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The Efficiency and the Conduct of European Banks
Developments after 1992

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and
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The Efficiency and the Conduct of European Banks: Developments after 1992*

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Abstract

This paper addresses the efficiency of the European banking sector in the five-year period following the implementation of the Second Banking Directive of the European Union (EU). We first determine the degree of cost efficiency of EU banks in the period 1993-1997. After that we explore to what extent efficient European banks are managed differently than their inefficient peers. Our datasets comprise 5 years of observations on 1347 savings banks and 873 commercial banks, and we use the new Recursive Thick Frontier Approach method to establish our results. We find that structural factors such as technological progress or increased bank competition have lowered the cost base of banks by about 5 percent annually in the sample period. Managerial inability to control costs is at 17-25 percent the main source of bank inefficiency in the EU. Managerial efficiency varies a great deal within Europe, and there seems to be no tendency towards convergence. We detect economies to scale for small savings banks. The savings bank sector as a whole can cut costs by about 3 percent through mergers of small savings banks.

JEL: D20, G21, L11, L23. Keywords: banking, cost efficiency, economies of scale, technological progress.

1 Introduction

On 1 January 1993 the Second Banking Directive of the EU[1] and a number of the other key EU directives[2] related to the financial service industry were implemented. This heralded a new episode of deregulation with a standardized procedure to acquire a banking license, standardized capital requirements, and standardized supervision rules. The general belief among bankers and academics is that competition in European banking has significantly increased in this changed environment. Indeed, as from 1 January 1993, European banks virtually compete on a level playing field, whereas before it was perhaps difficult to speak of a single EU banking sector. Apart from the major change in the regulatory and competitive environment, the banking industry has been affected by the availability of new computer and telecommunications technologies.

Some immediate questions that arise from the general picture above are: Have bankers reshaped their businesses into leaner (more cost efficient) institutions in order to face increased competitive pressure? Have banks moved into new strategies and products at the time in which traditional income streams such as interest rate margins have perhaps dried up? What has happened to the sector's profitability and viability after 1992? Answers to these questions help bankers to choose the right strategy for their institution. It also provides important feedback to regulators on the importance and the efficacy of their work. Finally, it helps to outline the shape of the future financial services market in the EU.

This study addresses some of the important questions above. First, through a cost

[1] Council Directive 89/646/EEC. The most important provisions of the directive are: (1) harmonised rules regarding the banking license (Articles 4-7), (2) harmonised mandate for regulation (Articles 10-17), and (3) mutual recognition, i.e. freedom of establishment in EU member states other than the home member state (Articles 18-21).

[2] Namely, the Money Laundering Directive (91/308/EEC), the Own Funds Directive (89/299/EEC), the Solvency Ratio Directive (89/647/EEC), the Consolidated Supervision Directive (92/30/EEC), and the Deposit-guarantee Directive (94/19/EC). The Large Exposures Directive (92/121/EEC), the Capital Adequacy Directive (C152/6/EEC), and the Investment Services Directive (93/22/EEC), came into force in 1994, 1996 and 1996 respectively.

frontier analysis we study developments in X-efficiency, returns to scale, and the impact of structural developments of EU banks in the period 1993-1997. We pay special attention on the questions whether, as predicted above, bank efficiency has increased due to increased competitive pressure, and whether the cost base for banks has come down due to structural factors. Secondly, we identify possible differences between the strategies of efficient and inefficient banks. We perform our study on two different bank samples, namely EU savings banks and EU commercial banks. This choice is inspired by initial findings that demonstrate important differences between these two bank types, and by Altunbas and Chakravarty (1998)'s point that different types of banking institutions play a distinct role in the financial system of the EU.

Our findings are the following. First, structural developments such as technological progress, or increased competition in banking, have had a notable impact on the EU banking sector. After accounting for changes in output levels and input prices, we find that both EU savings banks and EU commercial banks lowered their cost base in the period 1993-1997 at an annual pace of about 5 percent. This result confirms the recent findings of Altunbas, Gardener, Molyneux, and Moore (2001) and Carbo, Gardener, and Williams (2001). US evidence on structural developments in the same time period reveals small or even negative effects of structural developments.[3]

Second, we confirm the standard result for both EU and US banks that managerial ability to control costs (X-inefficiency) is at 17-25 percent the main source of inefficiency.[4] By contrast, the savings bank sector can reduce costs by about 3 percent by exploiting potential economies of scale.[5] Managers of large commercial banks are on average

[3] In particular, in his study on 661 big banks in the period 1991-1997, Stiroh (2000) finds annual cost improvements of about 0 to 0.5 percent. Berger and Mester (2001), who also take into account general business conditions in the sector, find that the cost base of best practice banks *increased* by about 1 percent annually over the same time period. They find an even worse cost figure for their entire set of banks, but, at the same time, also find that US banks improved in terms of profitability.

[4] An important survey of the empirical literature is Berger and Humphrey (1997).

[5] Carbo, Gardener, and Williams (2002) is the only other cross-country study of EU savings banks. They

more successful in controlling costs than managers of small commercial banks. A similar relationship does not hold for savings banks. A possible reason for this is that large commercial banks are more often publicly listed so that management is subject to more extensive shareholder scrutiny. Another potential reason for this important result could be that savings banks and small commercial banks typically operate in highly localized and non-competitive banking markets, while the relevant banking market of a large commercial bank is typically larger and more competitive so that their managers face more pressure to cut costs. The level of X-efficiency differs from country to country in Europe. Among the five big EU countries only German banks have been successful in attaining relatively high X-efficiency levels in 1993-1997; the UK and France have hovered around the EU average; and Italy and Spain have been bad performers in terms of X-efficiency. Most EU member states have not witnessed any improvement in the X-efficiency level of their banking sectors, however, the three Nordic EU countries have been a positive exception to this rule.

Finally, efficient banks and inefficient bank differ. First and foremost, efficient savings banks generate about 20 percent more profits than inefficient savings banks. Efficient savings banks also attract more capital in the form of deposits and they generate more income in the form of commissions than inefficient savings banks. Efficient commercial banks incur only two-thirds of the costs of inefficient commercial banks, however they are *not* more profitable than their inefficient counterparts. Efficient commercial banks are more often involved in off-balance-sheet activities and commission-generating business than inefficient commercial banks. They also hold more securities. Taken together, these results could suggest that efficient commercial banks rely on a more diverse portfolio of outputs, among which investment banking activities. It may also be that the set of commercial

report a possible cost reducing effect from choosing a bigger size to be between 7-10 percent. However, this figure represents an unweighted average of all banks, while we have weighted banks by their balance-sheet total.

banks is too diverse to compare them using a single frontier. In particular, commercial banks that are deemed efficient may often be investment banks in disguise.

This paper adds to the small but growing strand of literature that assesses the efficiency of the EU banking sector. Other works include Altunbas et al. (2001), Casu and Molyneux (2000), Carbo et al. (2001), Carbo et al. (2002), Maudos, Pastor, Pérez, and Quesada (2002), and Vander Vennet (2002).[6] Comprehensive EU datasets only became available relatively recently. Another major impediment for the emergence of more evidence on bank efficiency in Europe has been the fact that banking sectors within the EU differ. Altunbas and Chakravarty (1998) demonstrate this by showing that various EU member states host banking sectors of a different composition than others, and that different bank types offer services of a different nature and differ in terms of average efficiency. Thus, the approach in this study is to allow for a comparison between banks within the EU by treating bank types differently.[7]

Another contribution of this paper is that it is the first application of the new Recursive Thick Frontier Approach (RTFA) of Wagenvoort, O'Brien, and Schure (2001). RTFA is an econometric frontier approach to assessing technical efficiency that relies on an iterative procedure. Wagenvoort et al. (2001) show that RTFA is superior to the Stochastic Frontier Approach (SFA) for realistic features of the data. SFA is the approach taken in all the studies mentioned above. This paper hence provides an important robustness check for the evidence produces by the recent EU banking studies mentioned above.

The paper is organised as follows. The next section explains the methodology used in this study. We devote ample attention to explaining RTFA because it is a new approach. Section 3 describes the data, Section 4 discusses the results, and Section 5 concludes.

[6]Country studies in Europe have been available longer. Altunbas et al. (2001) devote a section of their paper to a survey.

[7]This approach is also explored by Vander Vennet (2002).

2 The methodology

2.1 The cost model and the estimation method

The study proceeds in two steps. In the first step we establish the so-called *cost frontier* and use it to assess the efficiency of the individual banks. The *cost frontier* represents the relationship between costs, output levels and input prices of the relatively efficient banks —the so-called *best-practice banks*— in the dataset.[8] We choose a parametric frontier specification and use the new Recursive Thick Frontier Approach (RTFA) of Wagenvoort et al. (2001) to estimate it. In the second step of our study we investigate to what extent efficient banks differ from inefficient ones.

Regarding the definition of the output variables in our study, we adopt the so-called *value-added approach* and view banking firms as *producers of services* such as screening projects, monitoring borrowers, enforcing contracts, portfolio selection, hedging risks, providing payment services, providing brokerage services, keeping deposits and other claims liquid, providing repayment insurance, etc. We assume the actual quantity of services produced by a bank can be proxied by relevant variables on the bank's balance sheet and the bank's profit and loss account. For example, deposits are an output, because deposits are a proxy for the bank's payment services among other things. We also defined loans to be an output because loans necessitate screening and monitoring activities.

Like the well-known Stochastic Frontier Approach (SFA) popularized by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977), we assume that deviations from the frontier can be caused by random error as well as X-inefficiency. Random error is included to represent measurement errors in the input or output variables, or factors which are beyond the control of the firm's management ('good luck' or 'bad luck'). In this

[8]The cost frontier is identical to the cost function in case these best-practice banks are actually technologically efficient.

study we estimate a (transformed) Cobb-Douglas cost frontier that has been augmented with dummies to allow for shifts over time and differences in the size of banks:

$$\frac{TC_{ti}}{TA_{ti}} = \gamma_0 \left(1 + \frac{y_{ti,1}}{TA_{ti}}\right)^{\beta_1} ... \left(1 + \frac{y_{ti,6}}{TA_{ti}}\right)^{\beta_6} p_{t1}^{\alpha_1} p_{t2}^{\alpha_2} p_{t3}^{\alpha_3} \sigma_1^{s_{1,ti}} ... \sigma_5^{s_{5,ti}} \delta_1^{t_1} ... \delta_4^{t_4} + \varepsilon_{ti},\ i \in E \quad (1)$$

In equation 1, E represents the set of best-practice banks in the dataset. TC_{ti} and TA_{ti} represent total costs and total assets (balance sheet total) of bank i in period t.[9] The equation incorporates six outputs and three inputs. Bank i's amount of output of type k in year t is denoted by $y_{ti,k}$, $k = 1, ..., 6$, and the price of input j in year t by p_{tj}, $j = 1, 2, 3$. In this study we have included five *size dummies*, $s_{1,ti}, ... s_{5,ti}$ to account for six size classes the banks can fall in, as well as four *time dummies* $t_1, ..., t_4$ as the dataset comprises $T = 5$ years. Finally, ε_{ti} is a random symmetrically distributed disturbance term.

Regarding the subset of inefficient banks in the dataset –i.e. the set of banks that are *not* on the cost frontier represented by equation 1– *no specific structure* is assumed. RTFA allows each individual inefficient bank to adopt any available technology and be inefficient to any possible degree (Wagenvoort et al., 2001). This freedom is a great advantage of RTFA when compared to SFA or similar methods.

We have estimated equation 1 in logs and under the standard restriction that the sum of the input price elasticities equals 1 ($\alpha_1 + \alpha_2 + \alpha_3 = 1$). Before estimating we detrended our input prices by regressing them on the time dummies. These three auxiliary regressions make sure that the interpretation of the coefficients of the time dummies correctly reflect the impact of structural changes. Schure and Wagenvoort (1999) discuss the novel auxiliary regressions in detail. They also show how to derive structural-form parameter estimates and their variances from the estimated reduced-form model. Time coefficients of many existing studies on panel data are biased because input prices reveal a clear time pattern as well.

[9] One of our six outputs, namely *commission revenue*, is scaled by the bank's total operating income, rather than total assets.

RTFA of Wagenvoort et al. (2001) is a relatively straightforward method based on recursive OLS estimation of subsets of the dataset. Because RTFA is a new approach to estimating technical efficiency, let us sketch the algorithm in the context of this study. Below, let j indicate the number of the iteration and let n_j be the number of banks that are left over in the sample during iteration j. In this application of RTFA let I_{ij} be an indicator function that takes on the value $I_{ij} = 1$ if four or five out of the five OLS residuals for bank i in iteration j have the same sign. Define $Z_j = \sum_{i=1}^{n_j} I_{ij}$.

The RTFA algorithm of Wagenvoort et al. (2001)

Step 1 (Initialization) Set $j = 0$ and $n_0 = N$, where N represents the number of banks in the dataset. Choose δ, i.e. the speed of the data reduction process. In this study we have set $\delta = 0.01$ which means that n_j is reduced by 1 percent in each iteration.

Step 2 (Estimation) Compute the OLS estimates for $(1 - j\delta) * 100$ percent of the data

Step 3 (Binomial test) Compute the test statistic $\lambda_j = \frac{(Z_j - 0.375 n_j)^2}{n_j 0.375(1-0.375)}$ and compare it with $\chi^2_{0.99}(1)$, the 99th percentile of the chi-squared distribution with one degree of freedom. If $\lambda_j < \chi^2_{0.99}(1)$ then stop the iterations and report the last OLS regression results as the output of the algorithm. Otherwise go to step 4.

Step 4 (Preparing for next iteration) Compute the mean m_{ij} of the five regression residuals of each bank i, including banks which were omitted in previous iterations. Set $j := j + 1$. Select the $n_j = (1 - \delta j)N$ banks that enter the next iteration by discarding the $\delta j N$ banks with the largest values of m_{ij}, $i = 1, ..., N$. Go to Step 2.

Step 3 of the algorithm needs explanation. First, notice that in general Z_j will be large in case the subsample still contains both efficient and inefficient banks (in this case relatively efficient banks tend to have 4 or 5 negative residuals, while inefficient banks tend to have 4 or 5 positive residuals). By contrast, in case only best practice banks are in the subsample, the five residuals of each bank tend to be scattered evenly around the frontier and there is a 50 percent chance a single residual falls on either side of the regression line. In this case theoretically there is a probability of $(0.5)^5 + 4(0.5)^5 + (0.5)^5 + 4(0.5)^5 = 0.375$ that each individual bank has either 4 or 5 positive residuals, or 4 or 5 negative residuals. Furthermore, these probabilities are independent, so that the number of banks with 4 or 5 residuals of the same sign follows a binomial distribution with success probability 0.375. It is a standard result that the binomial distribution approaches the normal, so λ_j is asymptotically $\chi^2(1)$–distributed.

X-efficiency measures the degree to which banks acquire and use their inputs in a efficient way. In this study we report *in*efficiency measures for each bank, rather than an efficiency measure. We measure the degree of X-inefficiency of a bank by its distance from the cost frontier. Define $\frac{\widehat{TC_{ti}}}{TA_{ti}}$ to be the costs over assets of bank i in year t if it were on the cost frontier, that is

$$\frac{\widehat{TC_{ti}}}{TA_{ti}} = \widehat{\gamma}_0 \left(1 + \frac{y_{ti,1}}{TA_{ti}}\right)^{\widehat{\beta}_1} \ldots \left(1 + \frac{y_{ti,6}}{TA_{ti}}\right)^{\widehat{\beta}_6} p_{t1}^{\widehat{\alpha}_1} p_{t2}^{\widehat{\alpha}_2} p_{t3}^{\widehat{\alpha}_3} \widehat{\sigma}_1^{s_{1,ti}} \ldots \widehat{\sigma}_5^{s_{5,ti}} \widehat{\delta}_1^{t_1} \ldots \widehat{\delta}_4^{t_4} \tag{2}$$

The degree of X-inefficiency of bank i in year t (T-ineff$_{ti}$) represents the mean percentage cost reduction the bank could have achieved without sacrificing any output:

$$\text{X-ineff}_{ti} = \frac{\frac{TC_{ti}}{TA_{ti}} - \frac{\widehat{TC_{ti}}}{TA_{ti}}}{\frac{TC_{ti}}{TA_{ti}}} \tag{3}$$

Size efficiency measures the degree to which banks can reduce costs per asset by choosing the right scale of their operations. Define $\sigma^{\min}$ to be the value of the size dummy of banks in the size class with minimum costs, i.e. $\sigma^{\min} = \min\{1, \widehat{\sigma}_1, ..., \widehat{\sigma}_5\}$. The *size-inefficiency* score of bank i in year t (S-ineff$_{ti}$) is defined as:[10]

$$\text{S-ineff}_{ti} = \frac{\widehat{\sigma}_1^{s_{1,ti}} \ldots \widehat{\sigma}_5^{s_{5,ti}} - \sigma^{\min}}{\widehat{\sigma}_1^{s_{1,ti}} \ldots \widehat{\sigma}_5^{s_{5,ti}}} \tag{4}$$

[10]That is, provided that $\widehat{\sigma}_1^{s_{1,ti}} \ldots \widehat{\sigma}_5^{s_{5,ti}} - \sigma^{\min}$ is statistically *significantly* different from zero. We have taken S-ineff$_{ti} = 0$ in case this was not the case.

In equation 1 the size dummies capture *(dis)economies of scale*, while the time dummies pick up *structural developments* in time, such as technological progress or the impact of deregulation.[11] We have introduced the dummies such that the dummy parameters $(\sigma_1, ..., \sigma_5, \delta_1, ..., \delta_4)$ all become one under the null hypothesis of no economies of scale and no structural changes such as technological progress. By contrast, if banks in size class j, say, have significantly lower (higher) costs than the banks in the reference class, the parameter estimate of the respective size dummy will be significantly smaller (larger) than unity. Likewise, an estimated time dummy that is significantly smaller (larger) than unity indicates that in that year costs have generally been lower (higher) than costs in the reference year 1993, for example due to technological progress.

In the second step of our study we exploit the fact that RTFA divides up the sample into an efficient subset of banks (i.e. subset E above) and an inefficient subset. We compute means of specific variables of interest in both subsets and test H_0: the means are identical versus H_1: the means differ. The test is performed with a standard pooled two sample t-test. This procedure is a relatively robust way to test for differences. It is worthwhile to stress, though, that RTFA also allows for analyses of the type introduced in Berger and Mester (1997).

2.2 Discussion

Bank outputs. By viewing services production as the business of banks we adopt what Berger and Humphrey (1992) call the *Value-Added Approach.* Viewing services as the bank's business is standard in the modern theoretical banking literature (see e.g. Bhattacharya and Thakor, 1993). In the value-added approach service production is proxied by relevant balance-sheet and profit and loss account data. The value-added approach hinges on the

[11]It remains to be proven whether the time dummies represent structural developments for the generated parameter estimates. The proofs for this for the present study are delivered in the theory appendix.

assumption that 1 Euro of output variable k implies the same quantity of service production as 1 Euro of output variable k held at another bank. Other methods such as the Intermediation Approach of Sealey and Lindley (1977) also suffer from the same drawback.

Some studies, notably Berger and Hannan (1989), Hannan and Berger (1991), and Neumark and Sharpe (1992), have tried to account for output quality differences by including bank profits in conjunction with the Herfindahl index (or another proxy for the bank's market power) in the regression. According to these studies higher profit indicates better-quality outputs. A market power index is included to control for the fact that higher concentration proxies more market power, thus also leads to higher profits (Bain, 1951). Recently, several studies have questioned the assumed link between market concentration and market power (e.g. Jackson (1992), Jackson (1997), Rhoades (1995), and Hannan (1997). These studies suggest that the approach only makes sense when correctly identifying the 'relevant banking market'. In reality the relevant banking market is typically small, especially for savings banks. Mester (1996) has taken another attempt to account for quality difference in bank assets. She has included the average volume of non-performing loans as a measure for the quality of the loan portfolio. In our study attempts to adopt either of the solutions above have failed due to data restrictions. First, no data were available that link banks to their respective banking market. In this case, including profitability leads to an endogeneity problem because cost efficiency and profitability are linked in principle.[12] Also, BankScope does not include data on nonperforming loans.[13]

Bank inputs. The choice of our inputs conforms to standard practice in the literature. However, we shall see below that our input prices are not based on the actual expenses incurred by each bank, but represent (proxies for) the *market prices* the banks face. While most studies define prices based on actual expenses, Mountain and Thomas (1999) and Berger and Mester (2001) argue that market prices should be used when available.

[12]Our savings banks results presented later show that cost efficient savings banks are more profitable than cost inefficient savings banks.

[13]However, a feasible idea used by e.g. Altunbas et al. (2001) would have been to include the amount of equity as an (imperfect) proxy of the bank's risk.

Cost model. Notice that our cost model is general. Different banking products can attribute differently to the costs of an efficient bank. In addition, the dummies allow the cost frontier to change over time and can change with the scale of the bank's operations. Possible changes over time would reflect structural changes, such as technological progress or the impact of changes in bank regulation. By allowing the frontier differ with the scale of a bank we allow for possible (dis)economies of scale.

The theory appendix shows that in our study the size dummies correctly reveal economies to scale. Introductory microeconomic textbooks show that the long-run cost curve must 'envelope' all short-run cost curves. The theory appendix to this paper derives how we can test whether our frontier has the enveloping property and also presents the test results. In this study there is very convincing evidence that the estimated frontier may indeed represent a long-run cost curve.

In equation 1 we have scaled total costs and the output variables by total assets. Scaling is necessary because our output variables are in nominal (Euro) terms, while a cost function requires outputs to be in real units. Thus, without scaling, our nominal output, proxies would not be comparable between different years in an environment with inflation. There is also an important econometric reason to scale. The amount wasted by inefficiency is typically thought of to be a *percentage* of the assets held by a particular inefficient bank. If so, and variables are not scaled, the disturbances are not orthogonal to the regressors in the cost model, so that the model parameters are not estimated consistently, unless we resort to instrumental variable estimation.[14]

[14]In case RTFA would be applied *without scaling* this would be problematic in all but the last iteration. We recommend scaling (or another solution to the problem outlined here) for other efficiency studies adopting an econometric frontier methodology as well.

We have also transformed our output variables by adding 1 to every scaled output. Transforming outputs is one solution to the problem encountered in many efficiency studies that some outputs values are zero or very small. Taking logs would then be infeasible or produce extremely large negative values.[15] Our variable transformation results in a shift to an interval where the log function curves less steeply. While this solution resolves the problem sketched above it should be noted that the estimated coefficients of the output variables can no longer be interpreted as elasticities.

The Cobb-Douglas specification implies a stronger restriction on the set of technologies than can be borne out by the data with respect to the other two specifications, and is perhaps therefore not used in other recent bank efficiency studies.[16] Most efficiency studies choose the translog cost frontier specification (that is, a second-order Taylor approximation in logs of a general cost function)[17] or the fourier flexible form (FF) specification that is said to provide a better global approximation of the cost function.[18] We have tried the translog cost function specification in our study as well, but it led to a slightly lower adjusted R^2 value. In addition, regression results of the translog specification are far more difficult to interpret because the specification implies a serious degree of multicollinearity.[19] Multicollinearity and interpretability is an even more severe problem for the FF specification since by construction it contains more variables than the translog specification. Altunbas

[15] Lang and Welzel (1996) and Al-Obaidan (1999) make explicit mention of this problem.

[16] However, the Cobb-Douglas specification has been applied in 'older' studies including Cooper (1980) and Fanjul and Maravall (1985)

[17] Examples include Berger (1995), Berger and Hannan (1998), Goldberg and Ray (1996), Lang and Welzel (1996), Hughes and Mester (1998), Maudos (1998), Mester (1996), Rogers (1998), and Vander Vennet (1996).

[18] Examples are McAllister and McManus (1993), DeYoung and Hasan (1998), and Altunbas et al. (2001).

[19] As an example, using the translog cost function we obtained one significantly negative price coefficient and two which exceeded one. Another reason to favour the augmented Cobb-Douglas specification in this study was that during the sample period input prices happened to change gradually. It is therefore nontrivial to distinguish the effect of price developments on costs from time-related effects such as technological progress. We found an appealing solution for this problem, but one which is not suitable for the translog or the flexible fourier transform specifications (see Schure and Wagenvoort, 1999).

and Chakravarty (2001) present an even more severe objection to using the FF specification in a recent article. They demonstrate that the FF specification leads to bad predictions of the cost base of banks not represented in the dataset when compared to the translog specification.

The Estimation Method (RTFA). RTFA is an econometric frontier approach that is used on panel data. A major advantage of RTFA when compared to econometric approaches that can be applied to cross-section data, such as SFA of Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977), the GMM method of Kopp and Mullahy (1990), and the Thick Frontier Approach (TFA) of Berger and Humphrey (1992), is that no specific distributional assumptions are made regarding the inefficiency term.[20] The only assumption that is made is that there exists a subgroup with a critical number of firms that are on the frontier *in each time period* (Wagenvoort et al., 2001).

RTFA also has advantages over econometric panel data methods such as Distribution Free Approach (DFA) of Berger (1993) and the Stochastic Varying Coefficients Frontier Approach (SVFA) of Kalirajan and Obwona (1994). DFA, i.e. the *within* estimator in a panel data model with fixed effects, assumes that the inefficiency of an individual firm stays constant over time. This assumption is problematic in an environment in which some firms become more or less efficient. A drawback of SVFA is that the data panel must cover a relatively large number of time-periods and/or relatively many restrictions on the response coefficients have to be made.

Wagenvoort et al. (2001) assess the properties of RTFA by means of a simulation study. They conclude that RTFA performs well in several simulation experiments which "describe production data more realistically than the SFA model". They show that SFA turns out to be highly sensitive to dynamics in production behaviour. If some firms become more or

[20] Note, however, that Kopp and Mullahy (1990)'s assumptions are testable, and less restrictive than for instance the SFA assumptions.

Table 1: The savings and commercial banks in our dataset. (Source: Bankscope)

Country	Savings banks	assets 1997 (in billions ECU)	Commercial banks	assets 1997 (in billion ECU)	Total # banks
Austria	22	88.1	16	150.8	38
Belgium	17	181.6	37	492.0	54
Denmark	27	6.2	44	74.4	71
Finland	1	1.9	5	90.1	6
France	82	1099.6	237	2019.8	319
Germany	968	1393.3	178	2850.7	1146
Greece	0	0	14	81.6	14
Ireland	0	0	5	109.7	5
Italy	161	422.2	64	1256.8	225
Luxembourg	3	26.1	88	310.2	91
Netherlands	1	193.6	27	641.9	28
Portugal	2	45.9	18	174.9	20
Spain	60	337.8	75	967.7	135
Sweden	0	0	4	231.2	4
United Kingdom	3	36.6	61	1737.1	64
EU-15	1347	3832.9	873	11188.9	2220

less efficient over time then SFA turns out to considerably biased in the estimation of productive efficiency of best practice firms. By contrast, RTFA finds the relevant production parameters as well as the set of efficient banks in a robust way.

3 The data

We have constructed our bank datasets from the 'BankScope' dataset of Bureau van Dijk. BankScope contains bank data from annual reports and rating agencies. To construct our price data we have drawn from the 1998 edition of 'Bank Profitability' of the OECD, the International Financial Statistics of the IMF, Datastream International, and the CRONOS data set of Eurostat.

We use annual balance-sheet and profit-and-loss data for BankScope's 'savings banks' and 'commercial banks' for the period 1993-1997. Notice that the start of the sample period coincides with the year the EU's Second Banking Directive (1989) came into force. The

Table 2: Desciptive statistics of the variables of the cost model: savings and commercial banks in 1997 (EU minus Luxembourg) (all scaled outputs in percentages).

	Mean	Median	St. Dev.	Min	Max
Savings banks:					
Total costs/total assets	6.62	6.44	1.03	3.79	15.41
Total deposists/total assets	83.61	87.36	11.49	7.45	97.65
Total loans/total assets	58.25	61.15	13.63	0.85	95.78
Equity investments/total assets	1.30	0.67	1.97	0.00	23.27
Off-balance sheet items/total assets	10.84	7.94	11.68	0.00	193.58
Commission revenues/total income	6.29	7.19	4.03	0.00	38.12
Commercial banks:					
Total costs/total assets	8.04	7.17	4.62	3.03	79.12
Total deposists/total assets	74.76	81.02	18.32	0.71	97.31
Total loans/total assets	48.47	49.97	23.75	0.00	98.34
Equity investments/total assets	1.91	0.52	5.16	0.00	82.08
Off-balance sheet items/total assets	25.24	15.61	32.44	0.00	256.04
Commission revenues/total income	8.93	3.91	13.53	0.00	98.98
Price data:					
Price of funds (percentages)	1.93	1.31	1.30	0.46	5.12
Price of labour (thousands of ECU)	50	54	11	33	65
Price of buildings (Germany 1995 = 100)	94	94	15	67	127

data appendix gives a detailed summary of the selection criteria we applied when retrieving our bank samples from BankScope, as well as several measures we adopted to clean the data. Table 1 displays the banks in our datasets, and breaks them up according to their home country. The set of savings banks comprises 1347 banks, notably from Germany, Italy, France and Spain. There are 873 commercial banks and each EU member hosts at least a few of them.

We define the explanatory variable *total costs* of each bank as the sum of the BankScope variables 'interest expense', 'total operating expense' and 'commission expense'. We identify six output variables: Total Deposits, Total Loans, Equity Investments, Off-balance-sheet Items, Commission Revenue, and Total Securities.[21] *Total Deposits* comprise de-

[21] While six outputs is more than the number most other efficiency studies use, we would have loved to break up deposits into finer parts, e.g. customer deposits and interbank deposits. Unfortunately, the data for German banks does not allow this.

mand, savings and time deposits. *Total Loans* corresponds to BankScope variables 'total loans' plus 'total other lending'. *Equity investments* are obtained by adding up 'equity investments' and 'other investments'. Equity Investments includes participations in companies with related business, and shares in non-financial affiliates (not shares held as part of the security portfolio). Thus, Equity Investments may imply costly activities such as screening and actively monitoring firms. *Off-balance-sheet Items* is as defined in BankScope and contains contingent liabilities arising from guarantees, irrevocable letters of credit, irrevocable facilities, discounted bills, etc. (derivatives are not included). Just like loans, Off-balance-sheet Items force the bank to screen and monitor projects. *Commission Revenue* is also as defined in BankScope. Contrary to the other output variables, Commission Revenue is a flow variable that is taken from the bank's profit-and-loss account. Finally, *Total Securities* is obtained by subtracting 'deposits with banks' and 'investments' from 'total other earning assets'. Table 2 contains some relevant descriptive statistics regarding the output variables.

We define three input prices, namely the *price of funds*, the *price of labour* and the *price of buildings*. The *price of funds* is obtained by taking a weighted average of the real deposit rate and the real 3-month interbank rate.[22] The *price of labour* represents the average wage rate in the banking sector in each country, and the *price of buildings* is created by taking an appropriate price index for newly delivered buildings and correcting it for the relative price levels in each country. The data appendix contains three tables with the price data, as well as a detailed description of how the tables were generated. Table 2 contains some descriptive statistics on the price data.

Let us have a quick look at the cost side of the data. Figure 1 and Figure 2 show the decomposition of total costs in 1993 and 1997 of the banking sectors of each EU member

[22]The weights differ for each bank. In particular, the weight of the real deposit rate equals the bank's deposit funding over the bank's total funding (total assets).

Figure 1: Decomposition of total costs of banking in the EU-15 in 1993. Individual banks are weighted by their total amount of assets.

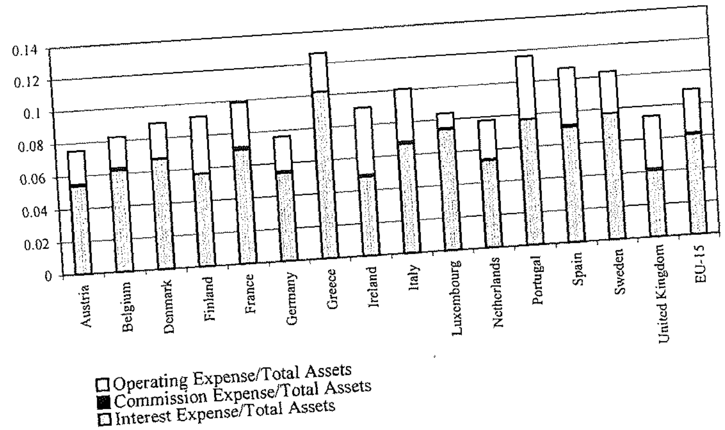
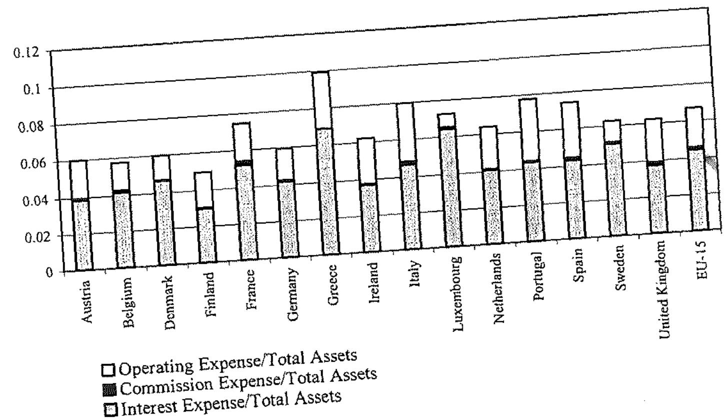


Figure 2: Decomposition of total costs of banking in the EU-15 in 1997. Individual banks are weighted by their total amount of assets.



state and the corresponding EU-15 averages. The tables reveal that costs per unit of assets differ considerably within the EU. There are also differences in the composition of costs between banks of different EU member states. Looking at changes over time, we see that, on average, the ratio of total cost over total assets dropped from almost 9 percent in 1993 to less than 7 percent in 1997. Possible candidates for the reason why costs have gone down are: (1) a less costly output mix, (2) structural changes, such as, for example, technological progress, or (3) cheaper inputs. O'Brien and Wagenvoort (2000) show that input price reductions, particularly an interest rate reduction, can only partially explain the cost reduction that took place over time. This indicates our study will likely find cost reductions resulting from a shift to lower-value-added outputs, or because of structural factors

4 The Results

4.1 Savings banks

RTFA yields that 317 of the total 1344 savings banks in the starting sample are on the estimated frontier. With an adjusted R^2 of 69 percent our model explains the variation in total costs over total assets of efficient banks very satisfactorily.

Before discussing the results let us first have a more careful look at whether RTFA has been applied in a reliable way. Table 3 gives a breakdown by country of the savings banks in the initial sample and on the frontier. With 968 banks in the initial sample and 286 on the frontier, German savings banks clearly dominate estimation. However, we have no indication that German domination is harmful because some other countries have similar percentages of their banks on the frontier as Germany. France has 17 banks on the frontier (20.7 percent of the 82 French banks in the starting sample), Austria 8 (36.4 percent),

Table 3: Savings banks. Breakdown of the number of banks, and the number of efficient banks by country.

Country	Number of banks used for frontier estimation	Efficient set of banks	Percentage selected
Austria	22	8	36.4
Belgium	17	4	23.5
Denmark	27	1	3.7
Finland	1	0	0
France	82	17	20.7
Germany	968	286	29.5
Greece	0	0	–
Ireland	0	0	–
Italy	161	0	0
Netherlands	1	0	0
Portugal	2	0	0
Spain	60	0	0
Sweden	0	0	–
United Kingdom	3	1	33.3
EU-15	1344	317	23.6

and Belgium 4 (23.5 percent). Italy and Spain host relatively many savings banks, but do not have a single efficient one, while Denmark has merely one efficient savings bank. The remaining countries hardly host savings banks.

Table 4 breaks down the savings banks on the frontier by size. Again, while in principle small banks could have dominated the regression there is no evidence of any harm done. To the contrary, savings banks that control more than 10 billion ECU in assets are more often found to be X-efficient. Observe that only six observations fall in the largest size class. Although the size dummy associated with the largest size class is not significantly different from one, six observations are too few to judge that the biggest size class can be combined with the reference class.[23]

Figure 3 presents histograms of the estimated X-efficiencies of the efficient as well as inefficient observations. The figure is based on 1344 banks × 5 years = 6720 observations.

[23] In fact, we introduced the size dummy for the biggest size class in the savings banks regression merely for reasons of symmetry with the commercial banks regression.

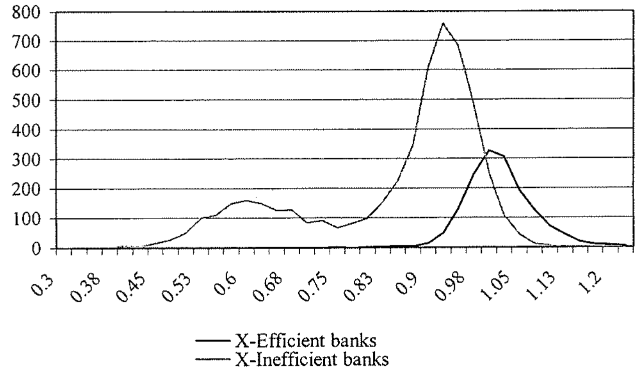
Table 4: Savings banks. Breakdown of the observations in the starting sample, and on the frontier by size. (# observations = 1344 savings banks × 5 years = 6720)

Size class (in billions of ECU)	Observations used for frontier estimation	Efficient set of observations	Percentage selected
Total Assets ≤ 2.5	5677	1343	23.6
2.5<Total Assets ≤ 5	603	130	21.6
5<Total Assets ≤ 7.5	158	41	25.9
7.5<Total Assets ≤ 10	77	15	19.5
10<Total Assets ≤ 100	184	50	27.2
Total Assets>100	21	6	28.6
Total number of observations	6720	1585	23.6
Total number of savings banks	1344	317	23.6

Recall that RTFA ensures that efficient banks cannot structurally lie above or under the frontier. Also, recall that inefficient banks may have years in which they perform very well so that observations of inefficient banks may achieve a high efficiency score in a given year. Importantly, the figure shows that X-efficiencies of efficient observations appear approximately symmetrically distributed. This suggests that efficient European savings banks constitute a relatively homogenous group. The histogram of the X-efficiencies of the inefficient observations seems to be bimodal. Bimodality in the data would suggest that typical econometric frontier methods such as SFA should not be used, theoretically speaking. By contrast, RTFA should have worked well since RTFA does not really make assumptions on the distribution of inefficient observations.

We have investigated whether the X-efficiencies of inefficient banks develop over time but did not discover any trend. We have also computed that the mean X-efficiency of efficient banks is equal to 1.008 with a standard deviation of 0.065. Thus, under normality, a 95% confidence interval for the X-efficiencies of efficient banks is (0.880,1.135). By contrast, inefficient banks turn out to have a mean X-efficiency of 0.833 and a standard deviation of 0.148. Here the normality assumption would imply a 95% confidence interval of (0.542,1.124). Again, however, the normality assumption in case of the inefficient banks

Figure 3: Histogram of the X-efficiencies of the X-efficient and X-inefficient savings banks (pooled observations)



seems inappropriate, and, evidently, the confidence interval will have an overestimated lower bound and an underestimated upper bound. Finally, we have established from the X-efficiency data that the mean value of the X-efficiencies of efficient banks and inefficient banks are significantly different at the 95 percent confidence level.

Table 5 presents the weighted averages of the X-inefficiencies per year for countries that have more than 10 savings banks in our dataset. To compute the percentages both efficient and inefficient banks were included, and each bank was weighted by its balance-sheet total. Weighting banks has the advantage of creating an overall impression of the savings bank sector in a given country, but it may also lead to jumps in efficiency levels in some years because a big bank may experience a good year or a bad year. The evidence suggests that the EU savings banking sector can cut costs by about 15-20 percent at the current level of production. The new EU banking laws that came into force in 1993 seem not to have had any positive impact in terms of reducing X-inefficiency of savings banks. Savings banks in

Table 5: Savings banks. Weighted average of X-inefficiencies per country per year. (Banks are weighted by their total assets)

Country	1993	1994	1995	1996	1997
Austria	11	9	15	3	6
Belgium	8	2	2	1	-1
Denmark	37	19	28	16	11
France	18	14	24	15	21
Germany	6	6	4	4	5
Italy	34	32	49	43	35
Spain	44	41	46	46	44
EU-15	18	15	20	17	18

Table 6: Weighted average X-inefficiencies of small and large savings banks. Small bank: bank has total assets amount of less than 10 billions of ECU in one or more years (large bank: more).

Country	1993	1994	1995	1996	1997
Small (n=48)	16	15	19	18	15
Large (n=1312)	21	17	21	16	19

Belgium and Germany, and to a lesser extent, Austria, are performing consistently well in terms of managerial efficiency. The savings bank sectors in Spain and Italy appear to be lagging well behind their European counterparts with X-inefficiency levels that well exceed 30 percent. The savings bank sector in Denmark and France are moderately inefficient in the sample period, however Denmark shows clear improvement over time.

Table 6 contrasts the inefficiency level of small and large savings banks. The evidence tentatively suggests that large savings banks are slightly more X-inefficient than small savings banks. This could for instance suggest it is a bit easier to manage a small savings institution.

Now let us take a closer look at the cost structure of the efficient European savings banks. Table 7 reports the relevant RTFA regression results. The table shows that scaled costs are positively related to the amount of deposits taken, the amount of loans granted, strategic equity positions (equity investments), and commission revenue (all scaled). These

Table 7: Savings banks RTFA regression results. (TA = Total Assets, TOI = Total Operating Income.)

Regressor	Estimate	t-value
Constant	0.00072	15.63*
Total Deposits/TA	0.55593	11.24*
Total Loans/TA	0.65342	28.17*
Equity Investments/TA	0.36644	7.02*
Off-balance-sheet Items/TA	-0.05443	-2.75*
Commission Revenue/TOI	1.48085	28.40*
Total Securities/TA	0.00991	0.43
Price of funds	0.00490	1.02
Price of labour	0.94291	27.56*
Price of buildings	0.05219	1.60
Dummy TA=2.5	1.04775	4.54*
Dummy 2.5<TA=5	1.05181	4.95*
Dummy 5<TA=7.5	1.06216	4.95*
Dummy 10<TA=100	1.04152	2.46*
Dummy TA>100	1.02237	0.96
Dummy 1997	0.68143	-5.72*
Dummy 1996	0.73083	-4.50*
Dummy 1995	0.79297	-3.18*
Dummy 1994	0.91132	-1.19
Adjusted R^2	0.69	
# banks on the cost frontier	317	
# banks under the frontier with zero weight	45	

* Significant at the 95% confidence level.

results exactly match our priors as these balance-sheet items are proxies for costly activities such as, for example, deposit services, originating and enforcing loans contracts, monitoring firms, and offering a variety of other services to firms. There is no clear relationship between costs and the bank's position in marketable securities. Again, this is not a surprising result because securities do not involve neither high transactions costs, nor great effort to acquire the necessary information. The only result that perhaps appears strange is the negative sign of the variable Off-balance-sheet Items. We conjecture that this result relates to the fact that the source of Off-balance-sheet Items involves several fee-based activities, so that the positive effect on costs has already been picked up by the variable Commission Revenue.

Regarding the influence of the *input prices*, the most remarkable result is the very low coefficient of the price of funds (about 0.005). O'Brien and Wagenvoort (2000) discuss this eyebrow-raising result at length. They find, first, that the relationship between the input prices and costs is unstable for different model specifications (see also Schure and Wagenvoort, 1999). This suggests that there are high correlations between the input prices. For the price of buildings and the costs of labour a high correlation may not be surprising. As for the price of funds, the data appendix shows that in the period 1993-1997 most countries experienced a steadily decreasing price of funds.[24] Needless to say, such a steady decline means high correlation to prices that are subject to steady inflationary pressure such as the price of labour and the price of buildings. O'Brien and Wagenvoort (2000) also find that, while the link between costs and the price of funds seems absent for efficient banks, there is a clear positive relationship for inefficient banks. This suggests that efficient banks use less working capital than inefficient banks, or that efficient banks hedge their interest exposure while inefficient banks do not. Based on the discussion above we place little value on the reliability of coefficients of the individual prices of funds.

The size dummies of our cost model reveal possible long-term economies of scale.[25] The evidence shows that economies of scale are exhausted for savings banks with total assets of more than 10 billion ECU. The evidence even tentatively suggests that a European savings bank has an optimum size between 7.5 and 10 billion ECU in assets. Assuming constant returns-to-scale for banks with more than 10 billion ECU in assets, we have computed that the EU savings bank sector can reduce costs by around 3 percent when small savings banks

[24]For 12 countries in our sample this was most likely affected by convergence related to the introduction of the single currency in January 1999.

[25]In the theory appendix the short-run economies of scale are derived for the purpose of verifying whether the RTFA parameter estimates actually constitute a well-defined cost function. In accordance with neoclassical theory, we find evidence of short-run decreasing returns to scale for banks in each size class.

Table 8: Comparing efficient and inefficient savings banks: The mean return on equity, the mean (scaled) cost level, and the mean (scaled) output levels. (standard deviations given in brackets) (TA = Total Assets, TOI = Total Operating Income.)

	Efficient banks		Inefficient banks		t-value[a]
Mean Return on Equity	8.05	(2.81)	6.56	(3.29)	29.02*
Total Costs/TA	0.0644	(0.0076)	0.0770	(0.0140)	-34.1*
Total Deposits/TA	0.8809	(0.0573)	0.8289	(0.1206)	16.6*
Total Loans /TA	0.5867	(0.1438)	0.5647	(0.1388)	5.5*
Equity Investments/TA	0.0143	(0.0321)	0.0137	(0.0246)	0.8
Off-balance Sheet/TA	0.0856	(0.1156)	0.0957	(0.0889)	-3.7*
Commission Revenue /TOI	0.0737	(0.0350)	0.0565	(0.0390)	15.8*
Total Securities/TA	0.2170	(0.0963)	0.2363	(0.1142)	-6.1*

[a]t-statistic for pooled two sample t-test.

*Significantly different at the 95% confidence level.

consolidate to take on the optimum size.[26]

The final piece of evidence in Table 7 regards the impact of *structural changes* over the time period. The time dummies reveal strong and significant shifts in the cost frontier. Managerially efficient savings banks were able to reduce cost over assets by on average 6.4 percent per year, after taking into account input price changes and variations in the output mix. O'Brien and Wagenvoort (2000) analyse this finding carefully and find that the percentage should be seen as an upper bound for the effect of structural changes. While they also attain significant positive (cost reducing) effects using different model specifications they tentatively suggest the order of magnitude of the cost reduction from structural changes for efficient savings banks is closer to 4.5 percent annually. The forces at work explaining the finding could be the impact of increased competition following the implementation of the Second Banking Directive in 1993, technological progress, or both.

An interesting question left open in many studies on bank efficiency is: In what way efficient banks are managed differently from inefficient banks? Are efficient banks involved

[26]As for the individual member states, Austria can realize 2.92 percent efficiency gains from consolidation of small savings banks, Denmark 4.78 percent, France 1.18 percent, Germany 3.10 percent, Italy 3.16 percent, and Spain 2.58 percent.

in different services? Are they exploiting economies of scope that the frontier leaves unveiled? Our final pieces of evidence should be seen as a first attempt to find the answers to these questions. In Table 8 we first investigate whether efficient savings banks are more profitable than their inefficient counterparts. We observe a significant relationship between profitability and efficiency for the European savings bank sector between 1993 and 1997. Efficient savings banks have a mean return on (average) equity is that is about one-and-a-half percent higher (namely about 8 percent) than the group of inefficient banks (6.5 percent). The evidence weakly supports the *efficient-structure hypothesis*, i.e. we observe that "firms with superior management or production technologies have lower cost and therefore higher profits" (Berger, 1995). Second, and unsurprisingly, we also find that scaled total costs are lower for efficient savings banks than for inefficient savings banks. Table 8 also shows that there are significant differences between the output mix for the efficient and the inefficient savings banks. We find that the means of scaled total deposits, total loans, off-balance-sheet items, commission revenue and total securities are all significantly different for efficient and inefficient banks. The most noticeable differences are that efficient savings banks offer more deposits than inefficient banks, and derive more operating income in the form of commissions.

4.2 Commercial banks

The evidence on the European commercial banks presented below suggests that the group of commercial banks is much more diverse than our sample of savings banks. This is true despite of our extensive efforts to clean the data. It may be that a one-size-fits-all frontier for commercial banks is simply not appropriate because perhaps subgroups of commercial banks are of an entirely different nature, and therefore employ different technologies. With this in mind we next present the evidence and our conclusions.

Table 9: Commercial banks. Breakdown of the number of banks, and the number of efficient banks by country.

Country	Number of banks used for frontier estimation	Efficient set of banks	Percentage selected
Austria	16	10	62.5
Belgium	35	17	48.6
Denmark	44	15	34.1
Finland	5	1	20.0
France	229	47	20.5
Germany	172	90	52.3
Greece	14	0	0
Ireland	5	1	20.0
Italy	63	1	1.6
Netherlands	25	11	44.0
Portugal	18	0	0
Spain	72	0	0
Sweden	4	0	0
United Kingdom	58	7	12.1
EU-15	846	200	23.6

RTFA yields that 200 commercial banks of the total of 846 in the starting sample are on the estimated frontier. The adjusted R^2-value for the regression is 43 percent. Our cost model is indeed less well designed to explain the commercial bank sector than the savings bank sector (adjusted R^2-value of 69 percent).

We have attempted to look into ownership data in order to establish what percentage of the efficient commercial banks are foreign-owned subsidiaries. Unfortunately, in some cases BankScope does report the identity of the owners or major shareholders of a specific bank. Some banks have indicated that they wish to keep information on the ownership of the bank confidential. There are also many instances in which the banks in our database ceased to exist, mainly because of mergers and takeovers. We found, however, that many efficient commercial banks have non-European, particularly Japanese, owners. Foreign-owned subsidiaries possibly rely in an important way on the support of their parent organisation. It may also be that, generally speaking, the nature of financial services supplied by foreign-

Table 10: Commercial banks. Breakdown of the observations in the starting sample, and on the frontier by size. (# observations = 846 commercial banks × 5 years = 4230)

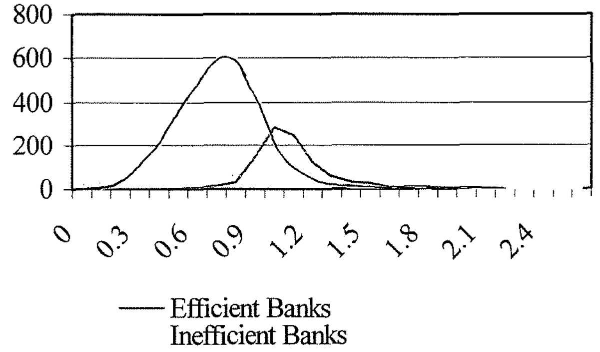
Size class (in billions of ECU)	Observations used for frontier estimation	Efficient set of observations	Percentage selected
Total Assets≤2.5	2878	744	25.9
2.5<Total Assets≤5	433	78	18.0
5<Total Assets≤7.5	231	37	16.0
7.5<Total Assets≤10	113	14	12.4
10<Total Assets≤100	452	79	17.5
Total Assets>100	123	48	39.0
Total number of observations	4230	1000	23.6
Total number of commercial banks	846	200	23.6

owned subsidiaries in Europe is different from the services offered by the home institutions. If this is indeed the case, the technology of foreign-owned subsidiaries in Europe is simply different from the technology of credit institutions from the home country.

Table 9 presents a summary of the numbers of banks in each country in our starting sample and in the set of efficient banks. Incidentally, the percentage of EU-banks on the frontier is 23.6, the same percentage as observed for savings banks. Observe that relatively large proportions (proportions greater than 40 percent) of Austrian, Belgian, German and Dutch banks lie on the cost frontier. In absolute numbers, German and French banks feature prominently on the frontier. In Table 10 we observe that each size class contains a sufficiently large number of efficient banks for reliable statistical inference. Like in the savings banks sample, we find that the largest credit institutions are most often efficiently run.

The distributions of the X-efficiencies for the efficient and inefficient commercial banks presented in Figure 4 can be shown to have fatter tails than the normal distribution suggests. The X-efficiencies for the efficient banks vary excessively with a mean X-efficiency of about 1.04 and a standard deviation of 0.212. A 95% confidence interval for the X-efficiencies is (0.624,1.455) under normality. Given fat tails, the bounds of this interval

Figure 4: Histogram of the X-efficiencies of the X-efficient and X-inefficient commercial banks (pooled observations)



seem to be under-estimated. X-efficiencies for the inefficient companies are this time close to the normal distribution. The inefficient banks have a mean X-efficiency of approximately 0.671 and a standard deviation of 0.248. A 95% confidence interval for X-efficiencies of inefficient banks is (0.185,1.157) if we are willing to assume normality. Note that the bounds of this interval lie far apart.

Table 11 contains weighted averages of the X-inefficiency levels of the commercial banks in our dataset. Clearly, we cannot derive too many conclusions from these results given the problems with the sample of commercial banks.[27]. Nevertheless, it seems safe to conclude that the average level of X-inefficiency of EU commercial banks is about 20-25%. Also, with inefficiencies exceeding 65, 30, 60, and 45 percent, respectively, on average Greek,

[27] In addition to the problems mentioned above, comparisons of commercial banking sectors across countries is not straightforward. For example, some countries have many foreign-owned subsidiaries, while other countries do not. It turns out, for instance, that almost all efficient Italian commercial banks are Italian owned, whereas just over a half of the efficient UK commercial banks are British owned.

Table 11: Commercial banks. Weighted average of X-inefficiencies per country per year. (Banks are weighted by their total assets)

Country	1993	1994	1995	1996	1997
Austria	8	16	9	10	10
Belgium	9	10	10	10	6
Denmark	19	11	9	-8	-19
Finland	35	35	25	24	19
France	18	23	26	23	27
Germany	2	11	5	8	8
Greece	72	77	72	71	68
Ireland	37	39	41	42	23
Italy	32	38	49	44	39
Luxembourg	23	18	25	24	30
Netherlands	18	21	18	14	9
Portugal	67	69	67	64	60
Spain	49	50	55	55	54
Sweden	27	32	29	14	1
United Kingdom	9	15	23	27	9
EU-15	18	24	25	25	22

Table 12: Weighted average X-inefficiencies of small and large commercial banks. Small bank: bank has total assets amount of less than 10 billions of ECU in one or more years (large bank: more).

Country	1993	1994	1995	1996	1997
Small (n=131)	29	31	34	33	30
Large (n=846)	18	23	24	24	20

Italian, Portuguese and Spanish commercial banks lag far behind commercial banks in the rest of the European Union in terms of cost efficiency. Notice also that the three Nordic countries seem have improved over time.

Table 12 splits up the sample into small banks and large banks. We clearly observe that large commercial banks are on average more efficient than their smaller peers. This may indicate that large commercial banks compete in larger and more competitive banking markets than small commercial banks. Another possibility is that large commercial banks who are more often publicly listed have shareholder that more actively monitor the bank managers. We also see in the table that neither small nor large commercial banks have

Table 13: Comparing efficient and inefficient commercial banks: mean return on equity, mean (scaled) cost level, and mean (scaled) output levels. (standard deviations given in brackets) (TA = Total Assets, TOI = Total Operating Income.)

	Efficient banks		Inefficient banks		t-value[a]
Mean Return on Equity	7.15	(5.54)	7.12	(7.69)	0.26
Total Costs/TA	0.0640	(0.0163)	0.0967	(0.0436)	-23.23*
Total Deposits/TA	0.7668	(0.1931)	0.7599	(0.1722)	1.07
Total Loans/TA	0.4688	(0.2374)	0.4421	(0.2435)	3.05*
Equity Investments/TA	0.0150	(0.0407)	0.0176	(0.0457)	-1.59
Off-balance Sheet/TA	0.2759	(0.3799)	0.2073	(0.2616)	6.45*
Commission Revenue /TOI	0.0887	(0.0997)	0.0671	(0.1210)	5.12*
Total Securities/TA	0.1951	(0.1843)	0.1579	(0.1577)	6.25*

[a]t-statistic for pooled two sample t-test.

*Significantly different at the 95% confidence level.

improved X-efficiency over time. This tentatively suggests that the new EU banking laws that came into effect in January 1993 have not increased competition in EU commercial banking in the five years to follow.

We examined the means and standard deviations for the X-efficiencies of inefficient commercial banks in each year. Inefficient commercial banks seem not to catch up with efficient commercial banks. In fact, the gap between the efficient and inefficient banks increases slightly with efficiency scores of inefficient banks lowering from 0.71 in 1993 to 0.68 in 1997.

Table 14 reports the details on the efficient frontier. Recall that the results should thus be interpreted with great care and that the 200 best-practice may form a diverse group of institutions (containing, for instance, foreign-owned commercial banks and EU based commercial banks; and 'true' commercial banks and investment banks in disguise). Having said this, most results do confirm common wisdom about banks.

There are significant positive relationships between (scaled) costs and Total Loans, Equity Investments, Off-balance-sheet Items, Commission Revenue and Total Securities (all scaled). One difference with the savings banks results is that there is no significant relationship between (scaled) costs and (scaled) deposits. Another difference is that Total Securities is a relevant variable for commercial banks. The last observation could be an artifact of the regression, but it could also suggest that some commercial banks earn money by underwriting securities. In this case securities involve investment banking activities and therefore raise the cost base of the bank. The impact of Commission Revenue on costs is lower for commercial banks than for savings banks, yet Off-balance-sheet Items have more impact. This may indicate again that there is an intimate relationship between these variables.

Turning to the input prices, again we observe the low coefficient of the price of funds. The impact of the price of labour is lower in this regression than in the last, while the impact of the price of buildings is now higher. We reiterate that we place little value on the reliability of the coefficients of the individual input prices.

We find evidence to suggest that there may be increasing returns to scale up to balance-sheet totals of 5 billion ECU, followed by constant returns to scale up to total assets size of 100 billion ECU. We find that there may be significant decreasing returns to scale for banks larger than 100 billion ECU. In light of the discussion regarding the validity of the regression results and the diversity of commercial banks, we refrain from predicting what cost savings could be attained in the EU commercial banking sector.

Finally, the time dummies in Table 14 indicate that commercial banks have attained cost reductions in 1993-1997 of the same magnitude as the group of savings banks. Again, this leads us to suggest that increased competitive forces after the introduction of the Second Banking Directive or the employment of new technologies has played a substantial role.

In our final analysis we assess whether there are significant differences in the profitability and the output mix of efficient and inefficient commercial banks. Interestingly,

Table 14: Commercial banks RTFA regression results. (TA = Total Assets, TOI = Total Operating Income.)

Regressor	Estimate	t-value
Constant	0.0008	14.82*
Total Deposits/TA	-0.0765	-1.64
Total Loans/TA	0.7085	17.74*
Equity Investments/TA	0.5239	3.13*
Off-balance-sheet Items/TA	0.1470	5.76*
Commission Revenue/TOI	0.5332	7.86*
Total Securities/TA	0.1857	3.95*
Price of funds	0.0088	0.93
Price of labour	0.5512	11.80*
Price of buildings	0.4400	10.02*
Dummy TA=2.5	1.1331	5.87*
Dummy 2.5<TA=5	1.0757	2.68*
Dummy 5<TA=7.5	1.0164	0.50
Dummy 10<TA=100	0.9283	-1.61
Dummy TA>100	1.0673	2.11*
Dummy 1997	0.6418	-7.15*
Dummy 1996	0.6839	-5.94*
Dummy 1995	0.7730	-3.80*
Dummy 1994	0.8125	-2.98*
Adjusted R^2	0.43	
# banks on the cost frontier	200	
# banks under the frontier with zero weight	38	

* Significant at the 95% confidence level.

and in contrast with the savings banks results, the evidence presented in Table 14 does not support the efficient-structure hypothesis. Average return on equity was, on average, similar for efficient and inefficient credit institutions. It appears that the return-on-equity of savings banks is primarily driven by cost considerations, while the profitability of commercial banks must be affected by different factors as well. Further research is required to explain this result. Note, however, that savings banks are usually smaller than commercial banks. Perhaps they have less power to set prices than commercial banks. On the other hand, smaller savings banks typically operate only in regions within countries so may have considerable market power in their relevant banking market.

The table also highlights that our regression technique RTFA, even for this diverse group of commercial banks, was successful in classifying the sample into low-cost and high-cost banks. Average cost for X-efficient banks equaled 6.4 percent of the balance-sheet total, while the cost of X-inefficient banks which was on average 9.7 percent of the balance-sheet total.

5 Conclusion

In this paper we have studied the efficiency of the European banking sector in the five-year period following the implementation of the Second Banking Directive of European Union (EU). The paper is the first application of the new RTFA method which has been shown to outperform the more standard SFA in case of realistic features in the data (Wagenvoort et al. (2001). To make a comparison between EU countries more meaningful we have split our sample into savings banks and commercial banks.

A noteworthy first finding is that commercial banks form a much more diverse group than savings banks. Future studies should keep account of the possibility that subsets of EU commercial banks offer services of different nature and use a different technology. Vander Vennet (2002)'s analysis confirms this picture. It could also be that a close look at ownership characteristics could be a fruitful approach to investigating better the determinants of efficiency.

We confirm the standard result for EU and international efficiency studies that managerial ability to control costs (X-inefficiency) is at 17-25 percent the main source of inefficiency. There seems to be no evidence of improvement over time. We find that big commercial banks are on average more cost efficient than small commercial banks, while the same pattern does not show for savings banks. Reasons for this could be stricter share-

holder monitoring or more competitive output markets for large commercial banks. The level of X-efficiency differs from country to country in Europe. Among the five big EU countries only German bank managers have been successful on average in keeping costs close to the efficient frontier in the period 1993-1997; France performed around the EU average; the UK perhaps slightly better than average; and Italy and Spain have been poor performers.

Potential economies of scale can be attained in the savings bank sector. Choosing the optimum scale could lead to a sector-wide cost reduction of about 3 percent. However, this potential gain may be wasted in practice as an average large savings bank performs a little worse than a small savings bank in terms of X-efficiency. Large commercial banks are on average better run than small commercial banks. One explanation for this result is that large commercial banks operate on a bigger scale and face more competitive pressure than small (niche?) commercial banks.

Structural developments have had a notable impact on the EU banking sector. After accounting for changes in output levels and input prices, we find that both EU savings banks and EU commercial banks lowered their cost base in the period 1993-1997 at an annual pace of about 5 percent. It is difficult to judge whether this result is due to technological progress, the direct effect of deregulation in the EU, the impact of deregulation on competition, or all of these factors. Stiroh (2000)'s and Berger and Mester's (2001) results of little or no technological progress in the period 1991-1997 in the US banking sector suggests that deregulation, and not technological progress has played a crucial role. Moreover, since X-inefficiency has been substantial during the sample period, and has not improved over time, it is likely that deregulation has impacted the cost base of banks directly and not through an increase in competitiveness in the EU banking markets.

Finally, efficient banks and inefficient bank differ. Most importantly, efficient savings banks generate about 20 percent more profits than inefficient savings banks. They also attract more capital in the form of deposits and generate more income in the form of commissions. Efficient commercial banks incur only two-thirds of the costs of inefficient commercial banks, however they are *not* more profitable than their inefficient counterparts. They are more often involved in off-balance-sheet activities and commission-generating business than inefficient commercial banks. They also hold more securities. These findings seem to suggest that efficient commercial banks are more often engaged in investment banking activities, and might even be investment banks in disguise.

A Data Appendix

A.1 Selection of the bank samples

Our bank datasets are constructed using an update of BankScope that was issued at the end of 1999. We selected all EU-15 "savings banks" and "commercial banks" that BankScope defines as 'living', and for which annual data for 1993-1997 is available.[28]

We set about preparing the two datasets in such a way they no longer contained banks which had missing values for the components of total costs or one of the six output variables. In this process we also removed various obvious data errors and inconsistencies in BankScope, and made sure banks were not counted twice. Finally, we homogenized the set of commercial banks somewhat.

First, we removed banks with missing, zero or negative values for 'interest expenses' or 'total operating expenses' in a given year, banks for which individual balance sheet items exceeded their respective balance-sheet total, and banks with a commission revenue exceeding total operating incomes.

It is believed that both the consolidated entry for a bank and its unconsolidated entry

[28] In BankScope terms, we selected all 'consolidated statements', 'unconsolidated statements', and some 'aggregate statements' (codes C1, C2, U1, U2 and A1).

(i.e. the banks main subsidiary that carries the same name) should only be included if these statements are of a sufficiently different nature. Thus, we removed the entry for the unconsolidated statement of a bank in case total assets on the unconsolidated statement exceeded 70 percent of total assets on the corresponding consolidated statement.

In treating missing values for equity investments, off-balance sheet items and commission revenue, we employed the following guidelines. For companies with missing values in not more than two out of five years, we replaced the missing value by the next value (or, in the case of a missing value for 1997, by the 1996 value). Banks with more than two but less than five missing values for any of these variables were removed altogether. For UK companies with five missing values in off-balance sheet items, the missing value entries were set to zero. In Greece, data on "commission revenue" were not available, so we used "net commission revenue" instead (Greek banks only report "net commission revenue" = "commission revenue" - "commission expense").

To homogenize the set of commercial banks, we removed a few banks with 'off-balance sheet items' of more than twice the balance-sheet total. In addition, we decided to exclude 27 banks with total costs of less than 3% of total assets. After a careful study we believe these banks to be pure investment banks.

A.2 The price data

Table 15 shows the *price of funds* in the EU member states. The price of funds represents a weighted average of the real 3-month interbank offered rate and the real deposit rate. The weight of the deposit rate of an individual bank equals the value of deposits over total assets; the weight of the interbank rate equals one minus the deposit rate weight. The relevant deposit rates are extracted from the IMF (IFS dataset, Line 601), while the interbank rate was retrieved from Datastream International. In Datastream we downloaded

Table 15: Weighted average of the real interbank interest rate and the real deposit rate in the EU-15 countries in the years 1993-1997, percentages (sources: IMF and Datastream International)

Country	1993	1994	1995	1996	1997
Austria	0.40	0.12	0.59	0.33	0.72
Belgium	4.49	2.58	2.67	0.67	1.25
Denmark	6.08	2.05	2.29	0.94	0.66
Finland	4.20	3.13	3.28	2.26	1.31
France	3.92	3.36	3.40	1.75	2.29
Germany	1.96	1.87	2.11	1.41	1.04
Greece	5.26	9.71	6.92	5.36	5.12
Ireland	2.23	-0.96	-1.00	-0.49	0.46
Italy	4.28	3.07	2.82	3.53	3.76
Luxembourg	2.15	2.91	3.06	2.12	2.08
Netherlands	1.14	1.98	2.47	1.41	1.05
Portugal	4.72	3.96	4.48	3.35	2.71
Spain	5.39	2.18	3.23	2.78	2.23
Sweden	3.01	4.51	5.20	4.02	3.02
United Kingdom	2.86	1.62	1.29	1.32	1.23

monthly data on the 3-month interbank offered rates in the EU-15 countries and used these to create year-averages. Real rates were constructed by subtracting the relevant country's inflation rate from the computed nominal rates.

Table 16 shows the *price of labour* in the banking sector in each country. The *price of labour* is constructed using BankScope and data published by the OECD. The 1996 and 1997 observations in each country are constructed using BankScope. We added up all labour expenses of all banks in the sample in a given country and divided the sum by the number of workers employed by these banks. A considerable number of banks report the necessary data, however only for the years 1996 and 1997.[29] The data for 1993-1995 is created by computing wage indices in the banking sector using the 1998 issue of 'Bank Profitability' of the OECD.[30] This process delivered wage indices in the banking sector

[29] In the case of Ireland the figures are based on only three banks for 1996 and four for 1997.

[30] Bank Profitability reports labour expenses in the banking sector and the total number of employees. For some countries the data is not available for the banking sector as a whole, but merely for commercial banks (Greece, Luxembourg, Portugal, Sweden and the UK) or for commercial plus savings banks

Table 16: Annual wage rate per bank employee in the EU-15 countries in the years 1993-1997 (thousands of ECU) (sources: BankScope and OECD

Country	1993	1994	1995	1996	1997
Austria	47.2	49.2	54.3	55.2	56.2
Belgium	56.6	58.4	60.5	62.0	63.2
Denmark	46.2	47.9	50.9	53.2	54.3
Finland	29.8	32.6	33.0	37.4	35.9
France	53.7	53.3	54.6	56.8	59.6
Germany	43.1	44.3	48.0	49.2	51.6
Greece	23.3	24.9	27.3	30.6	33.2
Ireland	30.1	30.1	30.1	32.7	39.9
Italy	54.3	53.9	49.8	58.3	59.9
Luxembourg	55.0	61.0	64.6	64.8	65.1
Netherlands	37.5	40.9	45.6	49.0	56.6
Portugal	26.6	26.5	29.1	31.1	32.5
Spain	42.4	38.8	40.3	43.0	38.6
Sweden	40.3	40.4	46.8	53.9	57.6
United Kingdom	37.2	36.5	36.6	36.0	43.7

in the EU-15 countries for 1993-1996, which were subsequently used to extrapolate the BankScope data to cover the period 1993 - 1996.

Table 17 shows the *price of buildings* in the banking sector in each country. The *price of buildings* is created by taking a price index for newly delivered buildings and correcting it for the relative price levels in each country. The data on newly delivered buildings is obtained from Eurostat (CRONOS dataset, series /theme4/ construc/ isti08a/ i8aa ind), and relative price levels are constructed from IMF data (IFS dataset: 'real effective exchange rate').

B Theory Appendix

In this appendix we verify whether our estimated cost model (equation 1) is well specified. Standard microeconomic textbooks show that the long-run cost curve should envelope

(Denmark).

Table 17: The price index of buildings in the EU-15 countries in the years 1993-1997 (Germany, 1995 = 100) (sources: Eurostat and IMF

Country	1993	1994	1995	1996	1997
Austria	94	99	102	104	104
Belgium	87	90	91	93	94
Denmark	110	112	116	122	127
Finland	97	99	100	98	103
France	92	91	90	94	96
Germany	95	98	100	100	99
Greece	61	65	68	79	82
Ireland	74	74	74	78	88
Italy	71	72	66	76	80
Luxembourg	81	83	85	86	87
Netherlands	86	89	92	94	97
Portugal	57	60	61	65	67
Spain	69	69	70	76	75
Sweden	95	98	100	111	113
United Kingdom	68	71	68	73	93

the short-run cost curves. Thus, we first show that the size dummies actually represent (long-run) economies to scale by testing whether our estimated cost model envelopes the short-run cost curves (i.e. the cost curves for given size classes).

Firstly, derive the cost output elasticity for an average firm in each size class. For notational ease, consider the simplified scaled cost function corresponding to the two-output case: $\frac{TC}{TA} = \left(1+\frac{y_1}{TA}\right)^{\beta_1}\left(1+\frac{y_2}{TA}\right)^{\beta_2}$. After multiplying both sides by TA we have the following curve

$$TC = \left(1+\frac{y_1}{TA}\right)^{\beta_1}\left(1+\frac{y_2}{TA}\right)^{\beta_2} TA \tag{5}$$

We have made the following assumptions

$$\frac{\partial TA}{\partial y_1} = \frac{\partial TA}{\partial y_2} = 1 \tag{A1}$$

$$\frac{\partial y_1}{\partial y_2} = \frac{\partial y_1}{\partial y_2} = 0 \tag{A2}$$

The first assumption holds for all but one output variable since outputs are taken from the

balance-sheet. The second assumption states we can increase an individual output without having to change another one.

Under assumptions we get the following derivative of cost with respect to the first output

$$\frac{\partial TC}{\partial y_1} = \beta_1\left(1+\frac{y_1}{TA}\right)^{\beta_1-1}\left(1+\frac{y_2}{TA}\right)^{\beta_2}\left(\frac{y_2-TA}{TA}\right) + \left(1+\frac{y_1}{TA}\right)^{\beta_1}\left(1+\frac{y_2}{TA}\right)^{\beta_2} \tag{6}$$

Using this equation and the equivalent equation for the other output, we can derive the cost to total output elasticity $c = \sum_{i=1}^{2} \frac{\partial TC}{\partial y_i}\frac{y_i}{TC}$. This elasticity represent the change in cost that would occur if all outputs increased by 1 percent (and the bank remained in the same size class)

$$c = \beta_1 \frac{\left(\frac{y_1}{TA} - \frac{y_1^2}{TA^2}\right)}{\left(1+\frac{y_1}{TA}\right)} + \frac{y_1}{TA} + \beta_2 \frac{\left(\frac{y_2}{TA} - \frac{y_2^2}{TA^2}\right)}{\left(1+\frac{y_2}{TA}\right)} + \frac{y_2}{TA} \tag{7}$$

Equation 7 shows that we can test the null hypothesis of (short-run) constant returns to scale versus the alternative of decreasing returns to scale by testing whether the restriction $R\widehat{\beta} = r$ holds, where

$$R = \left(\frac{\left(\frac{y_1}{TA} - \frac{y_1^2}{TA^2}\right)}{\left(1+\frac{y_1}{TA}\right)}, \frac{\left(\frac{y_2}{TA} - \frac{y_2^2}{TA^2}\right)}{\left(1+\frac{y_2}{TA}\right)} \right),\ \widehat{\beta} = (\widehat{\beta}_1, \widehat{\beta}_2)^T,\ r = 1 - \frac{y_1}{TA} - \frac{y_2}{TA} \tag{8}$$

This formula is extended in a straightforward way to cover our 6 outputs case. Notice that alternative hypothesis of (short-run) decreasing returns to scale is identical to the situation that short-run cost curve is enveloped by the estimated cost model of equation 1 in the main text.

Table 18 contains the elasticities and concomitant F-tests for the average firm in each size class. We find the F-test leads to rejections for all cases, that is the data reveal short-run decreasing returns to scale for banks in each size class for both savings banks and commercial banks. Hence, our estimated augmented Cobb-Douglas frontiers represent long-run curves, and, consequently, the size dummies represent economies of scale. We have

Table 18: Short-run output elasticities and the relevant F-test statistics. [$F(1,\infty) = 3.84$ at the 5 percent level]

Size class	Savings	Banks	Commercial	Banks
	Elasticity	F-test	Elasticity	F-test
TA≤2.5	2.03	16770.16	1.90	3834.69
2.5<TA≤5	1.90	12504.81	1.92	4343.33
5<TA≤7.5	1.79	9944.66	2.15	5102.01
7.5<TA≤10	1.66	7979.69	2.06	1867.63
10<TA≤100	1.80	7736.61	2.31	7523.68
TA>100	1.80	4575.70	1.79	2446.76

also established decreasing returns to scale for the largest savings banks and commercial banks in the datasets (not shown in Table 18). This shows that our cost frontier is not downward-sloping beyond the threshold value of 100 billion ECU that defines the class of largest credit institutions.

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