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A Study of German Universal Banks

von

Peter Welzel und Günter Lang

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Abstract

Based on 1989-92 data of 1407 German universal banks we perform a non-parametric analysis of efficiency in the German banking industry. Applying the „data envelopment" (DEA) approach, we solve four linear programs for each bank to calculate measures of overall, technical, allocative, and scale efficiency. In addition, we use the measure of scale elasticity recently suggested for DEA by Førsund and Hjalmarsson. Our results on overall efficiency and its first two components are in line with previous econometric evidence, emphasizing in particular the importance of technical inefficiency. However, DEA leads to a much lower efficient size than parametric frontier analysis.

JEL classification: C44, G21

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1. Introduction

In recent years the German banking industry saw a rapid decline in the number of banks. From end of 1990 to end of 1995, for example, about 22% of German banks ceased to exist as independent firms. The vast majority of these market exits were due to mergers and acquisitions within the industry. This is particularly true for the smaller firms among the groups of savings and cooperative banks whereas credit banks were hardly affected by this concentration process. Bank managers and many industry observers claim that the main incentive for creating larger units in German banking is cost-based and can be found in economies of scale which are currently not properly exploited by the smaller banks in the industry.[1] Compared to that, economies of scope are probably not a major force driving concentration in the industry, if we confine our interest to the roughly 3,500 universal banks in Germany. Even very small banks usually offer the full range of banking products, sometimes using head organizations as in the savings or cooperative banking sectors. While becoming bigger may be a way to reduce unit costs, however, for many banks there could be an alternative way: If a bank is inefficient in the sense of producing above the efficient cost frontier, reducing this inefficieny will also create a cost-based increase in competitiveness.

The empirical literature on banking recently has shifted its attention from merely analyzing economies of scale and scope to calculating both size and cost inefficiency and comparing the two (for a comprehensive survey of studies from 21 countries see *Berger and Humphrey, 1997*). Typically the potential cost savings from becoming cost efficient are much more important than the savings from reaching efficient size (see e.g. *Berger and Humphrey, 1991, 1992*, and *Bauer et al., 1993*). For the German banking sector there exist a small number of studies dealing with questions of efficiency. *Lang and Welzel (1994, 1995, 1996)* examine some 750 southern German cooperative banks, whereas *Lang and Welzel (1997)* is based on the data of about 1,450 German universal banks from all size classes, regions, and types (credit banks, savings banks, cooperative banks). All this work follows the parametric approach, i.e., a cost frontier is econometrically estimated and used to derive results on scale and cost efficiency. The main conclusions from these papers are the following: (1) German banks enjoy economies of scale up to total assets of 2-5 billion DM; cost disadvantages of surpassing this threshold are not significant. (2) Cost inefficiency is a much more important problem than size ineffi-

1 In 1996 there were rumours that large scale mergers among the biggest German banks might take place in the near future. These mergers could be motivated from the revenue side as opposed to the predominantly cost-induced mergers German banking experienced so far.

ciency. The basic insight for small German banks therefore is: Mergers do make sense, but internal cost inefficiencies very often offer a much higher potential for cost savings than the creation of a bank of minimum efficient size.

As opposed to the econometric work mentioned before, *Welzel (1996)* in a study of cooperative banks uses the non-parametric technique of „data envelopment analysis" (DEA) which generates a piecewise linear envelope of the data points. Applying this approach in addition to the econometric approach has become rather common in empirical research of the banking sector. Each one of these two methods has its merits and its drawbacks.[2] Our use of DEA in this paper is primarily motivated by the desire to apply an alternative technique in order to check the robustness of previous results based on econometric methods. For southern German cooperative banks a comparison of *Lang and Welzel (1996)* and *Welzel (1996)* shows that the main conclusions about the relevance of (technical and allocative) cost inefficiencies are very similar under both approaches. However, DEA seems to indicate a significantly smaller efficient size for the banks examined. The purpose of the present paper is to provide a basis for a similar comparison for a sample of universal banks which is representative for the German banking industry. By applying DEA we want to learn about the robustness of previous econometric results.

Our paper is organized as follows: In section 2 we describe the tools of non-parametric efficiency analysis to be used. Section 3 contains information on our data. In section 4 we present our results. Section 5 sums up.

2. DEA methods to evaluate bank efficiency

Under the non-parametric DEA approach we solve for each bank in our sample several linear optimization problems to calculate piecewise linear function which connect the most efficient firms (for a survey on DEA see e.g. *Seifford and Thrall, 1990*). Consider K banks each of which uses N inputs to produce M outputs. For each bank $i = 1,\ldots,\mathrm{K}$ denote input quantities by x_{ni}, $n = 1,\ldots,\mathrm{N}$, and output quantities by y_{mi}, $m = 1,\ldots,\mathrm{M}$, with $x_{ni} \geq 0$ and $y_{mi} \geq 0$, i.e., each bank has at least one strictly positive input and one strictly positive output. In order to derive an efficiency measure in this multi-input,

2 The parametric approach requires an assumption on the functional form of the frontier which is not needed in DEA. DEA emphasizes single observations and can therefore be affected by outliers in a much stronger way than econometric analysis which is focused on weighted averages. Under DEA all deviations from the efficient frontier are interpreted as inefficiencies whereas under the econometric approach we can distinguish between inefficiency and bad luck.

multi-output framework, we need an aggregate indicator of outputs relative to inputs (cf. *Farrell, 1957*). The DEA approach originating from *Charnes and Cooper (1962)* and *Charnes, Cooper and Rhodes (1978)* yields such an indicator. Denote by Y an M×K matrix of outputs with bank i's output in column i. Similarly, X is an N×K matrix of inputs. A measure $TE_i = \theta_i$ of technical efficiency can be calculated as a solution to

$$\min_{\theta_i,\lambda_i} \ \theta_i \quad \text{subject to}$$

$$\begin{aligned} &Y\lambda_i \geq y_i, \\ &X\lambda_i \leq \theta_i x_i, \\ &\theta_i \text{ free}, \ \lambda_i \geq 0. \end{aligned} \tag{1}$$

By solving this linear problem we identify a linear combination, described by the K×1 vector λ_i of weights, of all banks in the sample which produces at least the output quantities y_i of bank i and uses no more than a share $\theta_i \in]0,1]$ of its inputs x_i. Banks with a non-zero weight in λ_i are called reference banks for bank i. For $\theta_i = 1$ a bank is called technically efficient[3]; λ_i then has a value of 1 at element i as the only non-zero element. The way the problem was set up ensures that $\theta_i > 0$ and $\theta_i \leq 1$. By minimizing θ_i we maximize the proportionate reduction of bank i's inputs. This input-orientied perspective seems appropriate for an analysis of the German banking industry where management activity is strongly directed at increasing cost competitiveness.

The minimization problem (1) uses a constant returns to scale (CRS) technology as reference technology. To get a tighter fit of the efficient frontier and to be able to draw conclusions on size efficiency we also calculate (1) with either

$$e'\lambda_i = 1 \tag{2}$$

or

$$e'\lambda_i \leq 1 \tag{3}$$

as an additional restriction (cf. *Banker et al., 1984*, *Grosskopf, 1986*, *Aly et al., 1990*), where $e = [1,1,\ldots,1]'$ is a K×1 vector. Adding (2) implies convexity of the production possibility set, i.e., variable returns to scale (VRS), whereas using (3) restricts the technology to non-increasing returns to scale (NIRS).

Consider Figure 1 for the basic intuition (cf. *Färe and Grosskopf, 1985, p. 596*). There are seven banks A, B, C, D, P, R, and Q producing one output with one input. The fron-

3 Note that for the majority of the literature this is only weak efficiency. For strong efficiency we also require that all slack variables are zero. For a slightly different view see *Färe et al. (1987)* who prefer to interpret the slacks as an independent type of inefficiency.

tiers under CRS, NIRS, and VRS are represented by OB, OBCD, and $O^{VRS}ABCD$ respectively. By solving the three minimization problems (1), (1) and (2), and (1) and (3) we get three efficiency scores for each bank. For bank P this yields

$$TE_P^{CRS} = \theta_P^{CRS} = \frac{P_3P_2}{P_3P} = TE_P^{NIRS} = \theta_P^{NIRS}, \qquad TE_P^{VRS} = \theta_P^{VRS} = \frac{P_3P_1}{P_3P}. \tag{4}$$

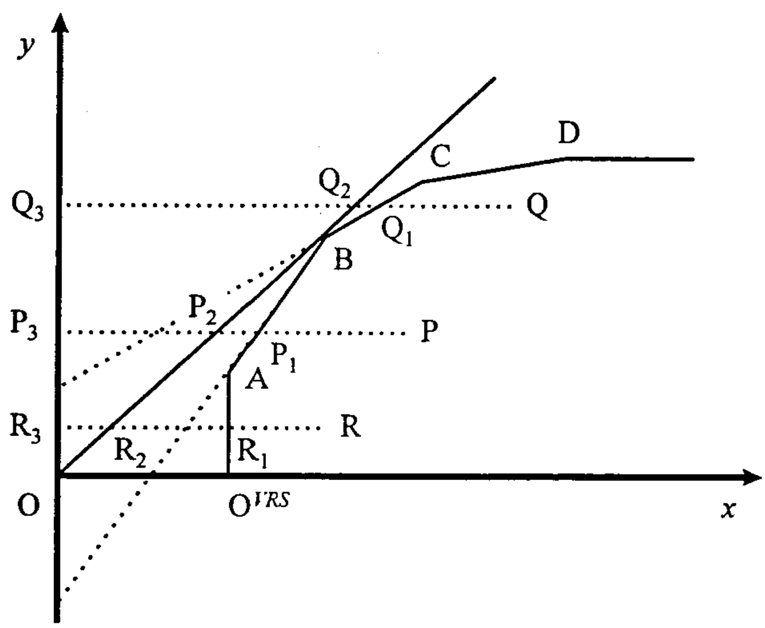
Using TE_i^{CRS} or TE_i^{NIRS} to evaluate a bank i 's technical efficiency can be inappropriate because these measures are influenced by non-optimal scale as is easily seen, for example, for bank P. Therefore TE_i^{VRS} is used to measure technical efficiency, and a ratio

$$SE_i = \frac{TE_i^{CRS}}{TE_i^{VRS}} \tag{5}$$

is defined as a measure of size efficiency of bank i . SE_i is the - proportionate, in the multi-input case - reduction of bank i 's inputs which can be achieved by adopting the CRS technology. $SE_i = 1$ is equivalent to size efficiency, whereas $SE_i < 0$ indicates size inefficieny.

Figure 1

Technical efficiency and size efficiency



Notice that for bank Q

$$TE_Q^{CRS} = \theta_Q^{CRS} = \frac{Q_3Q_2}{Q_3Q}, \qquad TE_Q^{VRS} = \theta_Q^{VRS} = \frac{Q_3Q_1}{Q_3Q} = TE_Q^{NIRS} = \theta_Q^{NIRS}, \tag{6}$$

which implies that both $SE_P < 1$ and $SE_Q < 1$ despite that fact P produces under increasing returns and Q produces under decreasing returns to scale. To arrive at a qualitative statement with respect to economies of scale one can exploit the fact that relaxing the convexity restriction, i.e., going from (2) to (3) and to altogether dropping the restriction, increases the distances from the frontier for some banks in a systematic way. We can then use a sequence of comparisons to determine whether a bank i operates under increasing (IRS), decreasing (DRS), or constant (CRS) returns to scale (see e.g. *Färe and Grosskopf, 1985, p. 597*):

$$\begin{aligned} \theta_i^{VRS} > \theta_i^{NIRS} \quad &\Rightarrow \quad \text{IRS} \\ \theta_i^{VRS} = \theta_i^{NIRS} > \theta_i^{CRS} \quad &\Rightarrow \quad \text{DRS} \\ \theta_i^{VRS} = \theta_i^{NIRS} = \theta_i^{CRS} \quad &\Rightarrow \quad \text{CRS} \end{aligned} \tag{7}$$

Banker et al. (1984) pointed out that the local scale properties of the technology at an efficient point which is not a vertex of the frontier can also be deduced from the sign of u_{0i} which is the dual variable for the convexity constraint (2) in the minimization problem under the VRS reference technology. Consider again Figure 1 for the intuition: As the broken lines indicate, the sign of the intercept of the (unique) supporting hyperplane for the production possibility set at a point such as P_1 or Q_1 tells us whether we have economies or diseconomies of scale. Formally u_{0i} determines this sign and scale properties as follows[4]

$$\begin{aligned} u_{0i} > 0 \quad &\Rightarrow \quad \text{IRS} \\ u_{0i} < 0 \quad &\Rightarrow \quad \text{DRS} \\ u_{0i} = 0 \quad &\Rightarrow \quad \text{CRS} \end{aligned} \tag{8}$$

This is not confined to efficient points: We can use θ_i^{VRS} to project an inefficient point onto the frontier and examine the sign of u_{0i}. Note that for efficient points such as A, B, C, or D which are vertices of the frontier the supporting hyperplane is not unique. In the case of B, for example, all lines between the two broken lines are equally valid. In those cases LP-solvers such as the linear programming tool in Gauss which was used in our calculations tend to give an arbitrary value for u_{0i} from the range of permissible values (cf. *Førsund and Hjalmarsson, 1996, pp. 19-20*). This can distort the classification of efficient banks as IRS, DRS or CRS firms as can be seen for observation B in Figure 1. While B operates under constant returns to scale, it will almost certainly be classified as either an IRS or a DRS bank.

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4 In the general case the hyperplane is given by $u_i'y_i - v_i'x_i + u_{0i} = 0$, where the u's and the v's are the solutions of the dual maximization problem to (1) and (2) (see e.g. *Førsund and Hjalmarsson, 1996*).

More recently *Førsund (1996)* and *Førsund and Hjalmarsson (1996)* derived explicit expressions for scale elasticity under piecewise linear multi-output technologies which lead to a quantitative measure that can easily be computed for the DEA model used before and is connected to qualitative measure suggested by *Banker et al. (1984)*. Basing the notion of scale elasticity on the relationship between the maximum proportionate expansion of outputs to a given proportionate expansion of inputs they show that under the input-oriented approach economies of scale can be calculated as

$$\varepsilon_i(y_i, \theta_i^{VRS} x_i) = \frac{\theta_i^{VRS}}{\theta_i^{VRS} - u_{0i}}, \tag{9}$$

where u_{0i} is defined as before. The role of θ_i^{VRS} is again to project the actual observation onto the VRS frontier, and (8) is valid as before. The minimum value of zero for ε_i is reached when u_{0i} takes its minimum value of minus infinity correspondig to a „horizontal" supporting hyperplane, and the maximum value of infinity for ε_i is reached when u_{0i} takes its maximum value of 1 for an efficient bank, corresponding to a „vertical" supporting hyperplane. Note that ε_i will also go to plus or minus infinity when θ_i^{VRS} is almost equal to u_{0i}.[5] For datapoints which are vertices of the frontier and therefore have multiple supporting hyperplanes *Førsund and Hjalmarsson (1996)* use a previous result from *Banker and Thrall (1992)* on minimum and maximum values of u_{0i} to deal with the problem non-uniqueness of the supporting hyperplane by calculating a lower and an upper bound for ε_i. The upper bound is given by

$$\varepsilon_i^{max}(y_i, x_i) = \frac{1}{1 - u_{0i}^{max}}, \tag{10}$$

where u_{0i}^{max} is the optimal value calculated from the program

$$\begin{aligned} \max_{u_i, v_i, u_{0i}} \quad & u_{0i} \quad \text{subject to} \\ & x_i' v_i = 1, \\ & Y' u_i - X' v_i + u_{0i} \leq 0, \\ & y_i' u_i + u_{0i} = 1, \\ & u_i, v_i \geq 0, \quad u_{0i} \text{ free,} \end{aligned} \tag{11}$$

suggested by *Banker and Thrall (1992)*. We transform this problem which has $\mathrm{K}+2$ restrictions into its computationally more convenient dual with only $\mathrm{M}+\mathrm{N}+1$ restrictions

5 If such cases were to exist in our sample, we would omit them unless $u_{0i} = 1$.

$$\min_{\theta_i,\lambda_i,\tau_i} \quad \theta_i + \tau_i \quad \text{subject to}$$
$$\begin{aligned} & Y\lambda_i + \tau_i y_i \geq 0, \\ & \theta_i x_i - X\lambda_i \geq 0, \\ & e'\lambda_i + \tau_i = 1, \\ & \lambda_i \geq 0, \quad \theta_i, \tau_i \text{ free.} \end{aligned} \tag{12}$$

The dual variable for the last restriction of this minimization problem gives us u_{0i}^{max}. For the lower bound we replace the objective function in (11) by $\max \; -u_{0i}$ and use the optimal value u_{0i}^{min} to calculate

$$\varepsilon_i^{min}(y_i, x_i) = \frac{1}{1 - u_{0i}^{min}} \tag{13}$$

So far our considerations were focused on technical efficiency and scale properties. In order to also determine overall efficiency and allocative efficiency, we solve

$$\min_{x_i,\lambda_i} \quad w_i' x_i \quad \text{subject to}$$
$$\begin{aligned} & Y\lambda_i \geq y_i, \\ & X\lambda_i \leq x_i, \\ & x_i \text{ free}, \; \lambda_i \geq 0, \end{aligned} \tag{14}$$

where w_i denotes the vector of input prices for bank i (cf. *Färe and Grosskopf, 1985, Ferrier et al., 1993*). This yields a cost-minimizing input vector x_i and a linear combination λ_i of all banks which produces at least bank i's outputs y_i and uses no more than its ideal input vector x_i^{CRS} under a CRS technology.[6] From the solution to (14) we get minimum costs as $w_i' x_i^{CRS}$. Comparing minimum costs to observed costs $w_i' x_i$ of bank i gives overall efficiency as

$$OE_i^{CRS} = \frac{w_i' x_i^{CRS}}{w_i' x_i}. \tag{15}$$

Since overall efficiency consists of allocative, technical, and scale efficiency we can use our knowledge of the latter two in order to infer the former. Writing $TE_i^{CRS} = \theta_i^{CRS}$ which is already known from (1) we then get allocative efficiency as

$$AE_i^{CRS} = \frac{OE_i^{CRS}}{TE_i^{CRS}} = \frac{OE_i^{CRS}}{TE_i^{VRS} \cdot SE_i}. \tag{16}$$

and a decomposition of overall efficiency as

6 Note that there is no restriction adding up the elements of λ_i which implies CRS for the reference technology.

$$OE_i^{CRS} = TE_i^{VRS} AE_i^{CRS} SE_i \,. \qquad (17)$$

3. Data

The database of this paper is an extension of the data used in *Lang and Welzel (1997)*. Our analysis is based on 1989-92 balance sheets income statements and additional information such as number of employees of 1,407 German universal banks.[7] Table 1 provides information on the size classes we defined for a condensed presentation of the output from the linear programs and to facilitate comparisons to the econometric results in *Lang and Welzel (1997)*.

Table 1

Number of banks by type and size class

Size Class	Total Assets (million DM)	Credit Banks	Savings Banks	Cooperative Banks	Total Number
class 1	0 - 25	1	0	16	17
class 2	25 - 50	0	0	116	116
class 3	50 - 100	4	0	214	218
class 4	100 - 250	15	0	272	287
class 5	250 - 500	15	0	114	129
class 6	500 - 1000	14	44	144	202
class 7	1000 - 2000	14	163	55	232
class 8	2000 - 5000	20	104	23	147
class 9	> 5000	20	36	3	59
	Total number	103	347	957	1407

Since at this stage we are not interested in issues of technological change, we calculate for each bank average values for all variables over four years (as in *Sheldon and Haegler, 1993*, *Sheldon, 1994*, on Swiss banking).[8] By taking averages we implicitly assume that a bank's efficiency does not change over time as we explicitly assumed in our panel study on cooperative banks in Germany. We also expect that stochastic influences - good and bad luck, measurement error - which DEA would lump together with inefficiency tend cancel out. The data covers about 40% of German universal banking in numbers and more than 80% in terms of total assets. As for the three types of German

7 We refer readers to this paper for a more detailed description of the data. Requiring that banks are observed for four years led us to a slightly lower number of banks than in the previous paper which applied the parametric approach.

8 The GDP deflator is applied to all nominal variables.

universal banks - (private) credit banks, (private) cooperative banks, and savings banks which are state-owned in the sense that cities or counties are the owners - our sample can be considered reasonably representative over types and over size classes with the exception of smaller savings banks.

As in most of the empirical literature our approach to modeling banking firms is based on the class of real resource models which have the advantage of accounting for operating expenses (cf. *Swank, 1996, pp. 192-198*). The most serious drawback of this approach admittedly is its failure to cope with the fact that risks like credit risk, funding risk, interest rate risk or price risk are inherent in banking. We follow the majority of the literature and apply the „intermediation approach" proposed by *Sealey and Lindley (1977)* which treats deposits as inputs and loans as outputs. Total costs consist of operating and interest costs, the former being defined as costs of labor and physical capital. Table 2 provides descriptive information on the variables entering our calculations.

Table 2

Description of the variables

Variable	Description	Mean Value	Standard Deviation	Minimum	Maximum
	total assets (million DM)	1754.1	10397.6	14.5	292726.9
y_1	short-term loans to non-banks (million DM)	360.6	3073.1	0.8	80232.5
y_2	long-term loans to non-banks (million DM)	579.8	2857.5	0.1	76264.2
y_3	loans to banks (million DM)	312.4	2982.2	1.2	90011.4
y_4	bonds, cash, shares (million DM)	335.0	1500.4	0.2	31269.8
y_5	commissions (million DM)	11.0	98.5	0.01	2743.2
x_1	labor (number of employees)	311.1	1755.4	2.3	46409.5
x_2	real capital (million DM)	21.7	88.8	0.1	1785.2
x_3	deposits (million DM)	1595.8	10397.6	13.4	259106.6
w_1	price of labor (thousand DM/employee)	73.0	14.0	41.8	190.4
w_2	price of real capital (%)	17.0	7.4	7.0	65.7
w_3	price of deposits (%)	5.0	0.8	3.1	11.0

Number of banks used: 1407; nominal variables deflated with GDP deflator; averaged over 1989 to 1992

We define inputs as labor (x_1), physical capital (x_2), and deposits (x_3). Input quantities are measured by the annual average of the number of employees, the value of fixed assets in the balance sheet, and the volume of deposits both from non-banks and banks, respectively. Factor prices for labor (w_1) and deposits (w_3) are calculated in a straightforward way by dividing expenses through input quantities. For the price of physical capital we draw upon the concept of user-costs: A price w_2 of capital is generated as sum of a bank's depreciation rate and opportunity cost. The former can be inferred from the balance sheet and the income statement. As for the latter, we use the (firm-specific) interest rate for loans less the expected rise in the value of the physical capital employed. We approximate this latter expectation by the growth rate of the producer price index for investment goods in Germany.

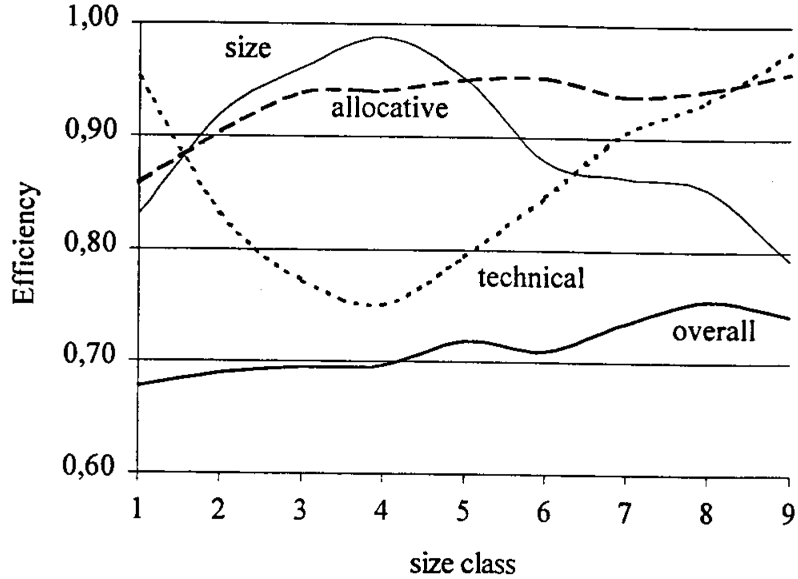
Reflecting both the limitations of the data and the German system of universal banking, we consider loans, security holdings, and commissions as outputs. More precisely, five outputs are defined as short-term loans to non-banks (y_1), long-term loans to non-banks (y_2), interbanking assets (y_3), a residual output (y_4), and commissions (y_5). Long-term loans have a duration of at least four years. The residual output includes bonds, cash and other assets held by a bank and not covered by outputs y_1 to y_3, with bonds dominating this variable. Notice that only share holdings for portfolio purposes were included in this variable which therefore does not cover investments German banks hold in other firms. Commissions, finally, are a proxy for off-balance-sheet assets. To the extent that they originate from services like buying and selling shares on behalf of customers, they are a consequence of the universal banking system in the German financial sector. Note that the definitions of our five output variables are motivated by theoretical considerations, by the institutional setup of German banking, by examples from the previous literature, but also by limitations of the data we had access to. We would very much like to include explicitly the services connected to current accounts in our analysis. Similarly, we are aware, as were *Sheldon and Haegler (1993)* and *Sheldon (1994)*, of the potential problem of mixing stocks (y_1, y_2, y_3, y_4) and a flow (y_5) which should be avoided by directly measuring the services related to trading shares and bonds. Like all authors in the empirical literature on banking efficiency we are forced to compromise about the way a banks's activities are measured.

4. Results

Table A-1 in the appendix contains the means, standard deviations, minimum and maximum values for overall, allocative, technical and size efficiency in each of the size classes defined above. In Figure 2 we present the means in graphical form. We observe a considerable degree of overall cost inefficiency across all size classes. On average total costs could be 47% lower in size class 1 and 35% lower in class 9, if all sources of inefficiency considered in our non-parametric approach were removed.[9]

Figure 2

Overall, technical, allocative, and size efficiency



The potential cost savings may appear rather high. However, they are roughly in line with previous econometric evidence in papers by *Lang (1996)* and *Lang and Welzel (1997)* on the German banking industry and with many DEA results from other countries (see Table 1 in *Berger and Humphrey, 1997*, for a comprehensive survey). If the numerical values for overall efficiency presented here are a bit lower than in our previous work, this can be explained by the fact the DEA lumps all stochastic influences such as measurement error and good or bad luck together with inefficiency. We should also point out that turning an average bank into a cost-efficient bank does not necessarily require laying off a large share of the bank's staff or selling its office buildings. In fact, total costs consist to about 75% of interest paid on deposits, whereas expenses for labor add only about 21%, and expenses for real capital at about 4% are almost negligible. Those banks which operate under full cost efficiency therefore must have an advantage related to buying or using deposits; they pay a lower interest rate and/or they need relatively less deposits to produce outputs. As can be seen from Figure 2, there is a tendency for overall efficiency to slightly increase with bank size. Only 18 banks are fully

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9 Overall cost inefficiency in percent is calculated as $(1/OE_i^{CRS} - 1)\cdot 100$. See the appendix for the algebra of transforming efficiency into inefficiency measures.

cost efficient, and none of these banks belongs to the lowest three size classes (see Table A-2 in the appendix).

By turning to the components of overall efficiency we find that allocative efficiency exhibits a very similar positive trend. From (16) we know that the measure of allocative efficiency is a (multiplicative) residual in our calculations. In order to get the similarity between the graphs of overall and allocative efficiency we observe in Figure 2 technical and size efficiency together must yield about a horizontal line. Notice that for all but the smallest and the largest banks allocative efficiency is greater than technical efficiency, i.e., the costs from proportionate waste of inputs dominate the costs from non-optimal adjustment to relative input prices (recall the terminology in *Farrell, 1957*). This again is a result in line with the literature such as *Lang and Welzel (1995, 1997)* and *Welzel (1996)* on German and *Berger and Humphrey (1991)* on U.S. banking. For the very smallest banks there are on average potential cost savings from removing allocative inefficiency of 16%. The very largest banks can save 4% of their costs by adjusting optimally to input prices. In our view it is rather plausible that larger banks do better in adjusting to relative input prices than smaller banks, since indivisibilities become less important as banks grow larger.

The graph of technical efficiency shows a striking U-shaped pattern indicating higher inefficiency for medium-sized banks. For the v-ry smallest and the very largest banks removing technical inefficiency would reduce total costs by 7% and 3%, respectively. For size class 4, on the other hand, getting rid of proportionate waste of all inputs offers cost savings of 35%. Our tentative explanation for these results is the following: At very small banks control of management functions rather well, i.e., there is little scope for wasting resources. These banks may suffer from indivisibilites, causing allocative inefficiency, and from unused economies of scale, causing size inefficiency, but they do not suffer very much from proportionate overuse of inputs. Very large banks, on the other hand, have better management tools and are scrutinized closely by their owners or by capital markets if they are listed joint-stock companies. In the middle range banks are too large to be easily overseen by owners and too small to have the most sophisticated management tools and to be under close control by capital markets. This interpretation is supported by a view at Table 1 which shows that the size classes where technical efficiency is lowest are those classes which consist almost exclusively of cooperative banks. As we argued in *Lang and Welzel (1996)* there are good reasons to expect agency problems to be most severe at banking firms of this particular legal structure.

One might object that the U-shaped graph of technical efficiency is an artificial result caused by the well-known tendency of DEA to generate high technical efficiency scores under the VRS reference technology for firms which are extreme in the sense of being very small or very large.[10] It is true, in fact, that the percentage of technically efficient banks is surprisingly high in size classes 1 and 9 as can be seen from Table A-2 in the appendix. However, even if the very smallest bank in our sample or „Deutsche Bank“ or the „Big Three“ of German banking were observations extreme enough for DEA to make them technically efficient for just this reason, we find it hard to imagine that the efficiency scores for such a large number of banks of relatively similar size in classes 1 and 9 should be biased upward all the way to 1 for lack of comparability. Furthermore, an upward bias of technical efficiency for extreme observations only poses a serious problem, if the dimensionality of the input/output space is high relative to the number of firms observed (cf. *Seiford and Thrall, 1990, p. 29*).

Size efficiency as the third component of overall efficiency exhibits a pattern inverse to the one of technical efficiency. Very small and very larger banks have low efficiency scores, whereas medium-sized banks do much better. If we again express our results in terms of inefficiency, it turns out that having the wrong size increases total costs by 24% in size class 1 and by 28% in class 9, whereas the level of size inefficiency in class 4 is only 1%. Banks in this class therefore almost operate at optimal size which in our sample seems to be found at total assets of only 100-250 million DM.[11]. This result on the optimal size in German banking is in line with the DEA-based evidence in *Welzel (1996)* where for 757 southern German cooperative banks full size efficiency was found at the very same level of total assets. Note that this also confirms a point made in our paper *Lang and Welzel (1997)* where based on the econometric approach we concluded that the instability recently emphasized by *McAllister and McManus (1993)* of optimal size with respect to the size of the banks included in the sample is not a problem with German data. However, since the parametric approach led us to conclude that efficient size of a German universal bank is given at total assets of 2-5 billion DM, we have a striking contradiction to our non-parametric result of 100-250 million DM. The only tentative explanation we currently have to offer for this discrepancy which shows up almost identically in the work of *Sheldon and Haegler (1993)* and *Sheldon (1994)* on Swiss banking points to the difference in the flexibility of the technology under the parametric and the non-parametric approach. In our previous econometric work we use a

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10 With a VRS technology imposed DEA tends to use neighboring firms as reference firms in the vector λ. Extreme observations have no neigbors and therefore are made their own reference firms, i.e., lack of comparision makes them appear technically efficient.

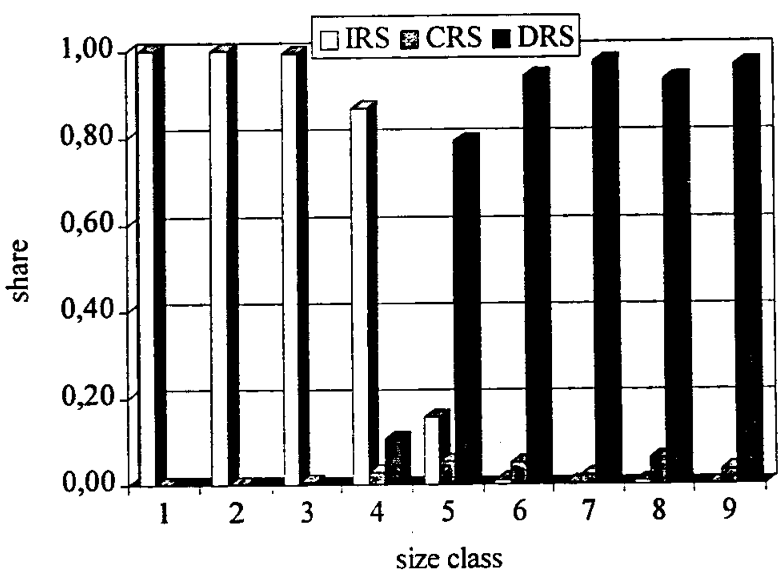
11 Note that size inefficiency at the two neighboring size classes 3 and 5 is also relatively low.

multi-product translog specification. This is clearly more restrictive than the description of the technology used under the DEA approach in the present paper.

In our reasoning on optimal scale we implicitly assumed that banks in size classes 5-9 where size efficiency declines suffer already from diseconomies of scale. To confirm this conjecture we refer our readers to Table A-3 in the appendix. In Figure 3 we show the share based on (7) of the number of banks in each class which operate under increasing, constant or decreasing returns to scale. Up to total assets of 250 million DM almost all banks enjoy increasing returns to scale, whereas beyond this threshold the vast majority of banks face decreasing returns. Thus our previous interpretation of the size efficiency measures was correct. Note that these results support the view widely held in the German banking industry that bank mergers among very small - in particular: cooperative - banks are beneficial due to scale economies.

Figure 3

Banks with increasing (IRS), constant (CRS), and decreasing (DRS) returns to scale



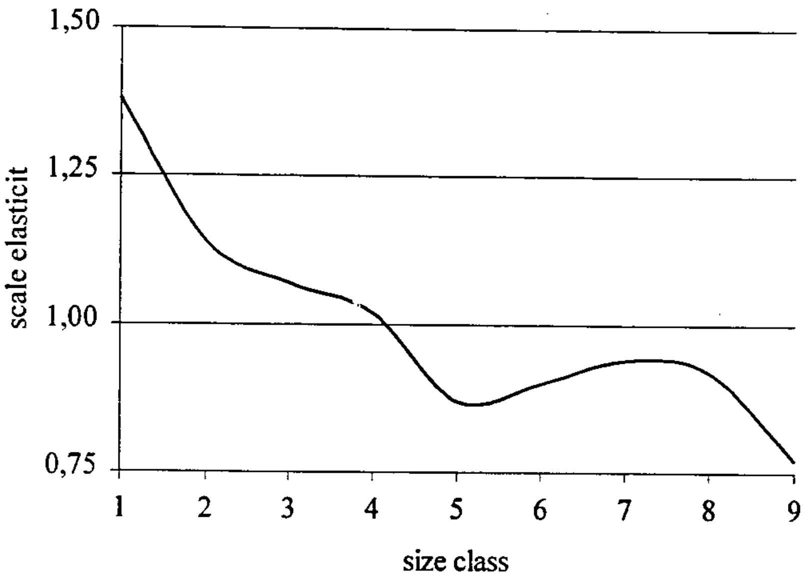
When we use (8) instead of (7) to sort banks there is no visible change in Figure 3. Only 42 banks are assigned scale properties different from the ones they had before. 41 of these banks are technically efficient and define vertices of the frontier, and one bank is technically inefficient but is projected into a vertex on the frontier. In all those cases the program gives an arbitrary value for u_{0i} from the range between a maximum and a minimum permissible value. Our reasoning in relation to Figure 1 suggested that CRS banks in particular run the risk of getting the wrong label. This is confirmed by our results which show that in 16 out of 42 cases banks which were CRS under (7) are now

IRS and in 24 out of 42 cases banks which were CRS are now DRS. The number of IRS, DRS and CRS banks is now 637, 767 and 3, respectively. All this does not affect the general picture of Figure 3.

Let us finally turn to scale elasticity as defined in *Førsund and Hjalmarsson (1996)*. Figure 4 shows the average values of $\varepsilon_i(y_i, \theta_i^{VRS} x_i)$ for the nine size classes, where we used u_{0i}^{min} if bank i is technically efficient. The diagram confirms our previous results on economies or diseconomies of scale in the German banking industry: Up to size class 4 banks on average enjoy increasing returns, beyond this threshold they suffer from decreasing returns. More detailed results on the number of IRS, CRS and DRS banks within size classes and their scale elasticities can be found in Table A-4 in the appendix.

Figure 4

Scale elasticity



5. Conclusions

In our introduction to this paper we emphasized two conclusions from previous econometric work on the efficiency or inefficiency of banking in Germany. As for the relative importance of allocative and technical inefficiency on the one hand and size inefficiency on the other, our earlier results are confirmed by our present non-parametric analysis for all but the very smallest and the very largest banks. For most German banks proportionate overuse of inputs at a given size is a much more serious problem than operating at non-optimal size. This is also in line with studies from other countries. Only for extremely small - typically cooperative - and for very large banks we would have to revise our earlier statement and point to the overriding importance of scale inefficiency. Note, however, that overall cost inefficiency, including all three components of efficiency, is still lowest for very large banks because they more than compensate for high size inefficiency with a low technical inefficiency. As we would expect, allocative inefficiency decreases with size.

As for optimal size in German banking there is a remarkable conflict between the econometric analysis and the DEA approach used here. Optimal size is now found to be no higher than 250 million DM of total assets with size inefficiency not being negligible beyond this threshold. This conflict is familiar from work on Swiss banking by *Sheldon and Haegler (1993)* and *Sheldon (1994)*. While the difference in the flexibility of the technology assumed here and in previous econometric work may be one reason for this discrepancy, we have to admit that we currently have no explanation to offer.

One striking feature in our results is the very high level of technical inefficiency of banks with total assets of 25-1,000 million DM. Since almost all banks in this range are cooperative banks, the following conclusion seems to be justified: Cooperative banks on average suffer more from proportionate overuse of inputs than other banks in the industry. This statement is also supported by the fact that previous DEA evidence in *Welzel (1996)* on southern German cooperative banks alone yielded much higher technical efficiency scores than our present analysis, where cooperative banks are not only measured against each other but also against credit and savings banks.

For those readers who are skeptical about the usefulness of non-parametric as opposed to econometric analysis for this type of research, we would like to mention recent comparisons by *Gong and Sickles (1992)* between DEA and stochastic frontiers in order to identify firm-specific inefficiencies. Using Monte Carlo techniques these authors conclude that DEA becomes more attractive as the misspecification of the functional form becomes more serious and as the degree of correlatedness of inefficiency with regressors increases. Also examining the links between parametric and non-parametric approaches, *Banker (1989)* states that the statistical properties of consistency and maximum likelihood estimation hold for DEA.[12] While these properties are almost taken as granted in econometric analyses, it should be pointed out that under DEA they do not require any assumptions about the parametric forms of the production function.

12 Firm-specific technical inefficiency is assumed to be a stochastic variable for this analysis.

There are a number of further steps we intend to take in this research. One is the use of bounds for the scale elasticity measure of efficient banks which currently are not included in the results we report. Another is an analysis of outliers and robustness of our conclusions. As a first step we will run the same calculations, but drop the very smallest and/or the very largest banks. More systematically, we plan to use the techniques suggested by *Fox and Hill (1996)* to test for the presence of outliers. Yet another step is to look into the - econometric - explanation of efficiency scores observed through variables not used in our DEA. This can also lead to conclusions on the relative efficiency of different types of banks in the industry. Finally, we plan to make use of recent insights in the field of stochastic DEA in order to run significance tests on average efficiency scores of size classes.

Appendix

Table A-1

Overall, technical, allocative, and size efficiency

	size class								
	1	2	3	4	5	6	7	8	9
overall efficiency									
mean	0.68	0.69	0.70	0.70	0.72	0.71	0.74	0.76	0.74
standard deviation	0.09	0.06	0.05	0.07	0.07	0.09	0.06	0.08	0.09
minimum	0.41	0.52	0.52	0.28	0.55	0.55	0.62	0.64	0.44
maximum	0.78	0.86	0.84	1.00	1.00	1.00	1.00	1.00	1.00
technical efficiency									
mean	0.95	0.83	0.77	0.75	0.79	0.85	0.91	0.93	0.98
standard deviation	0.06	0.07	0.07	0.08	0.08	0.06	0.04	0.04	0.03
minimum	0.86	0.64	0.59	0.56	0.67	0.73	0.81	0.84	0.91
maximum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
allocative efficiency									
mean	0.86	0.90	0.94	0.94	0.95	0.95	0.94	0.94	0.96
standard deviation	0.07	0.06	0.05	0.07	0.05	0.04	0.04	0.04	0.03
minimum	0.67	0.74	0.77	0.44	0.77	0.80	0.82	0.79	0.90
maximum	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
size efficiency									
mean	0.83	0.92	0.96	0.99	0.95	0.88	0.87	0.86	0.79
standard deviation	0.09	0.03	0.02	0.01	0.04	0.06	0.05	0.06	0.09
minimum	0.55	0.82	0.90	0.92	0.83	0.76	0.73	0.76	0.45
maximum	0.93	0.97	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table A-2

Number of frontier banks in problems for overall and technical efficiency

	size class								
	1	2	3	4	5	6	7	8	9
overall efficiency	0	0	0	4	1	5	2	5	1
percent of total	0.00	0.00	0.00	0.70	0.78	2.48	0.86	3.40	1.69
technical efficiency	8	1	3	9	8	10	8	17	29
percent of total	47.06	0.86	1.38	3.14	6.20	4.95	3.45	11.56	49.15

Table A-3

Banks with increasing, decreasing, and constant returns to scale

	size class								
IRS	1	2	3	4	5	6	7	8	9
number of banks	17	116	217	249	20	2	1	1	0
share of size class	1.00	1.00	0.99	0.87	0.16	0.01	0.01	0.01	0.00
mean SE_i	0.83	0.92	0.96	0.99	0.98	0.99	0.99	0.99	.
standard deviation SE_i	0.09	0.03	0.02	0.01	0.04	0.00	0.00	0.00	.
minimum SE_i	0.55	0.82	0.90	0.92	0.86	0.99	0.99	0.99	.
maximum SE_i	0.93	0.97	0.99	0.99	0.99	0.99	0.99	0.99	.
DRS	1	2	3	4	5	6	7	8	9
number of banks	0	0	0	30	102	190	226	137	57
share of size class	0.00	0.00	0.00	0.11	0.79	0.94	0.97	0.93	0.97
mean SE_i	.	.	.	0.99	0.94	0.87	0.86	0.85	0.79
standard deviation SE_i	.	.	.	0.01	0.04	0.05	0.05	0.05	0.08
minimum SE_i	.	.	.	0.95	0.83	0.76	0.73	0.76	0.45
maximum SE_i	.	.	.	0.99	0.99	0.99	0.99	0.99	0.96
CRS	1	2	3	4	5	6	7	8	9
number of banks	0	0	1	8	7	10	5	9	2
share of size class	0.00	0.00	0.01	0.03	0.05	0.05	0.02	0.06	0.03
mean SE_i	.	.	1.00	1.00	1.00	1.00	1.00	1.00	1.00
standard deviation SE_i	.	.	0.00	0.00	0.00	0.00	0.00	0.00	0.00
minimum SE_i	.	.	1.00	1.00	1.00	1.00	1.00	1.00	1.00
maximum SE_i	.	.	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table A-4

Scale elasticity for banks with increasing, decreasing, and constant returns to scale (u_{0i}^{min} used for technically efficient banks)

	size class								
IRS	1	2	3	4	5	6	7	8	9
number of banks	14	116	218	253	18	2	1	1	0
share of size class	0.82	1.00	1.00	0.88	0.14	0.01	0.01	0.01	0.00
mean ε_i	1.47	1.14	1.07	1.03	1.02	1.01	1.01	1.00	.
standard deviation ε_i	0.59	0.10	0.03	0.02	0.01	0.02	0.00	0.00	.
minimum ε_i	1.14	1.04	1.02	1.00	1.01	1.00	1.01	1.00	.
maximum ε_i	3.34	1.65	1.27	1.14	1.03	1.03	1.01	1.00	.
DRS	1	2	3	4	5	6	7	8	9
number of banks	3	0	0	34	111	200	231	146	59
share of size class	0.18	0.00	0.00	0.12	0.86	0.99	0.99	0.99	1.00
mean ε_i	1.00	.	.	0.90	0.84	0.90	0.94	0.92	0.77
standard deviation ε_i	0.00	.	.	0.17	0.14	0.09	0.10	0.18	0.24
minimum ε_i	1.00	.	.	0.02	0.19	0.41	0.03	0.06	0.07
maximum ε_i	1.00	.	.	1.00	0.99	0.99	0.99	0.99	0.99
CRS	1	2	3	4	5	6	7	8	9
number of banks	0	0	0	0	3	0	0	0	0
share of size class	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
mean ε_i	.	.	.	.	.	.	.	.	.
standard deviation SE_i	.	.	.	.	.	.	.	.	.
minimum ε_i	.	.	.	.	.	.	.	.	.
maximum ε_i	.	.	.	.	.	.	.	.	.

On the algebra of efficiency and inefficiency measures:

For those readers who prefer to think in terms of cost inefficiencies, i.e., percentages by which inefficiencies raise cost above minimum, we outline in the sequel how the efficiency measures originating from the linear programs described in the paper can be transformed into inefficiency measures.

Given overall cost efficieny OE^{CRS}, overall cost inefficiency is defined as[13]

$$IOE^{CRS} = \frac{1}{OE^{CRS}} - 1.$$

If this is multiplied by 100, it is the cost increase in percent from all three sources of cost inefficiency. Similarly, from AE^{CRS} we get allocative inefficieny as

$$IAE^{CRS} = \frac{1}{AE^{CRS}} - 1.$$

Taking the difference between these two inefficiency measures yields

$$ITE^{CRS} = IOE^{CRS} - IAE^{CRS} = \frac{1}{OE^{CRS}} - \frac{1}{AE^{CRS}}$$

as a broad measure of technical inefficieny which includes both (pure) technical inefficiency and size inefficiency. If, on the other hand, we use the VRS technology to calculate allocative efficiency as $AE^{VRS} = OE^{CRS}/TE^{VRS} = AE^{CRS}SE$, we get a second measure of allocative inefficiency

$$IAE^{VRS} = \frac{1}{AE^{VRS}} - 1,$$

which leads to pure technical inefficiency given by

$$ITE^{VRS} = IOE^{CRS} - IAE^{VRS} = \frac{1}{OE^{CRS}} - \frac{1}{AE^{VRS}}.$$

Taking the difference between technical inefficiency ITE^{CRS} inclusive of size inefficiency and technical inefficiency ITE^{VRS} exclusive of size inefficiency yields the following measure of size inefficiency

$$ISE = \frac{1-SE}{AE^{CRS}SE}.$$

This is equal to zero if $SE = 1$ and greater than zero if $SE < 1$. Note that overall cost inefficiency decomposes additively, i.e.

$$IOE^{CRS} = ITE^{VRS} + IAE^{CRS} + ISE,$$

whereas overall efficiency in (17) decomposes multiplicatively.

13 To keep the notation simple we drop the subscript „*i*".

References

Aly, H., Grabowski, R., Pasurka, C., Rangan, N. (1990), Technical, Scale and Allocative Efficiencies in U.S. Banking: An Empirical Investigation, Review of Economics and Statistics, vol. 72, S. 211-218.

Banker, R.D. (1989), Econometric Estimation and Data Envelopment Analysis, in: *Chan, J.L., Patton, J.M. (eds)*, Research in Governmental and Nonprofit Accounting. Volume 5, Greenwich et al.: JAI Press, 231-243.

Banker, R.D., Charnes, A., Cooper, W.W. (1984), Models for Estimating Technical and Scale Efficiencies in Data Envelopment Analysis, Management Science, vol. 30, 1078-1092.

Banker, R.D., Thrall, R.M. (1992), Estimation of Returns to Scale Using Data Envelopment Analysis, European Journal of Operational Research, vol. 62, 74-84.

Bauer, P.W., Berger, A.N., Humphrey, D.B. (1993), Efficiency and Productivity Growth in U.S. Banking, in: *Fried, H.O., Lovell, C.A.K., Schmidt, S.S. (eds)*, The Measurement of Productive Efficiency: Techniques and Applications, Oxford: Oxford University Press, 386-413.

Berger, A.N., Humphrey, D.B. (1991), The Dominance of Inefficiencies over Scale and Product Mix Economies in Banking, Journal of Monetary Economics, vol. 28, 117-148.

Berger, A.N., Humphrey, D.B. (1992), Megamergers in Banking and the Use of Cost Efficiency as an Antitrust Defense, Antitrust Bulletin, vol. 37, 541-600.

Berger, A.N., Humphrey, D.B. (1997), Efficiency of Financial Institutions: International Survey and Directions for Future Research, forthcoming in: European Journal of Operational Research.

Charnes, A., Cooper, W.W. (1962), Programming with Linear Fractional Functionals, Naval Research Logistics Quarterly, vol. 9, 181-185.

Charnes, A., Cooper, W.W., Rhodes, E. (1978), Measuring the Efficiency of Decision Making Units, European Journal of Operational Research, vol. 2, 429-444.

Färe, R., Grosskopf, S. (1985), A Nonparametric Cost Approach to Scale Efficiency, Scandinavian Journal of Economics, vol. 87, 594-604.

Färe, R., Grosskopf, S., Lovell, C.A.K. (1987), Nonparametric Disposability Tests, Journal of Economics, vol. 47, 77-85.

Farrell, M.J. (1957), The Measurement of Productive Efficiency, Journal of Royal Statistical Society, A 120, 253-281.

Ferrier, G.D., Grosskopf, S., Hayes, K., Yaisawarng, S. (1993), Economies of Diversification in the Banking Industry: A Frontier Approach, Journal of Monetary Economics, vol. 31, 229-249.

Førsund, F.R. (1996), On the Calculation of the Scale Elasticity in DEA Models, Journal of Productivity Analysis, vol. 7, 283-302.

Førsund. F.R., Hjalmarsson, L. (1996), Measuring Returns to Scale of Piecewise Linear Multiple Output Technologies: Theory and Empirical Evidence, paper presented at the 2nd Biennial Georgia Productivity Workshop, Athens, GA, November 1-3, 1996.

Fox, K.J., Hill, R.J. (1996), Indentifying Outlier Firms in Multiple Output - Multiple Input Efficiency Models, paper presented at the 2nd Biennial Georgia Productivity Workshop, Athens, GA, November 1-3, 1996.

Gong, B.-H. (1992), Finite Sample Evidence on the Performance of Stochastic Frontiers and Data Envelopment Analysis Using Panel Data, Journal of Econometrics, vol. 51, 259-284.

Grosskopf, S. (1986), The Role of the Reference Technology in Measuring Productive Efficiency, Economic Journal, vol. 96, 499-513.

Lang, G. (1996), Efficiency, Profitability and Competition. Empirical Analysis for a Panel of German Universal Banks, Discussion Paper No. 145, Institut für Volkswirtschaftslehre, Universität Augsburg.

Lang, G., Welzel, P. (1994), Skalenerträge und Verbundvorteile im Bankensektor. Empirische Bestimmung für die bayerischen Genossenschaftsbanken, ifo Studien, 40. Jg., 155-177.

Lang, G., Welzel, P. (1995), Strukturschwäche oder X-Ineffizienz? Cost-Frontier-Analyse der bayerischen Genossenschaftsbanken, Kredit und Kapital, 28. Jg., 403-430.

Lang, G., Welzel, P. (1996), Efficiency and Technical Progress in Banking: Empirical Results for a Panel of German Co-operative Banks, Journal of Banking and Finance, vol. 20, 1003-1023.

Lang, G., Welzel, P. (1997), Technology and Cost Efficiency in Banking - A „Thick Frontier"-Analysis of the German Banking Industry, forthcoming in: Journal of Productivity Analysis.

McAllister, P.H., McManus, D. (1993), Resolving the Scale Efficiency Puzzle in Banking, Journal of Banking and Finance 17, 389-405.

Seifford, L.M., Thrall, R.M. (1990), Recent Developments in DEA. The Mathematical Programming Approach to Frontier Analysis, Journal of Econometrics, vol. 46, 7-38.

Sheldon, G. (1994), Economies, Inefficiencies and Technical Progress in Swiss Banking, in: *Fair, D.E., Raymond, R. (eds)*, The Competitiveness of Financial Institutions and Centres in Europe, Dordrecht: Kluwer Academic Publishers, 115-132.

Sheldon, G., Haegler, U. (1993), Economies of Scale and Scope and Inefficiencies in Swiss Banking, in: *Blattner, N., Genberg, H., Swoboda, A. (eds)*, Banking in Switzerland, Heidelberg: Physica-Verlag, 101-134.

Swank, J. (1996), Theories of the Banking Firm: A Review of the Literature, Bulletin of Economic Research, vol. 48, 173-207.

Welzel, P. (1996), Kosten- und Größeneffizienz im Bankgewerbe. „Data Envelopment Analysis" der bayerischen Genossenschaftsbanken, Jahrbuch für Wirtschaftswissenschaften (Review of Economics), Bd. 47, 179-200.

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