European Investment Bank

Economic and Financial Report 2000/01

Some Empirical Findings on the Characteristics of Cost-Efficient Credit Institutions

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Notes

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[1] We thank Federico Galizia for useful comments.

Non-Technical Summary

The main empirical findings of this study and the Schure and Wagenvoort (1999) study can be summarized as follows:

- One out of five credit institutions in the European Union were operationally cost efficient during the period 1993-1997. The best performers in European banking were found most often in Austria, Belgium, Germany, the Netherlands and the United Kingdom. Interestingly, relatively large banks (total assets exceed 100 billion euro) are more often efficiently run than smaller banks. The X-inefficiency of these large banks (including both X-efficient and X-inefficient banks) is on average about 2 to 3 percent lower than the operational inefficiency of small banks.

- Commercial banks appear to incur moderately less average cost (around 6%) than savings banks while real estate/ mortgage banks and long-term/ non-banking institutions appear to have considerably less expenditures in proportion to total assets (by more than 10%) than savings banks. These findings are similar to those of Schure and Wagenvoort (1999).

- We find that both X-efficient savings banks and X-efficient commercial banks have realised around 5 percent structural cost reductions per year over the period 1993-1997, independent of changes in output structure or input prices, due to, for instance, technological progress or other structural changes in the banking sector. We note however that the RTFA regressions performed in SW, using a nominal price of funds instead of a real price, point in a different direction with regard to the commercial credit institutions. Although SW reported substantial downward shifts in the average cost of X-efficient savings banks, it did not find significant structural changes in the cost frontier of commercial banks. In this paper we have argued that this latter finding may have been a spurious result as the relationship between interest expenditures of efficient commercial banks and the real interest rate was very weak for our sample. Cost reductions experienced by these banks could thus not be explained by movements in the real interest rates.

- Although X-inefficient banks have also experienced substantial cuts in average cost, these cost reductions are mainly due to lower interest expenditures rather than structural improvements. We do not find evidence to suggest that the X-inefficient banks are moving closer to the X-efficient banks over time for any of the samples. Actually, the gap in cost efficiency with the best performers has slightly increased and thus X-inefficiency, in 1997, for the whole EU banking sector (including X-efficient banks), still on average at 16 percent, is the most important reason for the fact that average cost do widely range from one bank to the other of the same type.

- Looking at the full sample of credit institutions, we find that banks in The Netherlands and the United Kingdom are the best performers in terms of the weighted average X-efficiency of their banking sector, followed by the Austrian, German and Belgian banks. The banking sectors of the Netherlands and the UK were considered almost fully efficient on average in 1997.

The most efficient savings bank sectors are found in Austria, Germany and Belgium. France, Italy and Spain also host relatively many savings banks but savings banks in these regions are on average more than respectively 20, 30 and 40 percent inefficient than their X-efficient counterparts.

Commercial banks in France, Greece, Italy, Portugal and Spain lag well behind other commercial banks in the European Union since average inefficiencies in these countries are high, of the order, >20%, >60%, >30%, >50%, >40% respectively.

- For the full sample and the commercial banks sample there appears to be increasing returns to scale for banks up to total assets size of 5 billion ECU followed by constant returns to scale up to total assets size of 100 billion ECU and thereafter decreasing returns to scale. The results for the savings banks sample suggests that there may be scale economies up to total assets size of 10 billion ECU and then constant returns to scale. For all size classes in all regression analyses, short-run economies of scale were decreasing.

  Although there are many small players, the use of total assets of the overall European banking sector, from the point of view of total cost incurred in banking, would have hardly improved from mere consolidation through mergers and acquisitions. We estimate however, broadly in accordance with SW, that the savings bank sector in Austria, Denmark, France, Germany, Italy and Spain may obtain efficiency gains of about 3 percent by mopping up the small mutuals.

  Evidently, these results do not imply that economies of scale cannot be realised in the future.

- An examination of the output mix of efficient and inefficient banks reveals that the efficient banks are likely to be more involved in more ‘commercial’ (or fee-based) activities since their ratio of commission revenue to total operating income is higher and they hold more securities on their balance sheets. Efficient commercial banks appear to have significantly more off-balance sheet activities than inefficient commercial banks in proportion to their total balance sheet.

- The profitability of savings banks, as measured by the average return on average equity, is strongly determined by their cost efficiency. This result supports the efficient structure hypothesis. In favour of the structure-conduct-performance paradigm, we do not find that the average profitability of efficient commercial banks is significantly different from the average profitability of inefficient commercial banks. The return on equity of commercial credit institutions seems to be mainly driven by other factors, such as possibly output prices.

Abstract

This paper extends the Schure and Wagenvoort (1999) study, which considers economies of scale and efficiency in European banking, in a number of directions. Firstly, we introduce what we believe to be important improvements to estimating efficiency. Secondly, we examine more closely the characteristics of the banks on the cost frontier and draw comparisons between the characteristics of these banks and those of the relatively inefficient banks in our sample. In contrast with the results of Schure and Wagenvoort (1999), we find that both X-efficient savings banks and X-efficient commercial banks have cut their average cost, independent of input price movements or changes in the output mix, by about 5 percent each year during the five-year period following the implementation of the Second Banking Directive of the European Union on the first of January 1993. In other words, we observe structural shifts in the cost frontier, possibly due to technological progress. X-inefficient banks became only slightly more inefficient than their efficient counterparts. Therefore, these banks also experienced substantial reductions in average cost. However, these reductions are mainly explained by lower interest expenditures because of lower real interest rates rather than structural changes. Additionally to the results of Schure and Wagenvoort (1999), an examination of the output mix of efficient and inefficient banks reveals that the efficient banks are likely to be more involved in more 'commercial' (or fee-based) activities since their ratio of commission revenue to total operating income is higher. The profitability of savings banks appears strongly determined by their cost efficiency which supports the efficient structure hypothesis. The average profitability of efficient commercial banks seems mainly driven by other factors, such as possibly output prices, rather than cost considerations.

1. Introduction

The initial stages of this study follow along similar lines to the EIB-study by Schure and Wagenvoort (1999), hereafter shortened to SW, which considers economies of scale and efficiency in European banking. Following SW, we employ the Recursive Thick Frontier Approach (RTFA, Wagenvoort and Schure (1999)) to estimate an *augmented* Cobb-Douglas cost frontier in order to investigate the cost efficiency of over 2400 credit institutions over the period 1993-1997 in the 15 EU countries. The Schure and Wagenvoort study is extended in a number of directions. Firstly, we introduce what we believe to be important improvements to estimating efficiency. Secondly, we examine more closely the characteristics of the banks on the cost frontier and draw comparisons between the characteristics of these banks and those of the relatively inefficient banks in our sample. Furthermore, SW only provides estimates of long-run scale effects. In this paper we also derive the short-run size dynamics and verify whether the result of constant (decreasing) returns to scale for relatively large banks reported by SW is sustainable.

We determine a set of efficient banks from the full sample of banks which comprises four types of banks: commercial banks, savings and co-operative banks, real estate/mortgage banks and medium and long-term banking institutions. We then consider savings and co-operative banks only and finally commercial banks only. Thus we produce three sets of efficient banks and our study assesses the characteristics of the cost-efficient banks in each set. We examine the distribution of the X-efficiencies of the banks on the frontier and determine the type, size, location, output and ownership structure for each set of cost efficient banks. We also examine the X-efficiencies of the cost-inefficient banks. Furthermore, we investigate whether the inefficient banks have become more efficient, i.e. whether they were able to catch up with their efficient peers over the time period of our study.

The variation in the measured X-efficiencies of the banks on the frontier tells us something about the reliability of our study. We find that the X-efficiencies are at more realistic levels compared to those in SW. The X-inefficiencies in our study are generally 5 percent lower compared to those found in the previous study. In Section 2 we will explain why this is the case. However, the variance of our measure of X-efficiency for the group of commercial banks is still at such a high level that little can be said about individual bank efficiency for this category of financial institutions. Even at the country level only some very tentative conclusions can be drawn from our regression results since it seems highly unlikely that a "one-for-all" cost frontier was found for the commercial banks case. In section 4 some arguments will be given that explain why our simple cost model cannot fully capture the relationship between output, input prices and minimum cost for all types of banks. On the other hand, our analysis is useful in determining a group of commercial banks which on average are more cost efficient than the other commercial banks. The set of savings banks is more homogenous than the set of commercial credit institutions. Thus, for this category more satisfactory results are obtained.

The introduction is followed by four sections and three appendices. In section 2, we discuss the improvements in comparison to SW which we have carried out when applying RTFA to estimate the *augmented* Cobb-Douglas cost function. A short description of the data is given in Section 3. Section 4 contains an analysis of the regression results and an analysis of the characteristics of the cost efficient banks. In Section 5 we summarize the main conclusions that can be drawn from both the SW study and this paper. Appendix A contains our new sample selection criteria, new output variable definitions and new input price data. The tables consisting of the regression results can be found in Appendix B. Finally, in Appendix C we derive the short-run economies of scale and test whether our cost model is homogenous of degree one in the short run.

2. Improvements in Cost Frontier Estimations

We note that the regressions in our study have greater adjusted R^2-values relative to the corresponding values in SW. There are a number of explanations for the higher adjusted R^2-values.

Firstly, we employed a larger data set. The number of banks in the study has increased and this can be attributed to the fact that we were able to include all living banks from 1993-1997. SW did not include banks which did not deliver their results for 1997 until late the following year and thus beyond the date at which the data for their study was downloaded from Bankscope. This study analyses 2431 credit institutions located in the European Union.

Secondly, we include a further output variable which we refer to as Total Securities (see Appendix A2) and this new output variable is significant in two of the three regressions. The addition of total securities to our set of output variables leads to a higher adjusted R^2-value in each regression. We also chose to scale commission revenue by total operating income rather than total assets.[2]

Third, we have proposed a solution to a problem encountered in many efficiency studies. Some of the output variables may have zero values (or very low values) and taking logs of these values will be infeasible (or produce extremely large negative values). The Schure and Wagenvoort study suggests adding one to each output variable prior to scaling by total assets which goes some way to alleviating this problem. Our study differs in that we scaled the output variables by total assets (or commission revenue) and then added one. This results in a shift to an interval where the log function curves less steep and thus zero values or very low values for the output variables will have less of a dramatic influence on the results. We believe our solution resolves this problem but we should note that the estimates of the coefficients of the output variables can no longer be interpreted as elasticities. See Appendix C for our new specification of the cost model.

The consequence of our way of taking logs is that banks with zero values for certain output variables will be considered more efficient than in SW. Therefore, we find that X-inefficiencies are on average about 5 percent lower and average X-inefficiencies are more constant over time compared to those in the previous study.

[2] We do not scale commission revenue by a price index for banking services (see Table A1.6 in SW, p.47) any longer.

Fourth, we have also taken some measures to make the dataset more homogeneous. We have excluded banks from Luxembourg from the frontier estimations as Luxembourg has a very distinctive banking sector with many subsidiaries of foreign banks located there. This differs from the approach adopted in SW as Luxembourg banks were taken into account in the cost frontier estimations for that study. Moreover, we have taken some measures to eliminate investment banks from the group of commercial banks. See Appendix A1 for a detailed description of our sample selection criteria.

Fifth, SW employs nominal interest rates for the price of funds. However, using nominal interest rates may have distorted the SW results to a certain extent since all other terms in our cost function specification are real values. In this paper we report cost function estimates that are based on real interest rates (see Appendix A3 for input price data). Real interest rates are computed by subtracting inflation rates, based on Consumer Price Indices (CPI), from the nominal interest rates used in SW.

Taking real interest rates has a strong impact on our results since shifts in the frontier over time are found to be substantial and strongly significant. In SW, structural adjustments in the cost frontier were only significant for the savings banks.

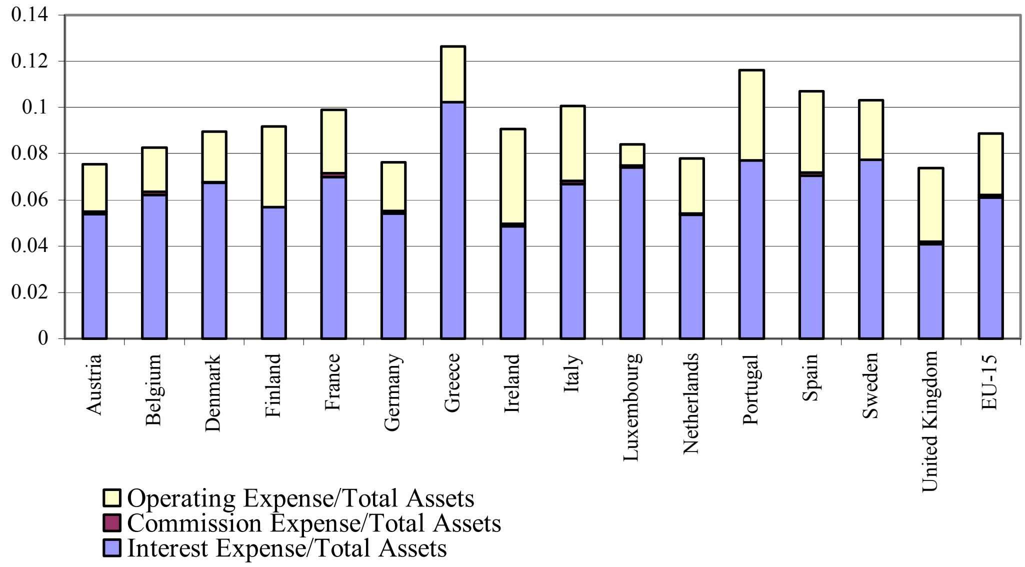
Now, one could argue that the ratio of expenses on funding to total assets could change more rapidly than is revealed by the real interest rate if the rate of inflation changes by large leaps and bounds during a short time span. Afterall, part of the book value of total assets of a bank will still be based on former prices.

During our sample period 1993-1997 many EU countries prepared themselves for the introduction of the Euro on the 1st of January 1999. Therefore, inflation rates were substantially reduced in countries such as Italy, Greece and Portugal. Would this suggest that taking nominal interest rates would be more adequate than taking real interest rates for our sample period? Unfortunately, we do not have a straightforward and decisive answer to this question.

Figure 1 and Figure 2 show the decomposition of total costs for each EU member state and the corresponding EU-15 averages for 1993 and 1997 respectively. On average, the ratio of total cost over total assets dropped by 2.16 percent from total cost being almost 9 percent of total assets in 1993 to less than 7 percent in 1997. A large part of this cost reduction, i.e. 1.65 percent, can be ascribed to a decrease in the ratio of interest expense to total assets. We performed simple regressions of the country averages of the ratio of interest expense to total assets on either the nominal fund rate[3] and a constant or the real fund rate and an intercept. Although, strictly speaking, the cost frontier input price elasticities should only depend on the relationship between cost and input prices that exist for the managerially efficient banks, these average (including both X-efficient and X-inefficient banks) sample correlations provide some insights. The OLS panel[4] regression with the nominal fund rate as the explanatory variable returns a price parameter estimate of 0.355 and concomitant adjusted R^2 of 0.75 whereas, when using the real fund rate, these numbers are equal to 0.651 and 0.63 respectively. Thus, changes in the nominal fund rate slightly better explain

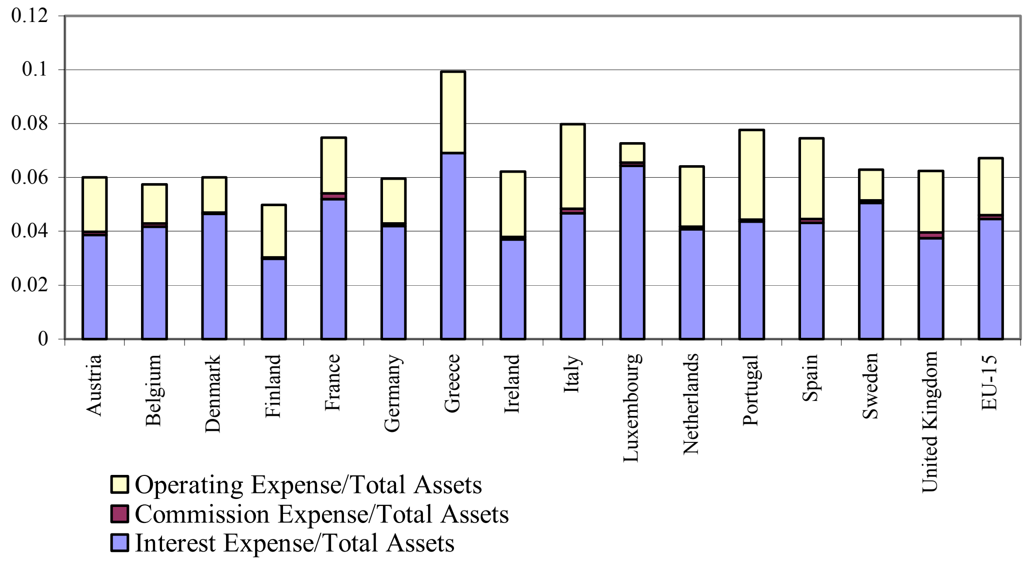
[3] The fund rate is computed as a weighted average of the 3-month interbank rate and the deposit rate (see SW, p.21).
[4] Variables in the regressions vary for different countries and different periods.

Figure 1 Decomposition of total costs[a], 1993



[a]Average values are computed by applying weights on the basis of the share of each bank in total assets of all credit institutions in its country.

Figure 2 Decomposition of total costs[a], 1997



[a]Average values are computed by applying weights on the basis of the share of each bank in total assets of all credit institutions in its country.

changes in the full-sample average of the ratio of interest expenses to total assets than the real fund rate.

Figure 3 illustrates these relationships over time between average fund rates and the EU-15 average of the scaled interest expenses. Interestingly, Figure 4 shows that the other two input prices considered in our study, i.e. the price of labour and the price of buildings, have slightly increased during each year of our sample period. The nominal EU-15 weighted average wage rate per employee and the price of buildings increased by 14% and 10% respectively from 1993 to 1997. The EU-15 average inflation rate came down from 3.48% in 1993 to 1.86% in 1997. The Consumer Price Index increased on average in the European Union by 10 percent between 1993 and 1997. As a consequence, we do not find that average costs have decreased because of lower wages or lower rents on office buildings. Given also the fact that the decrease in the average real interest rate does less well in explaining the decrease in the EU-15 average ratio of total cost to total assets, it is more likely that a price-independent structural change in average cost will be found when the real fund price is preferred to the nominal rate. Indeed, this is what we observe from our regression results in Section 4. This structural change could be attributed technological progress for example.

Is a slightly higher coefficient of explanation (R^2) a convincing argument for using the nominal fund rate rather than the (theoretically correct) real rate? We believe it is not. Figure 5 shows the average share of interest expenses in total assets, the nominal and real fund rate for a cross-section (1993) instead of the time series averages in Figure 3. This graph shows why we do not have a clear-cut preference for either of the two fund rates. For instance, the real fund rate seems more suitable to be included in the RTFA regressions when France is compared to Germany because German banks on average have lower (scaled) interest expenses and face a lower real price of funds but pay a higher nominal fund price in comparison to French banks. Strikingly, French bankers are less financed by deposits (66 percent of the balance sheet total) than German banks (85 percent of total assets are financed by deposits). On the other hand, Portugese bankers incur higher financing cost than their Spanish peers while real rates are higher and nominal rates are lower in Spain than in Portugal. Interestingly, Portugese banks have almost the same amount of deposits (83 percent in proportion to total assets) as Spanish banks on their balance sheet (85 percent of total assets are financed by deposits).

We conclude that, although on the basis of average statistics it seems more appealing to include the nominal fund rate, the real fund rate may be more appropriate when comparing the efficiency of banks between certain EU countries. Actually, the X-efficiency results presented in this paper are more in line with prior expectations about country differences than the ones shown in SW. We stress though that neither paper can be fully decisive with regard to the determination of the “actual cost frontier”. One should thus cautiously interpret our RTFA cost frontier parameter estimates which are shown in Appendix B and its derived efficiency measures which are discussed in Section 4.

Figure 3 EU-15 weighted average of the nominal interest rate, the real interest rate and the ratio of interest expenses to total assets, 1993-1997

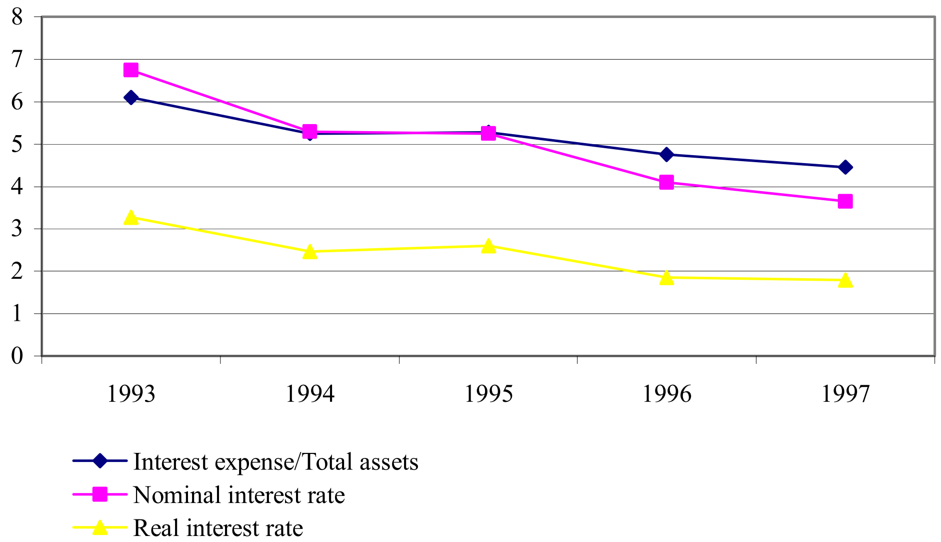


Figure 4 EU-15 weighted average of the wage rate per employee in thousands of ecu and the price index of buildings, 1993-1997

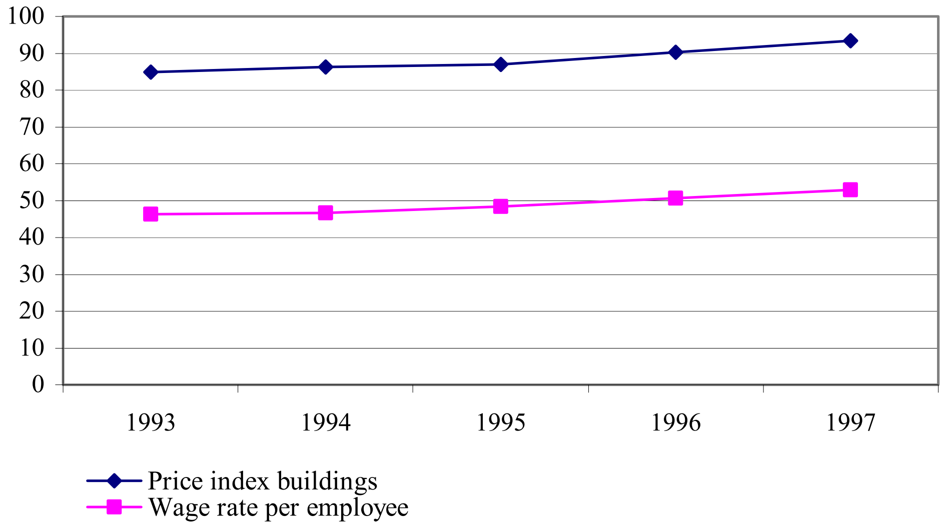
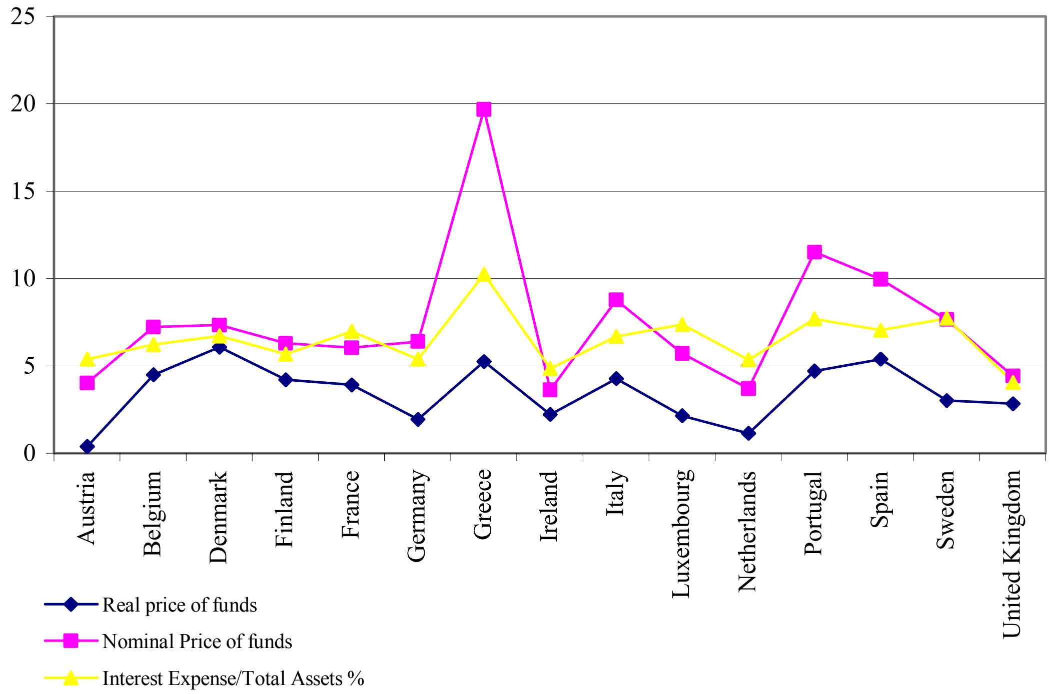


Figure 5 The nominal interest rate, the real interest rate and the ratio of interest expenses to total assets, 1993



3. The Data

Appendix A describes the dataset in detail and explains much of the data cleaning which was undertaken in both our study and the Schure and Wagenvoort study. We carried out some further cleaning of the data. Bankscope includes a separate category for investment banks. However, this list is not exhaustive as we discovered a number of investment banks in the commercial banks category. We felt that it would be inappropriate to include investment banks in our sample and thus we needed to identify in some way these investment banks. We decided to exclude banks with total costs less than 3% of total assets from the frontier estimation and efficiency computations. These banks we believed to be investment banks.[5] Accordingly, we removed 27 banks from a sample of 2431 banks. In addition, three banks with commission revenue greater than their respective total operating incomes (due to data errors) were excluded from the frontier estimation and the efficiency computations.

The price of buildings is constructed in the same way as we have computed a price index of buildings in SW (see page 43). However we use the 'real effective exchange rate' which is based on the relative Consumer Price Index (as published in the IFS of the IMF) instead of the series *reu* which is based on the relative labour cost in manufacturing. Our price index of buildings does not drastically change as a result of this modification.

[5] In some cases, the data for these very low cost banks contain typing errors.

4. Empirical Evidence

Very small banks (banks with total assets less than 0.1% of the total assets of all banks within a country) are ignored when estimating the full sample cost frontier so that this frontier is not dominated by mainly German savings banks. Banks in Luxembourg are excluded from the frontier estimation on the grounds that the banking sector is very unusual and including Luxembourg would distort the results. When computing scale inefficiencies and X-inefficiencies, small banks and banks located in Luxembourg are included. We do not exclude very small banks from the savings banks and commercial banks regressions.

4.1 Full Sample Results

The results from the full sample regression are displayed in Appendix B, Table B1. The adjusted R^2-value is approximately 65%, which means that our model explains 65-44=21 percent more of the variation in average cost of X-efficient banks than SW. The main conclusions that can be drawn from this study are broadly similar to those of Schure and Wagenvoort (1999). There are however also some striking differences.

Before analysing our efficiency measures we discuss in depth the distribution (type, size etc.) of the X-efficient credit institutions in order to gain more insight into the reliability of the regression results.

Distribution of banks around the cost frontier

Table 1 presents a breakdown of the numbers of observations in each size class for the starting sample and for the efficient set of banks. There appear to be sufficient numbers of observations in each size category for reliable inference. It is clear also that there is a large number of very small savings banks in the original sample.

A total of 136 banks have determined the cost frontier. By multiplying the number of observations of firms in each size category (first column of Table 1) by its associated percentage of observations of selected efficient banks (column 3) and dividing by the number of periods (5) we obtain a rough estimate of the number of banks which are efficient; around 445 credit institutions, out of a total of 2401, are considered to be managerially efficient. This means that about one out of five (more precisely, 19 percent) banks is well organised from a cost perspective. This number is close to the number of efficient banks reported in SW, i.e. 17 percent of the total number of credit institutions.

An interesting result is that the percentage of efficient banks selected per size class is considerably higher for banks greater than 100 billion ECU in comparison to the corresponding percentages in other categories. In other words, very large banks (> 100 billion ECU) are more often efficiently run than smaller banks.

Table 2 presents a summary of the numbers of each type of bank falling on the cost frontier. We note that a noticeably higher percentage of mortgage banks lie on the frontier relative to the respective percentages for the remaining classes. Furthermore, there are only 3 long-term/non-bank credit institutions which are positioned relatively close to the cost frontier. Little attention should thus be given to the t-statistic

Table 1. Number of observations in each size class for starting sample, for the sample used for frontier estimation (i.e. sample with Luxembourg banks and very small banks excluded) and for the efficient set of banks.

Size Class (in billions of ECU)	Number of observations			
	Starting sample	Sample used for frontier estimation	Efficient set	% Selected from estimation sample
Total Assets≤2.5	9122	833	144	17.3%
2.5<Total Assets≤5	1172	698	130	18.6%
5<Total Assets≤7.5	461	423	123	29.1%
7.5<Total Assets≤10	234	219	42	19.2%
10<Total Assets≤100	858	809	164	20.3%
Total Assets>100	158	158	77	48.7%
Total number of banks	2401	628	136	21.7%

Table 2. Breakdown of type of banks appearing in the efficient set of banks

Type (number of observations in starting sample in brackets)	Sample used for frontier estimation	Efficient set	% selected from estimation sample
Commercial (846)	305	48	15.7%
Savings (1347)	218	59	27.1%
Mortgage (113)	59	26	44.1%
Long-term/non-bank (95)	46	3	6.5%
Total no. of banks (2401)	628	136	21.7%

Table 3. Breakdown of number of banks on the frontier by country*

Country (number of banks in starting sample in brackets)	Number of banks used for frontier estimation	Efficient Set of banks	Percentage selected
Austria (45)	39	16	41.0%
Belgium (69)	34	15	44.1%
Denmark (75)	36	4	11.1%
Finland (6)	6	1	16.7%
France (351)	111	26	23.4%
Germany (1189)	92	52	56.5%
Greece (17)	17	0	0%
Ireland (7)	7	0	0%
Italy (233)	100	1	1%
Netherlands (28)	17	7	41.2%
Portugal (24)	22	0	0%
Spain (135)	91	0	0%
Sweden (9)	9	0	0%
United Kingdom (121)	47	14	29.8%

* Banks in Luxembourg are excluded from frontier estimation.

corresponding to the long-term/non bank dummy which is reported in Table B1 of Appendix B.

We present in Table 3 the number of banks in each country in our starting sample and also illustrate the geographical distribution of the efficient set of banks. We can observe that a relatively high percentage of Austrian, Belgian, German, Dutch and UK banks are chosen to lie on the cost frontier. We can also note that no single country dominates the frontier although banks from Germany and France are quite prominent.

Input price elasticities

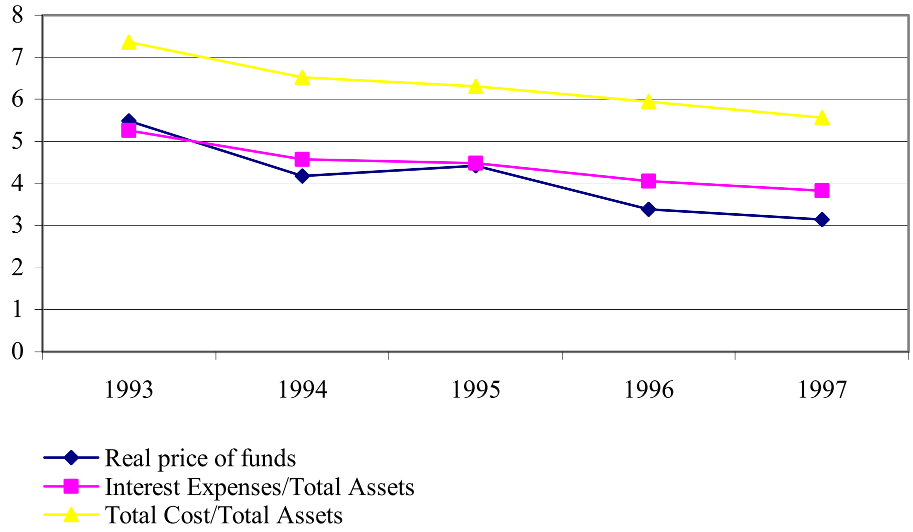
The input price coefficients are all positive and significantly different from zero. The coefficient for labour (0.85) is relatively large while the price elasticity of funds (0.0378) is extraordinarily low. Recall that we found a (scaled) interest expense fund price elasticity of 0.65 in a simple regression applied on the full sample (see Section 2) while two-thirds of total cost consist of interest expenses. We thus observe that the relationship between interest expenses and the real fund rate appears different for the group of efficient firms and the group of inefficient firms. For the efficient banks, the real exchange rate explains much less of the variation in their interest expenses than the nominal interest rate (SW reports a fund price elasticity of 0.426). Below we will give some possible explanations. The coefficients for buildings and labour are difficult to interpret as there are likely to be strong correlations between these price variables.

Structural changes in the cost frontier

As a result of a lack of explanatory power that can be attributed to the real fund price, we find strong structural, i.e. price and output independent, changes in the average cost of X-efficient banks. The model includes time dummies to model these structural changes (shifts) in the cost function and these were found to be significant and large. Managerially efficient credit institutions were able to reduce average cost (i.e. the ratio of total cost to total assets), after taking into account input price changes and variations in the output mix, by an average of 6.8 percent per year over the five-year period following the implementation of the Second Banking Directive in 1993. At first glance, this number seems rather high in an environment where the average bank in the full sample experienced substantial cost reductions during this episode due to cuts in interest expenses (see Figure 3). SW, using nominal interest rates, does not find significant cost reductions of efficient banks for the full sample regression.

Firstly, we note that the price of labour and the price of buildings were not corrected for inflation. In Section 2 we mentioned that, although the nominal wage rate increased by 14 percent, the real wage rate only increased by 4 percent from 1993-1997. Given the high cost wage elasticity of 0.85 (see Table B1), the annual shifts in the cost frontier may thus have been overstated by 0.85*10/5=1.7 percent. Similarly, due to including the nominal price index of buildings instead of a real index, another over-estimation of 0.12*10/5=0.24 percent may have occurred. This would leave us with structural reductions of about 6.8-1.9=4.9 percent in average cost per year realised by X-efficient banks.

Figure 6. The real price of funds, and the average value of the ratio of interest expenses to total assets[a] and the average value of the ratio of total cost over total assets[a] for X-efficient banks



[a] In percentages.

Figure 6 shows the course of the real price of funds, the ratio of interest expenses to total assets and the ratio of total cost over total assets for the average efficient bank during our sample period. Recall that from Figure 3, looking only at average time-series, we observe for the full sample of banks an almost one-to-one relationship between scaled interest expenses and total assets. Interestingly, Figure 6 reveals that this relationship does not hold true for the set of efficient banks. Interest expenses of X-efficient banks are more stable over time than the corresponding expenditures of inefficient banks, although they still decreased from 5.26 in 1993 to 3.83 percent of total assets in 1997, i.e. 1.43 percent (compared with 1.73 percent for inefficient banks)! Indeed, efficient banks are financed less by deposits of customers (see *differences in output mix,* Table 5 below). This result however vanishes for the separate samples of cost efficient savings banks and cost efficient commercial banks (see Table 9 and Table 13). These sub-samples were derived from regression results where time dummies were also significant!

One can think of several other explanations for a weaker relationship between the fund rate and interest expenditures of efficient banks. However, further analysis is required before asserting these hypotheses. First, efficient banks may possibly wish to borrow more often against fixed rates than variable rates if they have a favourable position in the credit market in comparison to inefficient banks. Secondly, efficient banks could have lost market power during the unification of the European banking markets. As a result, the interest expenses of the inefficient banks fell more in line with the interest expenditures of the efficient ones. Third, efficient banks are hedging their interest expenditures against unfavourable movements in the real interest rates. Evidently, during an episode of decreasing real interest rates these banks pay a premium for stabilizing their costs. Another explanation could have been that efficient banks increase their borrowings during episodes of low interest rates. For our sample of efficient banks, this however is not the case since the ratio of total deposits over total assets is constant at 71 percent during 1993-1997. Thus, bank and customer deposits finance around 70 percent of the banks' business.

In view of these explanations, one may strongly argue that efficient banks have indeed considerably reduced their average cost structurally during 1993-1997 by, for instance, the employment of new technologies or because of the introduction of other structural (institutional) improvements in the European banking sector.

Type of credit institution

In accordance with SW, our findings suggest that savings banks are the least efficient of the four types of banks in the sample. Commercial banks appear to be about 6% more efficient than savings banks. Real estate/ mortgage banks and long-term/non-banking institutions seem to be considerably more efficient (10% and 14% respectively) than the savings banks but it could be argued that these classes are not very comparable to savings banks. See SW, p.13, for a more extensive exposition on this matter.

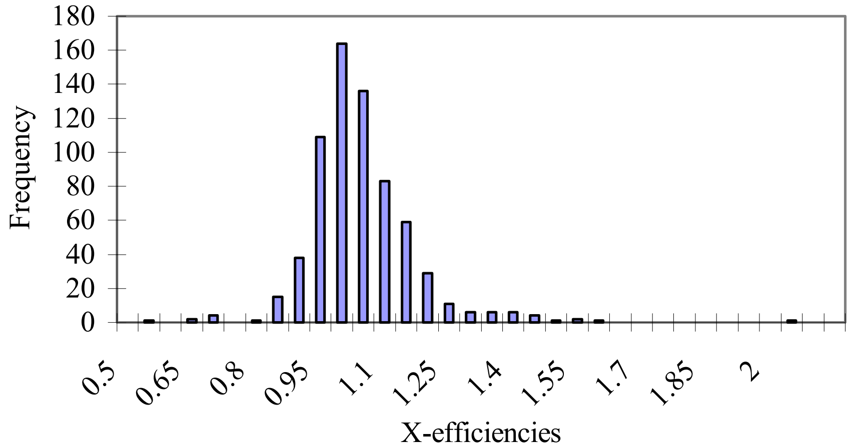
Long-run economies of scale

The size dummies in our cost function specification reveal the long-term economies of scale. In Appendix C the short-run economies of scale are derived for the purpose of verifying whether the RTFA parameter estimates constitute a well-defined cost function and for the purpose of testing whether the cost frontier, evaluated at the largest credit institution in our sample, is homogenous of degree one or higher. In accordance with neoclassical micro-economic theory, we find significant short–run decreasing returns to scale for firms in each size class.

According to the size dummies, there are significant increasing (long-term) returns to scale for banks up to total assets size of 5 billion ECU followed by constant returns to scale and then decreasing returns to scale for banks in the largest size class. Decreasing short-run scale economies are also found for the largest bank in our sample and thus our cost frontier is not downward sloping beyond the threshold value of 100 billion ECU that defines the class of largest credit institutions. It is thus safe to conclude from the (long-term) frontier size parameters that average cost do not significantly decrease with size beyond a balance sheet total of 5 billion ECU.

If we ignore cost improvements due to down-sizing very large credit institutions, we find, likewise for SW, that the overall European banking sector would be marginally more cost-efficient if the size of its smallest institutions were to be increased through mergers and acquisitions. Only for Austria, Germany and Italy, countries where relatively many savings banks are located, would the performance of the banking sector as a whole improve by more than 1 percent by up-sizing small banks. We estimate scale efficiency gains of 1.6, 1.3 and 1.7 percent for the total banking sector of Austria, Germany and Italy respectively.

Figure 7 Histogram of X-efficiencies for X-efficient banks in the full sample



X-efficiencies of banks on the Frontier

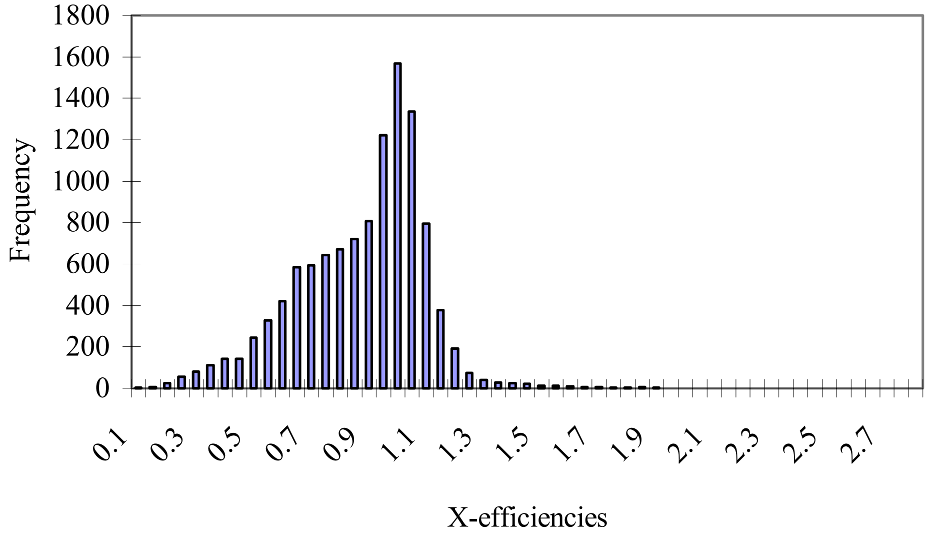
The X-efficiencies for the X-efficient companies appear to have a distribution which is slightly skewed to the right but approximately a normal distribution. The X-efficiencies for these efficient banks can vary considerably with a mean X-efficiency of about 1.019 and a standard deviation of 0.134 for the X-efficiencies. A 95% confidence interval for the X-efficiencies is thus (0.756,1.283) under the assumption of normality. As X-efficiencies are skewed to the right, the lower bound of this interval is under-estimated.

The RTFA regression technique ensures that banks are not systematically located above or below the cost frontier in all time periods. This means that our measure of X-efficiency of an individual bank may still vary considerably, more than one would reasonably expect. Our cost model and data sources are thus limited in capturing the efficient cost structure of banks. Below we will show that this is mainly due to the fact that the group of commercial banks is highly diverse. Our model is more successful in determining the cost function of savings banks, which make up a more homogenous group.

X-efficiencies of managerial in-efficient banks

The distribution of the X-efficiencies for the inefficient companies appears to be heavily skewed to the left as illustrated in Figure 8. The inefficient banks have a mean X-efficiency of approximately 0.853 and a standard deviation of 0.223. A 95% confidence interval for the X-efficiencies is (0.417,1.289) under normality. Evidently, the upper-bound of this interval is strongly over-estimated. We note that the 95% confidence intervals for the mean X-efficiencies for the efficient and inefficient banks do not overlap and thus we can conclude that the mean X-efficiencies for the two sets of banks are significantly different at the 5% level. Although our cost model is limited in returning the actual relationship between total cost, input prices and output, we have successfully determined a group of banks, what we call the X-efficient banks, that contains relatively more efficient banks than the other banks in the sample.

Figure 8 Histogram of X-efficiencies of X-inefficient banks in the full sample



We also investigated whether the inefficient banks were developing over time into more efficient banks relative to the X-efficient banks. The evidence suggests that this is not the case as we do discover a small downward trend in the mean X-efficiencies for these inefficient banks, from 0.87 in 1993 to 0.84 in 1997. However, recall that the cost frontier shifted down by about 5 percent per year. Therefore, inefficient banks did experience substantial cost reductions over 1993-1997. The reason for the decrease in average cost differs for the X-efficient banks and the X-inefficient banks. In the case of the former, the reduction in total cost is structural and possibly due to new technology whereas in the latter case, the reduction is almost entirely due to lower interest expenditures.

Table 4 presents the weighted averages of the X-inefficiencies per year for each country. Similar to SW, the most X-efficient banking sectors appear to be in the UK and the Netherlands. The banking sectors in Greece, Portugal and Spain appear to be very inefficient, with Greece being a big outlier. Using real interest rates in RTFA regressions rather than nominal rates leads to country differences in X-efficiency that are more in line with prior expectations. As an example, although the Italian banking sector is still in an early stage of restructuring, SW found that this sector was relatively efficient, whereas we find that Italian banks on average incurred 30 percent higher average cost in 1997 than the British credit institutions. On the other hand, contrary to our prior beliefs, our X-efficiency measure for a particular country may still fluctuate considerably. For instance, X-inefficiency dropped by 18-1=17 percent between 1996 and 1997 in the United Kingdom. At the same time, our UK price index of buildings increased from 73 to 93! This may have resulted in over-estimation of the efficiency of UK banks in 1997. For other countries, such as Germany, the X-efficiency measure is fairly stable. Evidently, high variation in weighted average X-inefficiencies can be explained by occasionally high variation in our individual bank efficiency measure. We note that there are less than 10 banks in the dataset from each of Finland, Ireland and Sweden (see Appendix A1).

Table 4 Weighted average of X-inefficiencies per country per year[a]

Country	1997	1996	1995	1994	1993
Austria	9	9	11	17	12
Belgium	10	12	8	7	14
Denmark	12	13	14	21	16
Finland	26	26	32	38	43
France	22	16	21	15	16
Germany	6	4	2	5	4
Greece	68	71	71	75	73
Ireland	21	46	47	43	36
Italy	30	35	42	26	25
Luxembourg	21	12	13	4	20
Netherlands	3	8	12	13	21
Portugal	61	63	66	65	67
Spain	49	48	49	43	44
Sweden	7	21	34	36	37
United Kingdom	1	18	15	2	1

[a] The weight applied to each bank is obtained from its total asset amount in its country

Moreover, in accordance with SW, we find that the major players (banks with total assets exceeding 10 billion ECU in 1997) are on average more efficient than small banks. Their weighted average of X-inefficiencies is about 2 to 3 percent lower than the corresponding inefficiency measure for small banks.

Differences in output mix between X-efficient and X-inefficient banks

We now investigate whether there are significant differences between the output mix for the efficient and the inefficient banks. We find that the means of scaled total costs, total deposits, off-balance sheet items and commission revenue for the efficient and inefficient banks are statistically significantly different (see Table 5). This suggests that the more efficient banks tend to have more ‘commercial’ (or fee-based) activities and to rely less on financing through deposits.

Interestingly, the X-efficient banks are on average slightly more profitable than the X-inefficient banks. Their return on average equity is about a half percent higher. This empirical evidence weakly supports the *efficient-structure hypothesis*, “firms with superior management or production technologies have lower cost and therefore higher profits” (Berger 1995) which can be contrasted with the *structure-conduct-performance* hypothesis, “the setting of prices are less favorable to consumers (lower deposit rates, higher loan rates) in more concentrated markets as a result of competitive imperfections in these markets”.

Table 5. Means of scaled total costs, scaled outputs and mean return on average equity for the efficient and inefficient banks in the full sample (standard deviations are given in brackets).

	Means for Efficient Banks		Means for Inefficient Banks		t-value°
Total Costs/TA	0.0630	(0.0114)	0.0811	(0.0313)	-15.03*
Total Deposits/TA	0.7133	(0.2405)	0.7972	(0.1709)	-12.10*
Total Loans /TA	0.5322	(0.2327)	0.5381	(0.2022)	-0.73
Equity Investments/TA	0.0175	(0.0356)	0.0148	(0.0350)	1.95
Off-balance Sheet/TA	0.1805	(0.2402)	0.1422	(0.2138)	4.50*
Commission Revenue /TOI	0.1027	(0.1414)	0.0647	(0.0774)	11.67*
Total Securities/TA	0.1891	(0.1551)	0.1974	(0.1387)	-1.51
Mean Return on Average Equity	7.66	(3.61)	7.10	(4.43)	6.25*

°t-statistic for pooled two sample t-test.

4.2 Savings Banks Results

The parameter estimates for the savings banks regression are presented in Table B.2 of Appendix B. The model specification explains the variation in total costs over total assets satisfactorily as the adjusted R^2-value is approximately equal to 69%.

Distribution of banks around the frontier

There are 317 banks on the cost frontier and these banks were distributed as follows (see Table 6): Germany 286, France 17, Austria 8, Belgium 4, Denmark and UK one each. Clearly, the frontier is very much dominated by German savings banks.

Table 6. Breakdown of number of savings banks on the frontier 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%

Table 7. Number of observations in each size class for starting sample, for the sample used for frontier estimation and for the set of efficient savings banks.

Size Class (in billions of ECU)	Sample used for frontier estimation	Efficient set of Savings banks	% selected from estimation sample
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 banks	1344	317	23.6%

Ownership of the efficient savings banks does not appear to be an issue as an examination of the ownership of the efficient savings banks reveals that almost all efficient savings banks have owners from within their respective countries. Thus we can conclude that the efficient set of savings banks contains very few subsidiaries of foreign banks.

We note though that there are few observations (6) in the size class for very large savings banks. In order to keep the results comparable across the three sets of regressions, we maintained the same definitions for the size classes. Although the size dummy associated with the largest size class does not appear significantly different from 1 we cannot say whether the biggest size class can be combined with the reference class given that the relevant t-statistic is based on so few observations. We can observe from Table 7 that relatively larger proportions of large banks are chosen to lie on the cost frontier as was also the case for the full sample results.

There is only one savings bank in our starting sample of Luxembourg banks so excluding Luxembourg from the sample for estimation has little effect.

Input Price elasticities

The scaled costs input price elasticity of labour is even higher (0.94), and the scaled costs fund price elasticity is even lower (0.005), in comparison to the full sample case.

Structural changes in the cost frontier

We find again strong significant shifts in the cost frontier. The estimated time effects are of similar magnitude as in the full sample case.

Long-run economies of scale

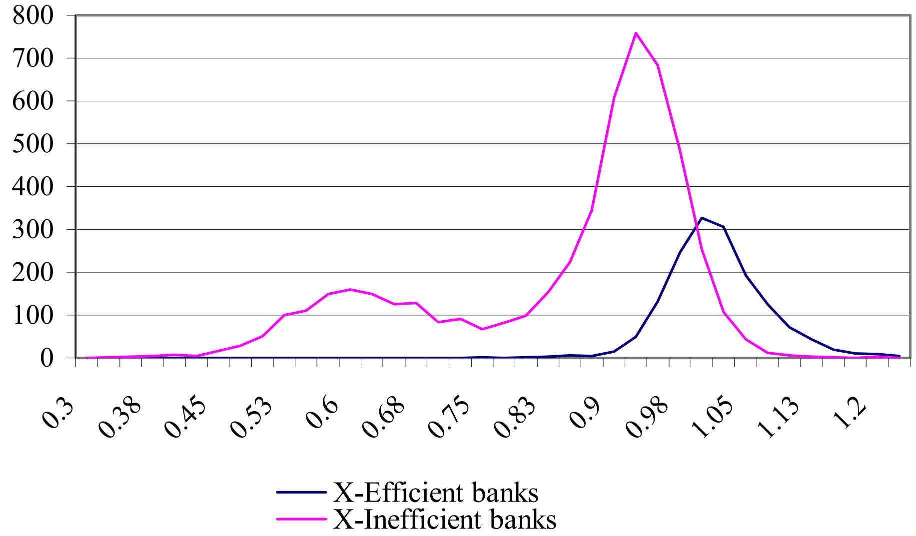
There is evidence to suggest that economies of scale are exhausted for total assets size greater than 10 billion. Beyond the reference class there are constant returns to scale. For the full sample case significant positive economies of scale were only found for banks smaller than 5 billion ECU.

In accordance with SW, the savings bank sector may improve in some EU countries from consolidation: Austria 2.92 percent efficiency gains, Denmark 4.78, France 1.18, Germany 3.10, Italy 3.16 and Spain 2.58 percent. We conclude that EU countries with relatively many saving banks may improve their saving bank sector, from an average cost perspective, with about 3 percent by consolidating small savings institutions.

X-efficiencies of banks on the frontier

The X-efficiencies for efficient banks vary considerably less than in the full sample case. The mean X-efficiency of these banks is equal to 1.008 with a standard deviation of 0.065. Under normality (see Figure 9), a 95% confidence interval for the X-efficiencies is (0.880,1.135).

Figure 9 Histogram of X-efficiencies of X-efficient and X-inefficient banks, savings banks



X-efficiencies of in-efficient Companies

The inefficient banks have a mean X-efficiency of approximately 0.833 and a standard deviation of 0.148. A 95% (normality based) confidence interval for the X-efficiencies is (0.542,1.124). An investigation of how the X-efficiencies of inefficient banks develop over time reveals that there is no clear upward trend in the mean X-efficiencies for these banks (0.84 both in 1993 and 1997).

The mean value of the X-efficiencies are clearly significantly different at the 5 percent level and thus RTFA has been successfully applied. This time also our cost model specification seems to be appropriate as the variation in our efficiency measure is limited for the efficient banks in comparison to the variance in X-efficiency for in-efficient banks.

Table 8. Weighted average of X-inefficiencies per country per year for savings banks[a]

Country	1997	1996	1995	1994	1993
Austria	5	2	14	9	10
Belgium	-1	0	2	1	8
Denmark	11	16	27	19	37
France	20	13	22	13	16
Germany	4	3	3	5	6
Italy	34	42	49	32	34
Spain	43	45	46	40	44

[a] The weight applied to each bank is obtained from its total asset amount in its country.

Table 8 presents the weighted averages of the X-inefficiencies per year for countries that have more than 10 savings banks in our sample. The evidence suggests that savings banks in Belgium and Germany, and to a lesser extent Austria, are performing consistently well in terms of managerial efficiency while the savings bank sectors in Spain and Italy appear to be lagging well behind their European counterparts. The savings bank sector in Denmark and France are moderately inefficient.

Differences in output mix

We investigate whether there are significant differences between the output mix for the efficient and the inefficient savings banks. We find that the means of scaled total costs, total deposits, total loans, off-balance sheet items, commission revenue and total securities for the efficient and inefficient banks are statistically significantly different. The most noticeable difference appears to lie between the mean commission revenue for efficient and inefficient banks. This would tend to suggest that the savings banks with activities more in common with commercial banks (with an emphasis on fee-based activities) are likely to be more cost efficient. The difference in scaled total securities seems negligible. Although inefficient banks appear to have more off-balance-sheet activities, the magnitude of the difference in means is small.

For the savings bank sector we however observe a strong relationship between profitability and efficiency. The average return on average equity increases with about one and a half percent from 6.56% for the group of inefficient banks to 8.05% for the group of efficient banks. Again we find evidence that supports the efficient-structure hypothesis.

To summarize, our cost model successfully explains the efficient cost structure for savings banks. The main empirical findings are broadly similar to the ones reported in SW.

Table 9. Means of scaled total costs, scaled outputs and mean return on average equity for the efficient and inefficient savings banks (standard deviations are given in brackets).

	Efficient Banks		Inefficient Banks		t-value*
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*
Mean Return on Average Equity	8.05	(2.81)	6.56	(3.29)	29.02*

*t-statistic for pooled two sample t-test.

4.3 Commercial Banks Results

We do not exclude very small banks from the sample but banks from Luxembourg are again excluded when estimating the cost frontier. The adjusted R^2-value for the commercial banks regression is 43%. Our cost model is thus less well designed to explain the commercial bank sector than the savings bank sector.

The financial services of commercial banks may be less well captured by our output proxies relative to the case for the savings banks. Commercial banks more often supply, besides the traditional banking products of deposit taking and lending, other services such as brokerage services, investment banking products, risk management and portfolio management services and, in several cases, insurance products.[6] Unfortunately, straightforward and precise output measures for non-traditional outputs are not available. Even the traditional banking outputs for commercial banks may be more difficult to measure if the set of clients of commercial banks exhibits higher diversity in comparison to the set of clients of savings banks.

Furthermore, although we tried to eliminate some investment banks from the group of commercial banks, this type of credit institution may still be present in our sample. In many cases a distinction between "investment bank" and "commercial bank" cannot be made since both typical investment banking products and traditional banking products are offered. Large financial institutions, such as the ABN AMRO in the Netherlands, is a clear example. Evidently, "investment banks", in the narrow sense, are expected to have a different cost structure than those "commercial banks" which only supply the traditional financial services.

Distribution of banks around the frontier

200 banks lie on the cost frontier for the sample of commercial banks (see Table 10). We attempted to identify the nationality of the owners of the efficient commercial banks in order to establish whether there are many subsidiaries in our efficient set of commercial banks. However, it is not always possible to determine who the owners or

[6] A comparison of the output mix of X-efficient savings banks and X-efficient commercial banks (see Table 9 and Table 13 respectively) reveals that commercial banks have on average substantially more off-balance sheet activities and a higher ratio of commission revenue to total operating income.

major shareholders are for each bank. In some cases this information is not available in Bankscope for some banks in our sample. Some banks have indicated that they wish to keep information on the ownership of the bank confidential. There are also many instances where the banks in our database no longer exist at the date when the data was downloaded as they have been involved in mergers.

We find that many banks in the sample of efficient commercial banks have non-European owners. Japanese-owned banks are particularly prominent. Just over one-half of the efficient British commercial banks appear to be British owned whereas almost all efficient Italian commercial banks are Italian owned. Thus comparisons of commercial banking sectors across countries is not straightforward as there are many subsidiaries in our sample of commercial banks for each country. Foreign owned subsidiaries can possibly rely in many ways on the support of their parent organisation. These subsidiaries could thus operate at substantially lower costs and it is no surprise that they figure prominently in our current set of efficient commercial banks. Moreover, it may also happen that the cost frontier associated with foreign subsidiaries is substantially different from the cost curve associated with credit institutions from the home country since the financial services supplied by both types of banks could significantly differ from one to the other. Our cost function parameters shown in Table B.3 of Appendix B will fit the cost structure of both types of credit institutions on average as best as possible. This means that the cost function that is found may be inappropriate to describe the cost/output/input price structure of either of the two optimally.

Summarising, there is a fundamental problem with the sample of commercial banks. It has not been possible to exclude all investment banks or non-conventional commercial banks from our sample. There are also some subsidiaries of foreign banks present in the sample and further cleaning of the commercial banks sample would be necessary in order to establish a more appropriate cost frontier for commercial (non-investment) banks.

Table 10. Breakdown of the number of commercial banks on the cost frontier 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%
Number of banks	846	200	23.6%

Table 11. Number of observations in each size class for the sample used for frontier estimation and for the set of efficient commercial banks.

Size Class (in billions of ECU)	Sample used for frontier estimation	Efficient set of Commercial banks	% selected from estimation sample
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 banks	846	200	23.6%

Table 10 presents a summary of the numbers of banks in each country in our starting sample and in the set of efficient banks. We can observe that relatively large proportions of banks (>40%) from the samples of Austrian, Belgian, German and Dutch banks are chosen to lie on the cost frontier. In absolute numbers, German and French banks figure quite prominently on the frontier.

From Table 11 we can observe that each size class contains a sufficiently large number of efficient banks for reliable statistical inference. Again we find that the largest credit institutions in the sample are most often efficiently run.

Structural changes in the cost frontier

The parameters corresponding to the time dummies (see Table B.3) indicate significant cost improvements of the same magnitude as were found for the group of savings banks. This result is in sharp contrast with the SW study where no structural shifts in the cost frontier were found for the efficient commercial banks. When using real interest rates in the cost frontier estimations, commercial banks also appear to have reduced average cost by about 5 percent each year from 1993 to 1997.

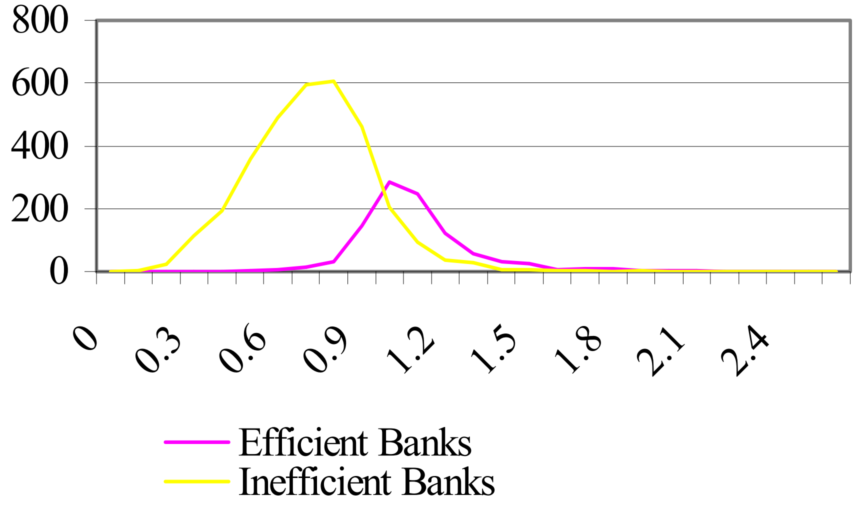
Long-run economies of scale

We find evidence to suggest that there may be increasing returns to scale for commercial banks up to total assets size 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 (see also Appendix C).

X-efficiencies of Efficient and Inefficient banks

The distribution of the X-efficiencies for the efficient and inefficient commercial banks seems to have fatter tails than the normal distribution would suggest. Figure 10 shows indeed that relatively many banks, which were deemed *efficient*, were located to the far right of one on the x-axis (100 percent efficient). In view of total cost and total output, these banks were thus extremely efficient. This would suggest

Figure 10. Histogram of X-efficiencies of X-efficient and X-inefficient commercial banks



that the cost frontier was wrongly determined. However, we recall again that the Recursive Thick Frontier Approach guarantees that efficient banks cannot systematically deviate from only one side of the cost frontier. More precisely, not more than 5 percent[7] of the X-efficient banks will have X-efficiencies exceeding one in all periods. We thus conclude that the cost frontier is not defined with sufficient flexibility due to the reasons outlined above. The X-efficiencies for the efficient banks can 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 seem to be under-estimated.

Figure 10 also illustrates that the distribution of the X-efficiencies for the inefficient companies is 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 these X-efficiencies is (0.185,1.157) if we are willing to assume normality. Note that the lower bound of this interval is substantially lower than the border line concomitant the savings bank group results. This result may again reflect the fact that the group of commercial banks consists of highly diverse credit institutions rather than the presence of extremely inefficient banks.

We examined the means and standard deviations for the X-efficiencies of inefficient commercial banks per year. There is no clear upward trend in the mean X-efficiencies of the inefficient banks for the period 1993 to 1997. Actually, the gap between the efficient and inefficient banks increases slightly from 0.71 in 1993 to 0.68 in 1997.

Table 12 contains the weighted averages, according to the proportion of the bank's assets in the total banking assets in its country, of the X-inefficiencies of all commercial banks. Clearly, we cannot derive too many conclusions from these results

[7] The confidence level applied to the binomial test statistic is equal to 5 percent.

Table 12. Weighted average of X-inefficiencies per country per year for commercial banks[a]

Country	1997	1996	1995	1994	1993
Austria	8	8	6	14	6
Belgium	3	8	7	8	6
Denmark	-22	-11	6	8	17
Finland	16	22	23	33	33
France	25	21	24	21	16
Germany	6	5	3	8	-1
Greece	67	71	71	76	71
Ireland	21	40	40	38	35
Italy	37	43	48	36	31
Luxembourg	29	22	23	16	21
Netherlands	6	12	16	19	16
Portugal	59	63	66	68	66
Spain	52	53	54	49	47
Sweden	-2	12	27	30	25
United Kingdom	6	25	20	13	7

[a] The weight applied to each bank is obtained from its total asset amount in its country.

given the problems with the sample of commercial banks. However, it seems safe to conclude that commercial banks in Greece, Italy, Portugal and Spain lag far behind other banks in the European Union since we have enough observations for these countries and X-inefficiencies are relatively constant. Inefficiencies are high, of the order >60%, >30%, >50%, >40% in the case of Greece, Italy, Portugal and Spain respectively. French bankers are also not among the best performers since average inefficiencies exceed 20 percent from 1994 to 1997. Commercial banks in the remaining EU countries have performed relatively well.

Differences in output mix

We investigate whether there are significant differences between the output mix for the efficient and the inefficient commercial banks (see Table 13). The evidence suggests that the more efficient of the commercial banks tend to have a greater emphasis on fee-based activities as evidenced by their greater mean values for the ratio of commission revenue to total operating income. We note also that the average scaled off-balance sheet items and total securities for efficient commercial banks are noticeably greater with respect to the corresponding values for the inefficient banks. We do not find significant differences for the relative amount of deposits and the relative amount of equity investments between efficient and inefficient banks. Table 13 also highlights that our regression technique RTFA, even for the diverse group of commercial banks, was very successful in classifying the sample into relatively efficient and inefficient banks. Although the variance in X-efficiency can be high for some cases, the average cost for X-efficient banks were equal to 6.4 percent and thus substantially lower than the average cost of X-inefficient banks which had on average expenditures equal to 9.7 percent of total assets.

Interestingly and in sharp contrast with savings banks, the commercial bank results do not support the efficient-structure hypothesis. Average return on equity was, on

Table 13. Means of scaled total costs, scaled outputs and mean return on average equity for the efficient and inefficient commercial banks (standard deviations are given in brackets).

	Efficient Banks		Inefficient Banks		t-value°
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*
Mean Return on Average Equity	7.15	(5.54)	7.12	(7.69)	0.26

°t-statistic for pooled two sample t-test.

average, similar for managerially efficient and inefficient credit institutions. Further research is required to explain this result. It appears that profitability, as measured by return on equity, is determined by cost savings for savings banks. The profitability of commercial banks is mainly driven by other factors. Note that savings banks are usually smaller than commercial banks, typically operate only in regions within countries, are often owned by public institutions or form a co-operation and, last but not least, are not always profit-maximising institutions. Therefore it may be that savings banks more often face output prices as given. For example, the co-ordinating parent organisation may set output prices for individual small regional savings banks. Without any flexibility in price setting, above average profitability will have to be generated by cost efficiency considerations. For commercial banks, differences in profitability could be output price driven rather than differences in cost structures.

5. Conclusions

The main empirical findings of this study and the Schure and Wagenvoort (1999) study can be summarized as follows:

- One out of five credit institutions in the European Union were operationally cost efficient during the period 1993-1997. The best performers in European banking were found most often in Austria, Belgium, Germany, the Netherlands and the United Kingdom. Interestingly, relatively large banks (total assets exceed 100 billion euro) are more often efficiently run than smaller banks. The X-inefficiency of these large banks (including both X-efficient and X-inefficient banks) is on average about 2 to 3 percent lower than the operational inefficiency of small banks.

- Commercial banks appear to incur moderately less average cost (around 6%) than savings banks while real estate/ mortgage banks and long-term/ non-banking institutions appear to have considerably less expenditures in proportion to total assets (by more than 10%) than savings banks. These findings are similar to those of Schure and Wagenvoort (1999).

- We find that both X-efficient savings banks and X-efficient commercial banks have realised around 5 percent structural cost reductions per year over the period 1993-1997, independent of changes in output structure or input prices, due to, for instance, technological progress or other structural changes in the banking sector. We note however that the RTFA regressions performed in SW, using a nominal price of funds instead of a real price, point in a different direction with regard to the commercial credit institutions. Although SW reported substantial downward shifts in the average cost of X-efficient savings banks, it did not find significant structural changes in the cost frontier of commercial banks. In this paper we have argued that this latter finding may have been a spurious result as the relationship between interest expenditures of efficient commercial banks and the real interest rate was very weak for our sample. Cost reductions experienced by these banks could thus not be explained by movements in the real interest rates.

- Although X-inefficient banks have also experienced substantial cuts in average cost, these cost reductions are mainly due to lower interest expenditures rather than structural improvements. We do not find evidence to suggest that the X-inefficient banks are moving closer to the X-efficient banks over time for any of the samples. Actually, the gap in cost efficiency with the best performers has slightly increased and thus X-inefficiency, in 1997, for the whole EU banking sector (including X-efficient banks), still on average at 16 percent, is the most important reason for the fact that average cost do widely range from one bank to the other of the same type.

- Looking at the full sample of credit institutions, we find that banks in The Netherlands and the United Kingdom are the best performers in terms of the weighted average X-efficiency of their banking sector, followed by the Austrian, German and Belgian banks. The banking sectors of the Netherlands and the UK were considered almost fully efficient on average in 1997.

  The most efficient savings bank sectors are found in Austria, Germany and Belgium. France, Italy and Spain also host relatively many savings banks but savings banks in these regions are on average more than respectively 20, 30 and 40 percent inefficient than their X-efficient counterparts.

  Commercial banks in France, Greece, Italy, Portugal and Spain lag well behind other commercial banks in the European Union since average inefficiencies in these countries are high, of the order, >20%, >60%, >30%, >50%, >40% respectively.

- For the full sample and the commercial banks sample there appears to be increasing returns to scale for banks up to total assets size of 5 billion ECU followed by constant returns to scale up to total assets size of 100 billion ECU and thereafter decreasing returns to scale. The results for the savings banks sample suggests that there may be scale economies up to total assets size of 10 billion ECU and then constant returns to scale. For all size classes in all regression analyses, short-run economies of scale were decreasing.

  Although there are many small players, the use of total assets of the overall European banking sector, from the point of view of total cost incurred in banking, would have hardly improved from mere consolidation through mergers and acquisitions. We estimate however, broadly in accordance with SW, that the savings bank sector in Austria, Denmark, France, Germany, Italy and Spain may obtain efficiency gains of about 3 percent by mopping up the small mutuals.

Evidently, these results do not imply that economies of scale cannot be realised in the future.

- An examination of the output mix of efficient and inefficient banks reveals that the efficient banks are likely to be more involved in more 'commercial' (or fee-based) activities since their ratio of commission revenue to total operating income is higher and they hold more securities on their balance sheets. Efficient commercial banks appear to have significantly more off-balance sheet activities than inefficient commercial banks in proportion to their total balance sheet.

- The profitability of savings banks, as measured by the average return on average equity, is strongly determined by their cost efficiency. This result supports the efficient structure hypothesis. In favour of the structure-conduct-performance paradigm, we do not find that the average profitability of efficient commercial banks is significantly different from the average profitability of inefficient commercial banks. The return on equity of commercial credit institutions seems to be mainly driven by other factors, such as possibly output prices.

REFERENCES

Berger, A.N., 1995, "The profit-structure relationship in banking – Tests of market-power and efficient-structure hypotheses", *Journal of Money, Credit and Banking*, vol. 27, no.2, 404-431.

Schure, P. and Wagenvoort, J.L.M., 1999, "Economies of Scale and Efficiency in European Banking: New Evidence", Economic and Financial Reports, 99/01, EIB.

Varian, H. R., 1992, *Microeconomic Analysis*, third edition, W.W. Norton & Company, New York.

Wagenvoort, J.L.M. and Schure, P., 1999, "The Recursive Thick Frontier Approach to Estimating Efficiency", Economic and Financial Reports, 99/02, EIB.

APPENDIX A

A1 Selection of Banks

The main resource for the data is the financial database Bankscope of Bureau van Dijk. This database provided all the data for total costs and the output variables. We focus our attention on credit institutions (as defined by EEC Council (Banking) Directives) across the 15 EU member countries and these banks can be categorised as follows: commercial banks (Commercial), savings and co-operative banks (Savings), real estate/ mortgage banks (Mortgage) and medium and long-term credit banks (Long-term and Non-bank). We consider 'living banks' (i.e. banks which continue to exist as a legal body) for the same time period 1993-1997 as Schure and Wagenvoort (SW). We selected all consolidated statements, unconsolidated statements and some aggregate statements for our subset of banks.

Our first sample comprised 3377 banks and we set about preparing the data in such a way that the sample no longer contained banks which had missing values for the components of total costs or the seven output variables. This process of cleaning the data involved many stages. We removed banks which had missing, zero or negative values for interest expenses or total operating expenses in any year, banks for which off-balance sheet items were greater than 2.5 times the balance sheet total and banks for which individual balance sheet items were greater than their respective balance sheet total. These criteria are the same criteria that were applied in SW.

It is believed that both the consolidated and unconsolidated entries for a bank should only be included if their statements are of a sufficiently different nature. Thus, we removed the entry for the unconsolidated statement of a bank when the total assets entry of the unconsolidated statement was found to be greater than 70% of the total assets value in the corresponding consolidated statement. Our approach here differs slightly from SW in that for the larger countries in the study we did not consider unconsolidated banks whose corresponding consolidated total assets value was less than 1% of the maximum total assets value within a country.

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). Companies with more than two but less than five missing values for any of these variables were removed. 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 as Greek banks only report "net commission revenue" (commission revenue – commission expense).

Our study attempts to introduce various refinements to the Schure and Wagenvoort study. We broaden the study to include a further output variable: Total Securities. We introduce what we believe to be an improved proxy for the price of buildings. The number of banks in the study has increased and this can be attributed to the fact that some banks deliver their results for a particular year late the following year. Thus some living banks may have been excluded from the Schure and Wagenvoort study as these banks may not have reported their results for 1997 before the study was undertaken. This problem of late delivery of results prevented us from updating the study to include 1998.

The purpose of this study is to examine more closely the characteristics of the efficient banks and to perform a preliminary investigation of the relationship between performance and efficiency. With this in mind we retrieved information on various bank performance measures including *Pre-tax Profits, Return on Average Assets and Return on Average Equity.*

Table A1.1 presents a breakdown of the country origin and type for the 2431 banks in the starting sample. We note that the numbers of German, French and UK banks in our study are noticeably greater than the corresponding numbers of banks in SW.

Table A1.1 Number of credit institutions in our sample by country and type

Country	Commercial	Savings	Mortgage	Long-term /Non-bank	Total
Austria	16	22	6	1	45
Belgium	37	17	1	16	71
Denmark	44	27	1	3	75
Finland	5	1	0	0	6
France	237	82	4	37	360
Germany	178	968	42	9	1196
Greece	14	0	1	2	17
Ireland	5	0	0	2	7
Italy	64	161	0	9	235
Lux	88	3	1	2	94
Netherlands	27	1	1	1	30
Portugal	18	2	2	2	24
Spain	75	60	1	2	138
Sweden	4	0	3	2	9
UK	61	3	51	9	124
qEU-15	873	1347	114	97	2431

Source: Bankscope

A2 Output Variables

We include the five output variables defined by Schure and Wagenvoort with some minor modifications. *Total Deposits* comprises demand, savings and time deposits. *Loans* corresponds to total loans plus total other lending as defined by Bankscope[8]. *Investments* is defined as the sum of equity investments and other investments.[9] The remaining two original variables are *Off-balance Sheet Items* and *Commission Revenue*.

[8] We agree with SW that 'loans to municipalities/ government' and 'loans to group companies/ associates' should not be included in the loans variable as a bank is not required to devote many resources to this form of service. These transactions do not involve the usual degree of vetting and the costs incurred by the bank are believed to be relatively small. However, as many of the banks do not report these items separately, 'loans to municipalities/ government' and 'loans to group companies/ associates' are included in our output variable loans.

[9] We noted that other investments are in some cases already included in equity investments.

We refer to the new output variable as *Total Securities*. Total Securities is not available directly but can be derived by subtracting deposits with banks and investments from total other earning assets. We feel that, with the introduction of this output variable, we can better represent the scope of service production of banks and as each service demands varying amounts of resources, each will contribute differently to the total costs of a bank.

A3 Price Data

Table A3.1 Weighted average of the real Interbank rate and deposit rate for the EU-15 in 1993-1997, percentages

	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

Table A3.2 Annual wage rate per employee in thousands of ECU in the EU-15, 1993-1997

	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

Table A3.3 Price index buildings (Germany 1995 = 100)

	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

APPENDIX B Regression Results

Table B.1 RTFA Regression Results, Full Sample

Regressor	Estimate	t-value
Constant	0.0011	13.30*
Total deposits over total assets	-0.1080	-3.26*
Total loans over total assets	0.7972	20.01*
Equity investments over total assets	0.6377	4.23*
Off-balance sheet items over total assets	-0.0543	-1.80
Commission revenue over total operating income	0.9073	20.95*
Total securities over total assets	0.3445	7.45*
Price of funds	0.0378	5.53*
Price of labour	0.8466	18.79*
Price of buildings	0.1156	2.64*
Dummy TA≤2.5	1.0773	3.74*
Dummy 2.5<TA≤5	1.0619	3.11*
Dummy 5<TA≤7.5	1.0298	1.57
Dummy 10<TA≤100	0.9714	-1.65
Dummy TA>100 billion	1.0525	2.42*
Dummy commercial	0.9410	-5.80*
Dummy mortgage	0.9046	-7.49*
Dummy long-term/non-bank	0.8623	-5.45*
Dummy 1997	0.6630	-5.72*
Dummy 1996	0.7244	-4.28*
Dummy 1995	0.8039	-2.75*
Dummy 1994	0.8862	-1.45
Adjusted R^2	0.65	
Number of observations under the frontier with weight nil	21	
Number of banks on the cost frontier	136	

* Significant at 5 percent level.

Table B.2 RTFA Regression Results, Savings Banks

Regressor	Estimate	t-value
Constant	0.00072	15.63*
Total deposits over total assets	0.55593	11.24*
Total loans over total assets	0.65342	28.17*
Equity investments over total assets	0.36644	7.02*
Off-balance sheet over total assets	-0.05443	-2.75*
Commission revenue over total operating income	1.48085	28.40*
Total securities over total assets	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 billion	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	
Number of observations under the frontier with weight nil	45	
Number of banks on the cost frontier	317	

* Significant at 5 percent level.

Table B.3 RTFA Regression Results, Commercial Banks

Regressor	estimate	t-value
Constant	0.0008	14.82*
Total deposits over total assets	-0.0765	-1.64
Total loans over total assets	0.7085	17.74*
Equity investments over total assets	0.5239	3.13*
Off-balance sheet over total assets	0.1470	5.76*
Commission revenue over total operating income	0.5332	7.86*
Total securities over total assets	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 billion	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	
Number of observations under the frontier with weight nil	38	
Number of banks on the cost frontier	200	

* Significant at 5 percent level.

Appendix C

We estimate the following cost model:

$$\frac{TC_{ti}}{TA_{ti}} = \gamma_0 \left(1+\frac{y_{ti,1}}{TA_{ti}}\right)^{\beta_1} \ldots \left(1+\frac{y_{ti,6}}{TA_{ti}}\right)^{\beta_6} p_{t1}^{\alpha_1} p_{t2}^{\alpha_2} p_{t3}^{\alpha_3} \sigma_1^{s_{1,ti}} \ldots \sigma_5^{s_{5,ti}} \delta_1^{t_1} \ldots \delta_4^{t_4} \gamma_1^{d_{1i}} \gamma_2^{d_{2i}} \gamma_3^{d_{3i}} + \varepsilon_{ti} \quad (1)$$

where TC_{ti}, TA_{ti} and $y_{ti,k}$ are the total costs, total assets, and output k of bank i in period t respectively. There are 6 outputs and 3 inputs. p_j is equal to the price of input *j*. We split our sample of European banks into 6 non-overlapping size groups (see Table C1 below) and thus include 5 size dummies $s_{1,ti},..,s_{5,ti}$. For example, the size dummy (s_1) for the group of smallest banks is defined according to $s_{1,ti} = 1$ if $TA_{ti} \leq 2.5$ ECU billion, $s_{1,ti} = 0$ otherwise. $t_1,..,t_4$ are four time dummies. $d_{1i},..,d_{3i}$ are the values of the type dummies to distinguish commercial banks, mortgage banks and long-term credit institutions respectively from savings banks and ε_{ti} is the random disturbance term.

Let $w = (\gamma_0, \beta_1,..,\beta_6, \alpha_1, \alpha_2, \alpha_3, \sigma_1,...,\sigma_5, \delta_1,..,\delta_4, \gamma_1, \gamma_2, \gamma_3)$ be the vector of parameters to be estimated. Under the null hypothesis of no economies of scale, no technological progress or other structural changes and equal cost structures across different types of institutions the parameters $(\sigma_1,..,\sigma_5, \delta_1,..,\delta_4, \gamma_1,..,\gamma_3)$ are all equal to one.

If the parameters associated with the size dummies are significantly different from 1 then these values show the long-run economies of scale. As explained in introductory microeconomic text-books (see for instance, Varian (1992), p. 71) the long-run cost curve envelops the short-run cost curves. Below we derive the short-run economies of scale by computing 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 where we omit input prices and dummies:

$$\frac{TC}{TA} = \left(1+\frac{y_1}{TA}\right)^{\beta_1} \left(1+\frac{y_2}{TA}\right)^{\beta_2}. \quad (2)$$

After multiplying both sides by TA we obtain

$$TC = \left(1+\frac{y_1}{TA}\right)^{\beta_1} \left(1+\frac{y_2}{TA}\right)^{\beta_2} TA. \quad (3)$$

Consider the following simplifying assumptions:

Assumptions:
(A1) $\partial TA / \partial y_1 = 1$,
(A2) $\partial TA / \partial y_2 = 1$,
(A3) $\partial y_2 / \partial y_1 = 0$,
(A4) $\partial y_1 / \partial y_2 = 0$.

Assumptions (A1) and (A2) hold in most cases for our bank output variables since they are taken from the bank's balance sheet. Furthermore, we assume that one output can be increased without necessarily increasing the other output (assumptions (A3) and (A4)).

Given the assumptions (A1)-(A4), the first derivative of total cost with respect to the first output y_1 can be written as:

$$\frac{\partial TC}{\partial y_1} = \beta_1 \left(1+\frac{y_1}{TA}\right)^{\beta_1 - 1} \left(1+\frac{y_2}{TA}\right)^{\beta_2} \left(\frac{TA - y_1}{TA^2}\right) TA + \left(1+\frac{y_1}{TA}\right)^{\beta_1} \left(1+\frac{y_2}{TA}\right)^{\beta_2}. \tag{4}$$

A formula similar to (4) is also derived for $\partial TC/\partial y_2$. Using (4) we derive for the total cost total output elasticity $c = \sum_{i=1}^{2} \frac{\partial TC}{\partial y_i}\frac{y_i}{TC}$ the following equation:

$$c = \beta_1 \frac{\left(\frac{y_1}{TA} - \frac{y_1^2}{TA^2}\right)}{\left(1+\frac{y_1}{TA}\right)} + \frac{y_1}{TA} + \beta_2 \frac{\left(\frac{y_2}{TA} - \frac{y_2^2}{TA^2}\right)}{\left(1+\frac{y_2}{TA}\right)} + \frac{y_2}{TA}. \tag{5}$$

c is equal to the percentage change in total cost if all outputs increase with 1 percent.

Under the null-hypothesis that the cost function is homogenous of degree 1 in total output we obtain the restriction $R\beta = r$ on the cost function parameters $\beta = (\beta_1, \beta_2)^T$ where

$$R = \left(\frac{\left(\frac{y_1}{TA} - \frac{y_1^2}{TA^2}\right)}{\left(1+\frac{y_1}{TA}\right)}, \frac{\left(\frac{y_2}{TA} - \frac{y_2^2}{TA^2}\right)}{\left(1+\frac{y_2}{TA}\right)} \right) \tag{6}$$

and

$$r = 1 - \frac{y_1}{TA} - \frac{y_2}{TA}. \tag{7}$$

A F-test statistic is computed in order to test the null-hypothesis of constant returns to scale. Formulas (5) – (7) can be easily extended to cover our 6 outputs case.

Table C1 contains the elasticities and concomitant F-tests for the average firm in each size class, i.e. the average value of each variable in each size class is inserted in the equations (5) – (7). We find short-run decreasing returns to scale for banks in each size class for the full sample, savings banks and commercial banks cost frontiers. For example, in the full sample case, total costs increase by 1.99 percent if total output increases by 1 percent for credit institutions that are smaller than 2.5 billion ECU. These results confirm the standard microeconomic neoclassical theory which predicts that short-run cost curves must lie above the long-run cost frontier. Recall that the full sample parameter estimate associated with the size dummy for the group of smallest banks reveals a significant positive longer-term scale effect of about 8 percent. This means that if these small banks considerably increase their size up to a value that brings them in the optimal size category then average cost can be reduced by 8 percent. These scale economies could be explained for instance by the introduction of a new production process. However, small banks face decreasing returns to scale when production is marginally increased by using their existing technology.

Table C.1 Short-run output elasticities and F-tests[a]

Size class (in billions ECU)	Full Sample		Savings Banks		Commercial Banks	
	Elasticity	F-test	Elasticity	F-test	Elasticity	F-test
TA≤2.5	1.99	5648.28	2.03	16770.16	1.90	3834.69
2.5<TA≤5	1.86	5214.59	1.90	12504.81	1.92	4343.33
5<TA≤7.5	1.83	4588.54	1.79	9944.66	2.15	5102.01
7.5<TA≤10	1.71	2277.00	1.66	7979.69	2.06	1867.63
10<TA≤100	1.75	3119.31	1.80	7736.61	2.31	7523.68
TA>100	1.88	4105.89	1.80	4575.70	1.79	2446.76

[a] $F(1,\infty) = 3.84$ at the 5 percent level.

All F-tests clearly reject the null hypothesis that the total costs total output elasticity is equal to one (see Table C1). Decreasing returns to scale are also found for the largest firm in our sample since its cost output elasticity was equal to 2.07 (not shown in Table C1). This empirical finding 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.