and Quesada (1997)), this means that their results for a specific country are difficult to compare with country-specific studies. Indeed, by computing a common frontier, they assume similar technologies across countries and include the impact of environmental effects on efficiency. Some estimate however national frontiers (Dietsch and Lozano (2000), Dietsch and Weill (2000)), which allows the comparison of their results with national studies.

Table 1 displays main research on banking efficiency in the five European countries of our analysis. We describe first the methodology: this includes the chosen frontier approach, the measured efficiency (technical, cost or profit²), the size of the sample and the period of the analysis. Then, we present the main results of the articles by focusing on the relevant aspects for our analysis.

Table 1: Summary of banking efficiency studies for the five European countries

Article	Methodology	Results
France		
Dietsch (1996)	DFA, cost efficiency, 375 banks, 1988-92	Mean cost efficiency 40.6%-70.7%
Dietsch and Weill (1999)	DEA, technical efficiency, 93 banks, 1994	Mean technical efficiency 78-91%. No clear relation with size. Cooperative and savings banks more efficient than commercial banks.
Dietsch and Lozano (2000)	DFA, cost efficiency, 223 banks, 1988-92	Mean cost efficiency 88%.
Chauveau and Couppey (2000)	DEA, technical efficiency, 38 banks, 1994-97	Mean technical efficiency: 89-95%
Allen and Rai (1996)	SFA and DFA, cost efficiency, 32 banks, 1988-92.	Mean cost efficiency 73.4% (small banks) and 84.3% (large banks)
Pastor, Perez and Quesada (1997)	DEA, technical efficiency, 67 banks, 1992	Mean technical efficiency 95%
Dietsch and Weill (2000)	SFA and DFA, cost and profit efficiency, 190 banks, 1993-97.	Mean cost efficiency 82.36%, mean profit efficiency 88.38%
Germany		
Lang (1996)	SFA, cost efficiency, 1425 banks, 1989-92	Mean cost efficiency 90%. Lower efficiency for commercial banks

² Technical efficiency is the ability to produce the maximum output for a given bundle of inputs. Cost efficiency is the ability to minimize costs for a given output. Profit efficiency is the ability to maximize profit for a given output.

		than for cooperative and savings banks.
Altunbas, Evans and Molyneux (2001)	SFA and DFA, cost and profit efficiency, 7539 bank observations, 1989-96	Mean cost efficiency: 81.3-86.6% Mean profit efficiency: 78.1-82.1% Higher cost efficiency for cooperative and savings banks than for commercial banks
Allen and Rai (1996)	SFA and DFA, cost efficiency, 38 banks, 1988-92.	Mean cost efficiency 87.6% (small banks) and 87.7% (large banks)
Pastor, Perez and Quesada (1997)	DEA, technical efficiency, 22 banks, 1992	Mean technical efficiency 65%
Dietsch and Weill (2000)	SFA and DFA, cost and profit efficiency, 1052 banks, 1993-97.	Mean cost efficiency 84.2%, mean profit efficiency 95.91%
Italy		
Resti (1997)	SFA and DEA, cost efficiency, 270 banks, 1988-92.	SFA: mean cost efficiency 69.6%, negative relation with size. DEA: mean cost efficiency 68.2%, relation with size: positive if variable returns-to-scale, no significant if constant returns-to-scale.
Allen and Rai (1996)	SFA and DFA, cost efficiency, 85 banks, 1988-92.	Mean cost efficiency 84.9% (small banks) and 79.9% (large banks).
Pastor, Perez and Quesada (1997)	DEA, technical efficiency, 31 banks, 1992	Mean technical efficiency 77.3%.
Dietsch and Weill (2000)	SFA and DFA, cost and profit efficiency, 178 banks, 1993-97	Mean cost efficiency 88.73%, mean profit efficiency 64.73%.
Spain		
Lozano (1997)	TFA, profit efficiency, 54 savings banks, 1986-91	Mean profit efficiency 72%.
Grifell-Tatjé and Lovell (1996)	DEA, Malmquist productivity index, 77 savings banks, 1986-91	Mean technical efficiency 75-80%
Dietsch and Lozano (2000)	DFA, cost efficiency, 101 banks, 1988-92	Mean cost efficiency 88%
Allen and Rai (1996)	SFA and DFA, cost efficiency, 52 banks, 1988-92.	Mean cost efficiency 79.8% (small banks) and 85.5% (large banks)
Pastor, Perez and Quesada (1997)	DEA, technical efficiency, 59 banks, 1992.	Mean technical efficiency 82.2%
Switzerland		
Sheldon (1994)	SFA and DEA, cost efficiency, 477 banks, 1987-91.	SFA: mean cost efficiency 3.9%, negative relation with size. DEA: mean cost efficiency 56%, positive relation with size.
Allen and Rai (1996)	SFA and DFA, cost efficiency, 53 banks, 1988-92.	Mean cost efficiency 83.4% (small banks) and 87% (large banks)

This table provides several interesting remarks. First, mean efficiency scores are relatively dispersed, which is not surprising, given the variety of samples and time periods considered. The average efficiency score is however between 80 and 90% in many cases, which suggests that bank inefficiencies are rather similar in European countries and in US. Second, regarding the comparison of frontier approaches, we do not observe any general rule about the hierarchy of scores obtained with parametric or nonparametric approaches. This comment is in marked contrast with Berger and Humphrey (1997), that point out a dominance of scores with parametric approaches in their survey on US studies.

Third, there is ambiguous evidence across literature concerning the relation between efficiency and size. In their analysis focusing on large banks, Allen and Rai (1996) observed differences between large and small banks, that vary depending on the country. However they found no relationship between efficiency and size when regressing cost efficiency score on size. Furthermore, Resti (1997) concludes that the frontier technique has an influence on this relation, while Dietsch and Weill (1999) do not find any significant relation between efficiency and size in a regression of efficiency scores. Fourth, only a few studies have compared the relative performance of commercial, cooperative and savings banks. They all agree on the dominance in cost efficiency of cooperative and savings banks on commercial banks, in France (Dietsch and Weill (1999)) or Germany (Lang (1996), Altunbas, Evans and Molyneux (2001)).

2.2 Earlier Efficiency Comparisons

In the vast literature about banking efficiency, only a few studies have applied two or more techniques for the estimation of efficiency scores on the same data set. We briefly summarize these works to extract main findings from this literature. The seminal work comes from Ferrier and Lovell (1990). They apply parametric SFA and non-parametric DEA on a sample of 575 US banks to estimate cost efficiency. Their results suggest both similarities and differences between the approaches. Both techniques broadly agree on the average value of cost efficiency: 74% with SFA and 79% with DEA. However, they observe a very different decomposition of cost inefficiencies between technical and allocative inefficiencies: technical inefficiencies dominate with DEA, while allocative inefficiencies are stronger with SFA. Furthermore, the rank-order correlation is particularly weak between both rankings of efficiency scores: the Spearman correlation coefficient is only equal to 0.02%.

Bauer, Berger, Ferrier and Humphrey (1997) implement a vast research about the consistency of frontier approaches. They apply four techniques on the same data set of 683 US banks to estimate cost efficiency, and then compare their results on the basis of several consistency conditions. These techniques include three parametric

approaches (SFA, DFA and TFA³) and one non-parametric approach (DEA). Their main conclusion is the consistency of efficiency measures between parametric approaches, while DEA scores are by no doubt not reliable to parametric scores.

Distributional characteristics of the efficiency scores are quite similar across parametric approaches with rather comparable values for means ranging from 77.9% to 93.3% and standard deviations (from 0.022 to 0.082). However, DEA provides efficiency scores with a weaker mean (30%) and a larger dispersion (0.15 for the standard deviation). It is also noticeable that the rank-order correlation is high across parametric approaches (75% on average), whereas DEA scores are not positively correlated with parametric scores (-0.8% on average). Moreover, the identification of best and worst banks leads again to very weak correspondences between DEA and parametric approaches, whereas these latter techniques tend to identify the same banks as best or worst ones.

Finally, they show that parametric approaches provide efficiency measures that are consistent with these standard measures of performance, while DEA does not. To sum it up, Bauer et al. (1997) provide evidence on the consistency of measures obtained by parametric approaches, and on the lack of robustness of results provided by parametric approaches and DEA. However, as it is argued in the introduction, this diagnosis can be only relevant on US banking data. Indeed, some evidence comparing parametric and non-parametric approaches on European banking data tends to suggest a very different result about the consistency of all frontier measures.

Resti (1997) measures the cost efficiency for a sample of 270 Italian banks with SFA and DEA. He mainly observes similarities between both approaches. On one hand, the mean efficiency values are comparable (68.1% with DEA, 69.5% with SFA). On the other hand, there is a high positive correlation between scores (86.7%) and also between scores rankings (88.5%). Consequently, he concludes that both efficiency approaches provide robust efficiency measures for the Italian banking sector. Drake and Weyman-Jones (1996) also apply SFA and DEA to estimate the cost efficiency of 46 British building societies. They observe different mean efficiency scores (98% with SFA, 87.6% with DEA). However, the rank correlation is very high with a Spearman coefficient of 97.15%.

³ Thick frontier approach, developed by Berger and Humphrey (1991), is scarcely applied in banking. TFA is generally used for regulatory conclusions as it requires assumptions only allowing the estimation of mean efficiency scores.

A third work concludes in a very different way. Sheldon (1994) applies again SFA and DEA on a sample of 477 Swiss banks. His results are rather surprising with a mean efficiency score of 3.9% with SFA, while the average value is 56% with DEA. Furthermore, he observes no relation between both rankings, as the Spearman coefficient of rank correlation is 1% and not significant. In comparison to both previous papers, this one looks however less reliable with very unusual results for SFA scores. Other studies comparing parametric approaches include Bauer, Berger and Humphrey (1993), Berger and Hannan (1994) and Berger and Mester (1997) on US data, Dietsch and Weill (2000) on European data, Allen and Rai (1996) on US and European data. All conclude to comparable mean values between parametric approaches.

Several general conclusions emerge from this literature. First, there is a consensus about the robustness of scores provided by parametric approaches. Second, studies disagree about the differences between mean efficiency scores provided by parametric and non-parametric approaches. Third, whereas US studies suggest the lack of rank correlation between SFA and DEA scores, European evidence tends to show the high rank correlation between SFA and DEA rankings of scores. However this evidence remains scarce and limited.

As a result, our study aims to provide new evidence about these issues with the estimations of efficiency scores with three approaches (SFA, DFA and DEA) on five national samples. It will then allow us to provide a substantial amount of empirical evidence to evaluate the robustness of means and orderings of efficiency across approaches.

3. Data

We use unconsolidated accounting data for 688 banks: 135 from France, 296 from Germany, 99 from Italy, 85 from Spain, 73 from Switzerland. These are commercial, cooperative and savings banks. The period of observation is 1992-1998. Data come from the "Bankscope" database of BVD-IBCA. We keep only banks with available data for the seven years in the sample. We adopt the Turkey box-plot, based on the use of interquartile range to clean data. Banks with observations out of the

range defined by the first and third quartiles more or less one and half the interquartile range were excluded for each mean input price over the period.

For the definition of inputs and outputs, we adopt the intermediation approach proposed by Sealey and Lindley (1977) which assumes that the bank collects deposits to transform them, using labor and capital, in loans by opposition to the production approach which views the bank as using labor and capital to produce deposits and loans⁴. Two outputs are included: $Y_1 = \text{loans}$, $Y_2 = \text{investment assets}$ ⁵. The inputs, whose prices are used to estimate the cost frontier, include labor, physical capital and borrowed funds.

As data on the number of employees are not available, the price of labor, w_1 , is measured by the ratio of personnel expenses on total assets, following Altunbas et al. (2000) and Dietsch and Weill (2000). The price of physical capital, w_2 , is defined as the ratio of other non-interest expenses on fixed assets. The price of borrowed funds, w_3 , is measured by the ratio of paid interests on all funding. Total costs are the sum of personnel expenses, other non-interest expenses and paid interests.

The inputs and outputs are all measured in millions of dollars. Table 2 displays summary statistics for outputs, inputs, input prices and total assets. When comparing average values for loans and investment assets, these means are comparable in France, Italy and Spain, while the average value of loans largely exceeds the average value of investment assets in Germany and Switzerland. This may suggest that in our sample German and Swiss banks are more involved in retail banking than banks from other countries. This distinction in two country groups is also relevant for size, as in our sample the mean-sized bank in France, Italy and Spain is largely bigger than the mean-sized bank in Germany and Switzerland. The analysis of input prices provides evidence in favor of large differences in input costs between countries. Price of labor is strongly lower for Swiss banks than for other banks from our sample, especially the Italian ones. When looking at the price of physical capital, French banking sector seems an outlier with a mean value particularly high. These mean excessive values for prices of labor and physical capital may be either the result of the overuse of one input (for instance, physical capital in France) or the consequence of different choices in

⁴ Two studies analyzed the influence of the choice of the treatment of deposits on efficiency results (Wheelock and Wilson (1995), Berger, Leusner and Mingo (1997)). Both concluded that the chosen approach has an impact on the levels of efficiency scores but does not imply strong modifications in their rankings.

input mixes between countries. Differences are weaker but significant for the price of borrowed funds.

Table 2: Descriptive statistics: mean values for the period 1992-1998

	France	Germany	Italy	Spain	Switz.
Number of observations	135	296	99	85	73
Outputs					
Loans	4,445,450.4	1,670,488.1	4,816,457.4	3,858,478.1	772,528.7
Investment assets	5,223,290.0	986,264.4	4,442,352.3	3,758,508.2	364,467.8
Inputs					
Personnel expenses	117,854.8	35,020.5	177,179.9	128,564.2	10,842.7
Other non interest expenses	84,284.7	20,757.85	114,778.67	79,622.7	12,849.0
Interest paid	523,163.3	114,073.4	525,215.8	434,912.0	44,217.5
Input prices (in %)					
Price of labor	1.78	1.43	2.06	1.75	0.72
Price of physical capital	156.48	54.49	66.24	41.58	75.52
Price of borrowed funds	5.22	4.77	6.20	5.70	5.75
Other characteristics					
Total assets	9,177,941.4	2,394,190.9	9,081,743.6	7,146,222.5	1,032,650.2

All values are in millions dollars, except where indicated.

4. Methodology

This section describes the three analytical techniques for the estimation of efficiency scores: two parametric approaches based on econometric tools (stochastic frontier analysis, distribution-free approach), one nonparametric approach using linear programming techniques (data envelopment analysis). The main difference between the various methods of estimation is based upon the approach chosen for the decomposition of the residual between the random disturbance and the efficiency term. SFA relies on distributional assumptions for both components of the residual to disentangle them, while DFA is based on more intuitive assumptions allowed by the use of panel data. DEA simply assumes that the residual represents the whole inefficiency term, which can overestimate the inefficiencies. Moreover, parametric

⁵ This item includes the « other earning assets » in the IBCA terminology, which are all the earning assets other than loans.

approaches specify a functional form for the efficiency frontier, while nonparametric approaches do not need this assumption. This can be viewed as a disadvantage of the parametric approaches, as the functional form may not fit to data.

We choose here to measure the cost efficiency, as it is the most commonly specified efficiency concept in the literature. It measures how close a bank's cost is to what a best-practice bank's cost would be for producing the same bundle of outputs. It then provides information on wastes in the production process (technical efficiency) and on the optimality of the chosen mix of inputs (allocative efficiency). We estimate national frontiers rather than one common frontier for all countries. Both alternatives have been chosen in the literature: the common frontier allows the comparison of efficiency scores across countries but assumes similar technologies in all countries. National frontiers do not need to assume the same technology. They are thus more relevant for our analysis as the focus of our analysis is on the comparison of frontier techniques. As a result, the estimation of five national frontiers in five countries provides evidence about our issues in five different frameworks.

4.1 Stochastic frontier approach

SFA was initially proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van der Broeck (1977). The basic model assumes that total cost deviates from the optimal cost by a random disturbance, v , and an inefficiency term, u . Thus the cost function is $TC = f(Y, P) + \epsilon$ where TC represents total cost, Y is the vector of outputs, P the vector of input prices and ϵ the error term which is the sum of u and v . u is a one-sided component representing cost inefficiencies. v is a two-sided component representing random disturbances, reflecting bad (good) luck or measurement errors. u and v are independently distributed. v is assumed to have a normal distribution with zero mean and variance σ^2 .

Several distributions have been proposed in the literature for the inefficiency component u : half-normal, truncated normal, gamma, exponential. Here we assume a gamma distribution for inefficiency terms following Greene (1990). According to Jondrow et al. (1982), bank-specific estimates of inefficiency terms can be calculated by using the distribution of the inefficiency term conditional to the estimate of the

composite error term. Greene (1990) has then provided the estimate of the cost inefficiency term with a gamma distribution⁶.

We estimate a system of equations composed of a translog cost function and its associated input cost share equations, derived using Shepard's lemma. Estimation of this system adds degrees of freedom and results in more efficient estimates than just the single-equation cost function. Since the share equations sum to unity, we solve the problem of singularity of the disturbance covariance matrix of the share equations by omitting one input cost share equation from the estimated system of equations. Standard symmetry constraints are imposed. Homogeneity conditions are imposed by normalizing total costs and price of labor by the price of borrowed funds. Thus, the complete model is the following:

$$\begin{aligned} \ln\left(\frac{TC}{w_3}\right) &= \beta_0 + \sum_m \alpha_m \ln y_m + \sum_n \beta_n \ln\left(\frac{w_n}{w_3}\right) + \frac{1}{2} \sum_m \sum_j \alpha_{mj} \ln y_m \ln y_j \\ &+ \frac{1}{2} \sum_n \sum_k \beta_{nk} \ln\left(\frac{w_n}{w_3}\right) \ln\left(\frac{w_k}{w_3}\right) + \sum_n \sum_m \gamma_{nm} \ln\left(\frac{w_n}{w_3}\right) \ln y_m + \varepsilon \\ S_n &= \partial \ln\left(\frac{TC}{w_3}\right) / \partial \ln w_n = \beta_n + \sum_k \beta_{nk} \ln\left(\frac{w_k}{w_3}\right) + \sum_m \gamma_{nm} \ln y_m + \eta_n \end{aligned}$$

where TC total costs, y_m m^{th} bank output ($m=1,2$), w_n n^{th} input price ($n=1,2$), w_3 price of borrowed funds, S_n input cost share⁷ ($n=1,2$), η_n error term (η_n independent from ε). The system of equations is estimated using Iterative Seemingly Unrelated Regression (ITSUR) estimation technique⁸.

4.2 Distribution-free approach

SFA requires distributional assumptions on the random error and the inefficiency term to disentangle the residual that might be invalidated by data. DFA was then developed by Berger (1993) to substitute some intuitive assumptions to these arbitrary assumptions in the decomposition of the residual. This approach assumes the cost differences owing to cost inefficiency are stable over time while random errors

⁶ See Kumbhakar and Lovell (2000) for further details on Stochastic Frontier Analysis.

⁷ S_n is equal to the expenses for the input n divided by total costs.

⁸ Kmenta and Gilbert (1968) proved that this procedure generates maximum likelihood estimates.

are varying and tend to their average, zero, over time. The stability of each bank's inefficiency over time is based upon the notion of a firm-effect of efficiency, suggested by Schmidt and Sickles (1984). As mentioned by Berger (1993, p.263), "good management maximizes long-run profits by keeping costs relatively low over long periods of time, although costs may fluctuate from trend because of luck and measurement error". So by favoring a long-term perspective, managers of firms do not influence their efficiency from one year to the next one, the variations are all caused by chance or measurement errors.

We estimate the same cost function model than with SFA, including a translog cost function and two factor share equations obtained by applying Shephard's lemma. The system of equations is then estimated again by using ITSUR estimation technique. To compute inefficiencies, we assume the average residual for each bank serves as an estimate of the efficiency term for that bank, given that the annual random error term tends in average to zero over the period. The average residual of each bank is then used in the computation of cost efficiency.

Nevertheless, this measure of inefficiency is not totally correct if random errors do not cancel each other out during the period. This error is likely to be larger for banks near the extremes of the average residual. These banks may have experienced good (or bad) luck all along the period. Furthermore, the minimum average residual which serves as a benchmark could be overestimated. To prevent this problem, we compute truncated measures of cost efficiency, where the value of the 1th (99th) quantile was given to each observation for which the value of the average residual is below (above) the 1th (99th) quantile value.

4.3 Data envelopment analysis

DEA is a methodology oriented on the frontiers instead of the central tendencies: it determines a linear surface on the top of observations. DEA was developed by Charnes et al. (1978) who employed a mathematical planning program to measure the technical efficiency under constant returns-to-scale. Then Banker et al. (1984) described a revised model including variable returns-to-scale, thus allowing the computation of pure technical efficiency and scale efficiency. We follow here the programming developed by Färe, Grosskopf and Logan (1985) to estimate cost efficiency :

$$\begin{aligned} & \text{Min}_x \quad p \cdot x \\ & \text{subject to} \quad \text{(i) } y \leq z \cdot Y \\ & \quad \quad \quad \text{(ii) } \lambda \cdot x \geq z \cdot X \\ & \quad \quad \quad \text{(iii) } z \in \mathfrak{R}_+ \end{aligned}$$

In this problem, y is the m dimensional vector of output produced by a particular bank, x is the n dimensional vector of inputs utilized by a particular bank, Y is the $(k \cdot m)$ matrix of outputs where k represents the number of banks, X is the $(k \cdot n)$ matrix of inputs, z is the vector of intensity parameters or weights attached to each of the banks in the determination of minimum cost, p is the column vector of input prices. The program thus requests the minimization of the input costs px subject to the production technology, given by the three constraints. The input values generated by the solution to this problem represent the minimum cost level for a particular bank. Cost efficiency is then measured by the ratio of the calculated minimum cost to the actual cost for a particular bank⁹.

SFA and DEA provide yearly efficiency scores, while DFA computes efficiency scores for the whole period of the study. To allow the comparison of efficiency scores in the following sections, we then need to compute average efficiency scores for SFA and DEA. Consequently, we will consider the SFA and DEA scores for each bank as the arithmetic means of yearly efficiency scores for the seven years of the study.

⁹ A more detailed review of the DEA methodology is provided by Ali and Seiford (1993).

5. The estimation of efficiency scores

This section is devoted to the presentation of the efficiency scores obtained with the three applied approaches. We first present the distributional characteristics of the three estimations. Then, we analyze the correlation between the efficiency scores provided by the three approaches.

5.1 Comparison of efficiency levels

We compute first the efficiency scores by approach and each country. Table 3 reports information on cost efficiency scores obtained with each frontier technique¹⁰. Several conclusions emerge. First, the efficiency techniques do not provide comparable means in all countries. Indeed, the mean efficiency scores are on a broad range in every country of the study: the lower range is in Italy from 67.91% with DEA to 84.20% with SFA, the higher range is in France from 40.16% with DEA to 70.56% with SFA. The only comparable means are those for SFA and DEA in Spain and Switzerland, and for DFA and SFA in Italy. Otherwise, average efficiency scores are close to one another in terms of level.

Second, SFA provides the highest estimations in all countries. However, we do not observe a higher proximity of SFA means with DFA means than with DEA means. Indeed, DEA mean is closer from SFA mean in three countries, and these means are even undoubtedly comparable in Spain and Switzerland. In the meantime, DFA mean is not comparable to SFA mean in any country. Third, we observe the same ranking of standard deviations according to the frontier technique in all countries: SFA provides the least dispersed distribution of efficiency scores, while DFA estimates the most dispersed one. Here again, we do not observe any resemblance between SFA and DFA.

As a consequence, we clearly observe strong differences in distributional properties of the efficiency scores provided by the three techniques in all five

¹⁰ It is noticeable that maximum DEA scores are not necessarily 100%, which can be viewed as a surprising result as DEA determines a linear surface on the top of the observations. This fact is simply the result of the fact that scores are average efficiency scores by bank for the period of the study.

countries of our study. Thus, the answer to question Q1 is by no doubt negative. Our results on European data consequently disagree with the consensus of US studies about the robustness of efficiency scores across parametric approaches. Indeed, we do not find greater similarities between means computed by DFA and SFA than between any parametric technique and DEA.

However, this lack of robustness between the three frontier approaches is not necessarily a problem for the use of efficiency scores. Indeed, the differences in distributional properties of efficiency scores may result from the various assumptions required by the approaches. In the meantime, the frontier techniques can generate similar rankings of efficiency scores and then give consistent results in terms of ordering. This would then allow extracting some public policy conclusions from the analysis of efficiency scores. Therefore, it is of the highest interest to analyze if the frontier techniques provide correlated efficiency scores.

Table 3: Descriptive statistics for mean efficiency scores

France (N=135)				
	Mean	Standard dev.	Minimum	Maximum
DFA	50.29	17.45	17.30	100.00
SFA	70.56	10.70	32.92	86.04
DEA	40.16	13.58	11.30	79.76
Germany (N=296)				
	Mean	Standard dev.	Minimum	Maximum
DFA	59.68	12.63	35.75	100.00
SFA	83.50	5.83	47.35	93.33
DEA	70.54	9.60	45.44	100.00
Italy (N=99)				
	Mean	Standard dev.	Minimum	Maximum
DFA	69.11	12.16	38.21	100.00
SFA	84.20	6.32	56.19	92.86
DEA	67.91	11.88	45.53	99.49
Spain (N=85)				
	Mean	Standard dev.	Minimum	Maximum
DFA	62.19	14.49	29.57	100.00
SFA	79.28	8.09	48.23	90.44
DEA	77.77	10.01	40.30	97.81
Switzerland (N=73)				
	Mean	Standard dev.	Minimum	Maximum
DFA	43.08	16.95	11.20	100.00
SFA	66.74	11.23	28.95	83.54
DEA	64.87	15.75	20.83	96.51

All scores are in percentage.

5.2 Correlations of efficiency scores

We now proceed to the measurement of the correlations between the efficiency scores computed with each approach. The results of the correlation tests are reported in table 4. Correlations show the highly significant positive relation between SFA and DFA scores for all countries. However, in the meantime, we do not observe any significant positive relation between DEA scores and parametric approaches scores. These correlations are in most cases not significant, or sometimes even significantly negative (between DEA and SFA scores) and Germany (between DEA and both parametric approaches). The answer to question Q2 is consequently clearly negative.

Table 4: Correlation of scores

France (N=135)			
	DFA	SFA	DEA
DFA	1.0000	0.8671*** (0.0001)	-0.0400 (0.6444)
SFA		1.0000	-0.2374*** (0.0056)
DEA			1.0000
Germany (N=296)			
	DFA	SFA	DEA
DFA	1.0000	0.8808*** (0.0001)	-0.1248** (0.0318)
SFA		1.0000	-0.1304** (0.0248)
DEA			1.0000
Italy (N=99)			
	DFA	SFA	DEA
DFA	1.0000	0.9127*** (0.0001)	-0.0827 (0.4182)
SFA		1.0000	-0.1134 (0.2664)
DEA			1.0000
Spain (N=85)			
	DFA	SFA	DEA
DFA	1.0000	0.9226*** (0.0001)	-0.0965 (0.3798)
SFA		1.0000	-0.0156 (0.8871)
DEA			1.0000
Switzerland (N=73)			
	DFA	SFA	DEA
DFA	1.0000	0.8961*** (0.0001)	-0.1103 (0.3528)
SFA		1.0000	-0.1014 (0.3935)
DEA			1.0000

*, **, *** denote an estimate significantly different from 0 at the 10%, 5% or 1% level

Thus, our results are in accordance with US studies and in particular with Bauer et al. (1997) regarding the correlation of efficiency scores across parametric approaches, and the absence of correlation between DEA and parametric approaches. In comparison to European studies, we agree with Sheldon (1994) on Swiss banks, but we provide results in marked contrast with Drake and Weyman-Jones (1996) on British banks, and Resti (1997) on Italian banks.

We then provide clear evidence against the robustness of frontier approaches on all five European countries of our study. Two questions remain however unanswered. First, even if scores are not correlated between frontier approaches, they can still provide similar diagnosis on important public policy issues such as the link of efficiency with size or specialization. Second, this absence of correlation does not allow evaluating which approach provides the “best” measures of performance. To bring some elements about this major issue in the debate about frontier efficiency measures, we can test the links between efficiency scores and standard measures of performance to know which frontier technique provides the efficiency scores the most related to these measures. Both questions are investigated in the following sections.

6. Efficiency issues for the regulatory analysis

Our aim in this section is the test of the consistency of the answers provided by the three techniques about two major issues in the banking literature: the relation between cost efficiency and size, the differences in cost efficiency relative to bank specialization. The section is organized so as to answer each question in turn. Namely subsection 1 studies the link between efficiency and size, while subsection 2 analyzes efficiency scores by specialization.

6.1 Efficiency and size

We perform the analysis of the relation between cost efficiency and bank size in two steps. In a first step, we test the single-variable correlations of efficiency scores with measures of bank size. However this may not be a sufficient evaluation if there exists a nonlinear relation between bank size and efficiency. As a result, in a second step, we compute the mean efficiency scores for five size classes. We then allow for

nonmonotonicity and nonlinearities in the relation between size and efficiency. In this aim, we divide each national sample in five size classes depending on the mean total balance sheet over the period: until 400 million dollars, from 400 million to 1 billion dollars, from 1 to 2 billion dollars, from 2 to 5 billion dollars, above 5 billion dollars.

Table 5 reports information on single-variable correlations. Here size is measured by the mean total balance sheet of the bank for the period (*Assets*) and also by the logarithm of the mean total balance sheet of the bank for the period (*Logass*). With the variable *Assets*, there are some similarities as the variable is not significant with all approaches in France and Spain. However we observe a significant relation only for one frontier technique in Germany (positive with DFA), Italy (positive with DEA) and Switzerland (negative with DEA).

Table 5: Single-variable correlations of efficiency scores with bank size

France			
	DFA	SFA	DEA
<i>Assets</i>	0.1301 (0.1327)	0.0834 (0.3364)	0.1315 (0.1284)
<i>Logass</i>	0.0822 (0.3434)	0.0303 (0.7274)	0.3467*** (0.0001)
Germany			
	DFA	SFA	DEA
<i>Assets</i>	0.1232** (0.0341)	0.0840 (0.1493)	0.0945 (0.1046)
<i>Logass</i>	0.0721 (0.2163)	0.0795 (0.1728)	0.3956*** (0.0001)
Italy			
	DFA	SFA	DEA
<i>Assets</i>	0.1194 (0.2414)	0.0612 (0.5495)	0.4216*** (0.0001)
<i>Logass</i>	0.0451 (0.6592)	0.0392 (0.7019)	0.5924*** (0.0001)
Spain			
	DFA	SFA	DEA
<i>Assets</i>	-0.1293 (0.2381)	-0.0661 (0.5479)	0.1436 (0.1899)
<i>Logass</i>	-0.0884 (0.4210)	0.0075 (0.9455)	0.2722** (0.0117)
Switzerland			
	DFA	SFA	DEA
<i>Assets</i>	-0.0479 (0.6876)	0.0200 (0.8666)	-0.2178* (0.0641)
<i>Logass</i>	-0.0752 (0.5273)	0.0075 (0.9500)	-0.2613** (0.0255)

*, **, *** denote an estimate significantly different from 0 at the 10%, 5% or 1% level

Furthermore, the most striking result of these tests concerns the results of the correlations of cost efficiency scores with the variable *Logass* : in all countries, the relation is not significant with DFA and SFA scores, whereas it is significant with DEA scores (negative in Switzerland, positive in the four other countries). This result

clearly supports the lack of similarities between the frontier techniques regarding the diagnosis on the link between efficiency and bank size. However, on the other hand, the specific significantness of DEA scores with the variable *Logass* tends to suggest that the DEA methodology provides more foundations to a relation with size. Thus, these correlations broadly show the lack of similarities between parametric approaches and DEA.

Table 6: Efficiency and size

Size is measured by the mean total balance sheet over the period: 1st class until 400 million dollars, 2nd class from 400 million to 1 billion dollars, 3rd class from 1 to 2 billion dollars, 4th class from 2 to 5 billion dollars, 5th class above 5 billion dollars. The last column presents the variation between the 1st and the 5th classes.

France						
	1 st class	2 nd class	3 rd class	4 th class	5 th class	Variation
N	24	24	24	39	24	
DFA	48.28	50.11	50.86	51.02	50.72	+2.44
SFA	69.00	70.62	71.88	71.27	69.59	+0.59
DEA	35.54	36.18	35.85	43.63	47.46	+11.92
Germany						
	1 st class	2 nd class	3 rd class	4 th class	5 th class	Variation
N	83	64	73	51	25	
DFA	58.90	58.57	61.27	58.77	62.33	+3.43
SFA	83.04	82.82	84.33	83.25	84.86	+1.82
DEA	65.28	70.34	71.25	74.94	77.43	+12.15
Italy						
	1 st class	2 nd class	3 rd class	4 th class	5 th class	Variation
N	4	21	21	27	25	
DFA	65.02	71.33	70.89	65.02	70.97	+5.95
SFA	79.63	85.37	85.47	82.31	84.98	+5.35
DEA	63.01	61.15	62.59	66.89	79.54	+16.53
Spain						
	1 st class	2 nd class	3 rd class	4 th class	5 th class	Variation
N	6	8	15	30	26	
DFA	61.01	64.36	62.32	65.23	58.23	-2.78
SFA	76.88	80.14	79.24	80.72	77.92	+1.04
DEA	71.64	71.92	81.33	76.84	80.01	+8.37
Switzerland						
	1 st class	2 nd class	3 rd class	4 th class	5 th class	Variation
N	46	11	6	5	5	
DFA	44.47	37.29	48.94	37.77	41.26	-3.21
SFA	66.88	64.43	71.83	63.56	67.69	+0.81
DEA	67.99	60.38	63.14	53.95	59.06	-8.93

All scores are in percentage.

We now measure the mean cost efficiency by size class to analyze any nonlinear evolution of efficiency with size, that would be reported by all frontier

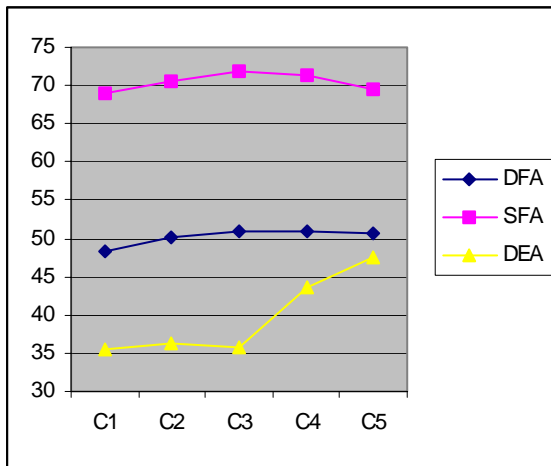
techniques. Table 6 describes the mean cost efficiency estimated by size class and by frontier technique for each country. Graph 1 displays these results by country. Several observations can be made. First, the movements between size classes are parallel between DFA and SFA scores in all countries. Indeed in almost all cases, the sign of the variation of cost efficiency between both size classes is similar with DFA and SFA. Second, the movements between DEA scores and parametric approaches are only similar for Swiss banks. In the four other countries, the evolution of efficiency with size does not follow the same trend according to the parametric or nonparametric status of the frontier technique.

Third, in accordance with the above results on the correlation between efficiency and bank size, DEA efficiency scores seem to increase monotonically with size, whereas there is no clear trend for DFA and SFA efficiency scores. Fourth, when restricting the analysis to the comparison of cost efficiency between the extreme classes (1st and 5th classes), we can however observe some similarities between DEA and parametric approaches. The three techniques conclude to the higher efficiency of the largest banks relative to the smallest banks in France, Germany and Italy. In the meantime, DEA agrees with SFA in Spain about the advantage in efficiency to the largest banks, in opposite to DFA, and with DFA in Switzerland about a better efficiency for the smallest banks, unlike SFA.

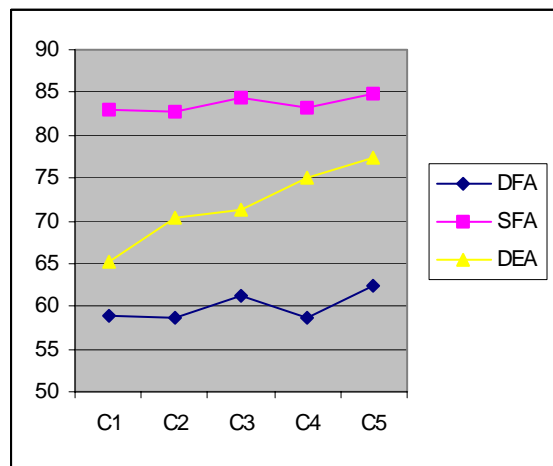
Our conclusion about the consistency across approaches of the link between efficiency and size is then mixed rather than in favor of the lack of robustness among frontier approaches. Whereas DEA suggests a monotonous evolution of efficiency with size, parametric approaches do not observe any clear trend. However when comparing only the smallest and the largest banks, all approaches broadly agree about the diagnosis in three countries (France, Germany, Italy) suggesting that the efficiency approaches may be satisfactory to evaluate if the largest banks have an advantage in efficiency, which is after all the key issue for the debate on bank mergers. Then, concerning the first part of the question Q3, the answer is ambiguous.

Graph 1 : Evolution of cost efficiency with size classes

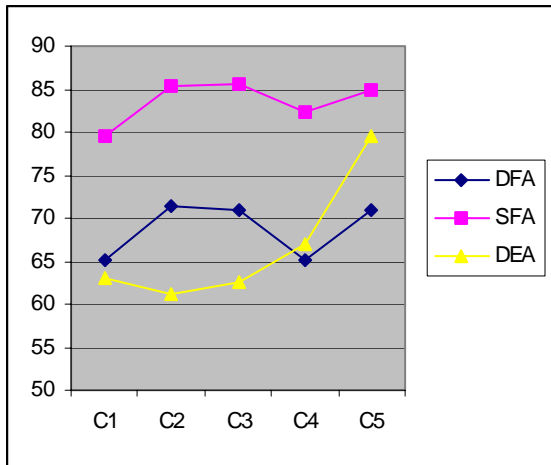
France



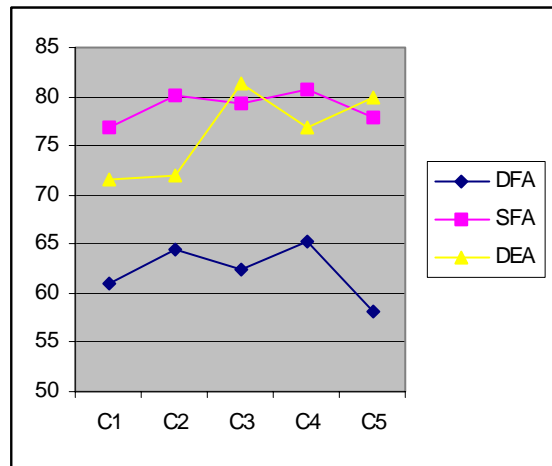
Germany



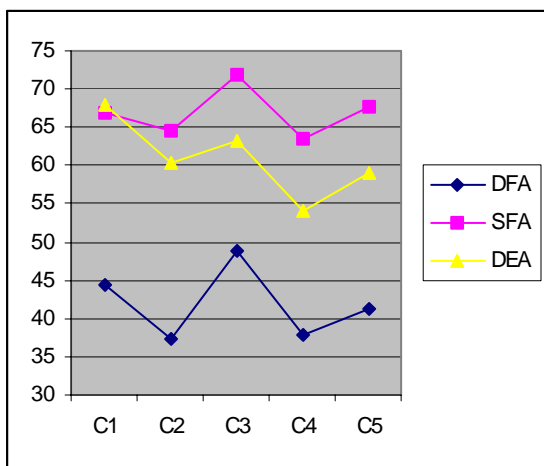
Italy



Spain



Switzerland



6.2 Efficiency and specialization

The relative performance of banks depending of their specialization is a key question in Western Europe where cooperative and savings banks own a significant market share. Ownership differences between categories of banks make this issue one of the highest interest for public policy recommendations, notably in terms of privatization of banks or incentives to develop the cooperative sector. We aim here to analyze if the frontier techniques conclude in a similar way about this issue.

Former studies analyzing the relative efficiency of specialization categories in countries of our work conclude all to a lower efficiency for commercial banks than for cooperative and savings banks in France (Dietsch and Weill (1999) with DEA), and Germany (Lang (1996) with SFA, Altunbas, Evans and Molyneux (2001) with SFA and DFA). This is a rather counterintuitive result. Indeed, to sum it up, the main specific feature of commercial banks is their private ownership, in opposite to the mutual or public ownership of other specializations. Therefore, from the perspective of corporate governance theories, the private ownership should result in higher incentives for managers because of a better control of private shareholders and a higher constraint on profitability. Is this diagnosis robust to the specification of the technique?

Table 7: Efficiency and specialization

France			
	Commercial banks	Cooperative banks	Savings banks
N	84	42	9
DFA	52.09	48.68	40.99
SFA	70.44	71.56	67.01
DEA	39.56	40.16	45.80
Germany			
	Commercial banks	Cooperative banks	Savings banks
N	11	111	174
DFA	65.79	60.12	59.02
SFA	82.38	83.85	83.35
DEA	72.40	64.95	73.99
Italy			
	Commercial banks	Cooperative banks	Savings banks
N	33	27	39
DFA	69.57	75.09	64.58
SFA	84.28	86.82	82.30
DEA	67.33	73.24	64.72
Spain			
	Commercial banks	Cooperative banks	Savings banks
N	35	2	48
DFA	66.07	53.45	59.73
SFA	80.80	76.61	78.27
DEA	73.00	78.41	81.22
Switzerland			
	Commercial banks	Cooperative banks	Savings banks
N	50	4	19
DFA	43.66	44.61	41.22
SFA	68.07	70.95	62.36
DEA	62.48	70.41	69.98

All scores are in percentage.

Mean efficiency scores for commercial, cooperative and savings banks are presented in table 7 by country to answer this question. We observe the lack of robustness across frontier techniques regarding the relationship between specialization and efficiency, if we except Italy. Indeed, only this country obtains the same ranking of specializations with each frontier technique: the cooperative banks are the most efficient, followed by the commercial and then the savings banks. In other countries, the hierarchy of specializations in terms of efficiency considerably varies with the applied frontier technique. For instance, in Germany, each frontier technique concludes in a different way about the most efficient specialization.

Next to these differences in hierarchy, it is also noticeable that there are very few cases of dominance of one specialization against one other: the cooperative banks

are more efficient than other banks for all techniques in Switzerland, while in Spain, the savings banks dominate the cooperative banks.

A key element to evaluate the potential influence of the frontier technique on the efficiency results by specialization is the possible robustness of the results provided by any technique across countries, even if they are not consistent across approaches for any given country. We find evidence in favor of this robustness across countries by approach. When comparing commercial banks and cooperative banks, SFA and DEA scores provide a diagnosis of higher efficiency for cooperative banks in four countries, whereas DFA leads to different conclusions according to the country of study. If we compare commercial banks and savings banks, a striking result is that parametric approaches suggest in almost all cases an advantage in efficiency for commercial banks, while DEA concludes in an opposite way for all countries except Italy. Finally, now looking at the relative efficiency of cooperative banks and savings banks, parametric approaches agree on a higher efficiency of cooperative banks in four countries, when DEA provides mixed evidence with a higher efficiency for savings banks in three countries.

It has been above-mentioned that the scarce studies comparing the relative efficiency of European banks according to their specialization agree on the dominance of cooperative and savings banks on commercial banks. We find here that this dominance is dependent of the chosen approach in all countries other than Italy. However we obtain results that are consistent with most former studies when considering the same approach. Indeed, like Dietsch and Weill (1999) we conclude that DEA scores are higher for the cooperative and savings banks than for commercial banks in France. In accordance with Lang (1996) and Altunbas, Evans and Molyneux (2001), we also observe that SFA scores are weaker for commercial banks than for cooperative and savings banks in Germany. The only difference with former literature concerns the use of DFA in Germany, where we do not conclude to the dominance of cooperative and savings banks on commercial banks, unlike Altunbas, Evans and Molyneux (2001).

We have then observed a higher consistency of efficiency scores across countries by approach than across approaches by country. Thus, it can be argued that the characteristics of the approaches may have an impact on the diagnosis about the relative efficiency by specialization. If we except the case of Italy, the choice of the

frontier approach is then not neutral and the answer to the second part of question Q3 is consequently clearly negative.

7. Consistency with standard measures of performance

In the previous sections, we analyzed for three frontier approaches the consistency of their levels, their rankings, and their conclusions on two public policy issues. Our finding is in many cases the lack of robustness across these approaches. Next to this test of the consistency across approaches, it is of the highest importance to evaluate their consistency with some standard measures of performance such as average cost ratio. As observed by Bauer et al. (1997), if the efficiency scores are related to standard financial ratio measures of performance, then authorities could be more confident that these scores are accurate indicators of performance and not just some artificial measures resulting of specific assumptions. In a way, this step can help to determine the “best” frontier technique, as we have observed above that the results of the various approaches were not robust.

We compute here by country the correlations between efficiency scores and two standard measures of cost performance¹¹: the average cost ratio (TC/TA, defined as total costs as a fraction of total assets) the cost-to-income ratio (TC/INC, defined as total costs divided by total revenues). We compute the mean ratios by bank for the whole period and we then test the correlation with the average efficiency scores over the period. The expected relation between the cost ratios and the cost efficiency scores is negative. Indeed, a high cost efficiency score is more likely to be associated with a low cost ratio.

¹¹ We do not measure the correlation between efficiency scores and profitability measures, as the ambiguity to interpret this relation makes it out of the field of this analysis. Indeed, a higher cost efficiency is supposed to mean lower costs and consequently a higher profitability, as less costs mean more profits. As a result, the expected pattern is a positive relationship between cost efficiency and profitability. Nevertheless, on the other hand, the “quiet life” assumption suggests that the banks with the higher profitability are the most incited to relax their control over costs. Consequently the causation may be reversed with a negative influence of profitability on cost efficiency. Thus, an observed negative relation between cost efficiency and profitability may be the result of competition imperfections rather than the consequence of the lack of consistency of the used cost efficiency technique.

Table 8: Efficiency scores and raw-data measures of performance

France			
	DFA	SFA	DEA
TC/TA	-0.1906** (0.0268)	-0.1794** (0.0373)	-0.3210*** (0.0001)
TC/INC	-0.0110 (0.9013)	-0.1117 (0.2058)	-0.1204 (0.1724)
Germany			
	DFA	SFA	DEA
TC/TA	-0.1640*** (0.0047)	-0.1154** (0.0473)	-0.6454*** (0.0001)
TC/INC	-0.1497** (0.0103)	-0.1742*** (0.0028)	-0.4409*** (0.0001)
Italy			
	DFA	SFA	DEA
TC/TA	-0.1338 (0.1889)	-0.1034 (0.3110)	-0.7476*** (0.0001)
TC/INC	-0.2554** (0.0116)	-0.1879* (0.0653)	-0.0363 (0.7244)
Spain			
	DFA	SFA	DEA
TC/TA	-0.0049 (0.9645)	-0.0056 (0.9593)	-0.7602*** (0.0001)
TC/INC	-0.2004* (0.0659)	-0.2078* (0.0563)	-0.6139*** (0.0001)
Switzerland			
	DFA	SFA	DEA
TC/TA	-0.1453 (0.2199)	-0.1069 (0.3679)	-0.8094*** (0.0001)
TC/INC	-0.2253* (0.0570)	-0.2846** (0.0154)	-0.4090*** (0.0004)

*, **, *** denote an estimate significantly different from 0 at the 10%, 5% or 1% level

TC/TA : average cost ratio, TC/INC: cost-to-income ratio

Table 8 displays by country the correlations between efficiency scores obtained for each technique and both standard measures of cost performance. A few interesting comments can be made from this table. First, the relationship with the TC/TA ratio is negative and significant at the 1% level for DEA cost efficiency scores for all countries, while it is significantly negative for SFA and DFA only in France and Germany. In all countries however, this relation is negative. Second, the relationship with the TC/INC ratio is rather different. We observe a negative and significant relation of this ratio with the three cost efficiency scores in Germany, Spain and Switzerland. There is only a negative and significant relation in Italy for both parametric approaches. Finally, we do not observe any significant relation of cost efficiency scores with the TC/INC ratio in France, which is a rather surprising result relative to our finding about the TC/TA ratio in this country.

To sum it up, all approaches provide efficiency scores that are connected to standard measures of cost performance. Parametric approaches estimate cost efficiency scores that are negatively correlated to TC/TA ratio in France and Germany, and to TC/INC ratio in all countries other than France. DEA provides cost

efficiency scores negatively linked to TC/TA ratio in all countries, and to TC/INC ratio in Germany, Spain and Switzerland.

Our results differ from Bauer et al. [1997]. Indeed they suggest that the cost efficiency scores estimated with parametric approaches are broadly consistent with standard measures of cost performance, while the DEA cost efficiency scores are not. Consequently, we agree on the similarities between SFA and DFA results, but we disagree on the better consistency of parametric approaches than for DEA. Thus, unlike this study on US data, we provide evidence on the consistency of DEA efficiency scores with standard measures of performance.

To conclude, we can observe that all frontier approaches provide efficiency scores in connection to standard measures of performance with varying degrees, meaning that these scores are not too dependent of the underlying assumptions. Thus, the answer to question Q4 is rather positive. Furthermore, following our results about the lack of consistency across approaches for the levels and correlations, this section aimed to analyze which approach was the most related to the standard measures of performance, to help us knowing which frontier technique is the most adapted to European banking. Our results do not bring to a firm conclusion, as we observe correlations with standard cost ratios for each approach, even if we can give to DEA a slight advantage in this debate due to its very significant relation with the TC/TA ratio.

8. CONCLUSION

The research presented here has analyzed the robustness of the frontier approaches applied in banking on five European banking sectors. This is an issue of considerable interest, due to the increasing volume of literature devoted to the efficiency in European banking.

We investigate this question by answering four questions about the consistency of the frontier approaches. First, the frontier techniques do not provide comparable average efficiency scores in all five countries. In some cases, means are comparable but it is the exception more than the general rule. Furthermore, the means are not more comparable between parametric approaches than between one of these techniques and DEA. Second, the efficiency scores are positively correlated between

parametric approaches for all countries, while there is no positive relation between any parametric approach and DEA. Third, regarding the size, the evidence is mixed, as there are some connections with the results from all approaches, even if parametric approaches provide more connected results.

However, the link between efficiency and specialization is clearly not robust in all countries other than Italy, which is the only one with a consistent hierarchy of specializations across approaches. Fourth, the efficiency scores computed by all three techniques are broadly consistent with standard measures of cost performance with some differences regarding the approach and the country. As a result, this suggests that all three techniques provide efficiency estimates that are not too dependent of the assumptions needed for the frontier efficiency technique.

To sum it up, our conclusions mainly support the lack of robustness of frontier approaches, even if there are some similarities depending on the country or the compared approaches. Frankly speaking, these results are at best innovative, suggesting some ways to further research to explain these differences in the results, at worst problematic as they suggest that the chosen frontier technique has some influence about the results and that there is no best approach, due to the fact that all techniques are linked to standard measures of performance.

Our results should however be considered with care. Indeed, there is very little literature about the comparison of frontier techniques especially on European data. Consequently, our main findings are difficult to be compared. Furthermore, applied frontier techniques needed to make some specific assumptions that may influence the outcome, such as the 1% truncation with DFA or the gamma distribution with SFA. It can then be argued undoubtedly that some variants of each approach should have also been tested. Nevertheless, two observations have to be suggested about this point. On one hand, most applications of efficiency approaches use only one variant of a frontier technique without taking care of its robustness and then provide some results about banking efficiency. Consequently, it may be already satisfactory to compare only one variant of each main frontier technique with the others. On the other hand, the application of these variants would have weighed this work which already contains a large amount of information.

To conclude, we have to provide the same advice on European data than Bauer et al. (1997) when ending their comparison of frontier techniques on US data: with the

lack of evidence on robustness for efficiency measurement approaches, any work based on efficiency measures needs to use several techniques to validate its results.

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