Efficiency and technical progress in banking: empirical results for a panel of German co-operative banks

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von

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Abstract

Using 1989-1992 individual data of 757 German co-operative banks we specify a multi-product translog cost function for this part of the German banking industry. We apply the intermediation approach and estimate both a fixed and a random effects model. Measures of economies of scale and scope are calculated in addition to indicators of overall cost efficiency and of technical progress. For all size classes we find moderate economies of scale. There is also evidence of economies of scope which supports the notion of universal banking. The average banks of all size classes in the sample deviate considerably from the best practice cost frontier. All banks enjoy growth of total factor productivity which is higher for the smaller banks in the sample.

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1. Introduction*

Industry observers frequently point to an increase in concentration in the banking sector during the last decades which is expected to continue throughout the 1990s. In Germany, for example, the number of banks decreased by 16% from end of 1990 until end of 1993. Unlike in the U.S., however, the economics of this trend towards larger banks have not been sufficiently analyzed in Europe. Notable exceptions are *Hermann and Maurer (1991)*, *Sheldon (1993)* and *Sheldon and Haegler (1993)* on Swiss banking, *Berg and Kim (1993, 1994)* on Norwegian banking, and *Kolari and Zardkoohi (1990)* and *Zardkoohi and Kolari (1994)* on Finnish banking. Despite considerable interest in research on the technology of this service sector on the part of both banks themselves and their regulators, there are no such analyses for Germany. Little is known, for example, about efficiency gains from increasing the size of a bank or from extending the range of its products. This deficit in empirical research on the German banking sector is probably due to a lack of accessible micro data.

For a long time the empirical literature was dominated by research on scale economies in banking. Studies in this tradition treated banks as single-product firms (see e.g. *Benston et al., 1982*, *Clark, 1984*, *Hunter and Timme, 1986*). Theoretical work by *Baumol et al. (1982)*, but also empirical results by *Kim (1986)* on the consequences of using highly aggregated output measures, led to models of banks as multi-product firms and to the analysis of economies of scope. Among others *Murray and White (1983)*, *Gilligan and Smirlock (1984)*, *Gilligan et al. (1984)*, *Kim (1986)*, *Mester (1987)*, *Berger et al. (1987)*, *Sheldon (1993)* followed this line of research. More recently, *Berger and Humphrey (1991, 1992)* and *Bauer et al. (1993)* showed the existence of considerable cost inefficiencies in the banking industry which dominate the potential cost savings from adjusting to optimal sizes.

In the present paper, we are able to use data of all Bavarian co-operative banks for the years 1989 to 1992. Our aim is to provide answers to the following questions: (1) Do larger banks enjoy a cost advantage over smaller competitors? This is the question of economies of scale. (2) Do banks with joint production of several outputs enjoy a cost advantage compared to banks specializing in a more restricted output mix? This is the

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question of economies of scope. (3) Do all banks operate on the best practice cost frontier? This is the question of cost efficiency. (4) Do banks enjoy technical progress? This is the question of changes in factor productivity over time. Since the banks in our sample cover only a small fraction of the market, we are currently in no position to derive conclusions for German banking as a whole. Given the lack of such analyses and the considerable merger activities among co-operative banks during recent years, however, insights into the technology of these banks are clearly of interest.

The plan of the paper is as follows: In section 2 we present our specification and estimation methods, and give a brief review of measures used to analyze the technology of banking. In section 3 our data are explained. Section 4 contains our empirical results. Finally, section 5 sums up.

2. Theoretical Background

2.1. Econometric Specification

Observations on output quantities and input prices are used to estimate a cost function which allows us to draw conclusions on the technology of banks. More specifically, we employ a non-homothetic functional form of the translog-type (cf. *Diewert and Wales, 1987, Pulley and Braunstein, 1992).* Total costs C of an individual bank are given as a function of three factor prices w_i, $i = 1,2,3$, six output levels y_m, $m = 1,\dots,6$, the number of branch offices *br,* a dummy variable *merger,* and a time index $t = 1,\dots,4$. Using subscripts *k* and *t,* the translog cost function for a given bank *k* at time *t* is specified as follows:

$$\begin{aligned}\ln C_{kt}(w_{kt}, y_{kt}, br_{kt}, merger_{kt}, t) = {} & a_0 + \sum_{i=1}^{3} a_i \ln w_{ikt} + \sum_{m=1}^{6} b_m \ln y_{mkt} \\ & + \frac{1}{2}\sum_{i=1}^{3}\sum_{j=1}^{3} \alpha_{ij} \ln w_{ikt} \ln w_{jkt} + \sum_{i=1}^{3}\sum_{m=1}^{6} \gamma_{im} \ln w_{ikt} \ln y_{mkt} \\ & + \frac{1}{2}\sum_{m=1}^{6}\sum_{n=1}^{6} b_{mn} \ln y_{mkt} \ln y_{nkt} + \theta \ln br_{kt} + \frac{1}{2} c\,(\ln br_{kt})^2 + \sum_{i=1}^{3} d_i \ln w_{ikt} \ln br_{kt} \\ & + e_0 t + \frac{1}{2} e_1 t^2 + \sum_{i=1}^{3} \lambda_i \ln w_{ikt}\, t + \sum_{i=1}^{3} g_i \ln w_{ikt}\, merger_{kt} + \mu_k + u_{kt}\end{aligned}$$

As in *Mester (1987)* the branching variable *br* is treated as a technological condition of production and interacts with other exogenous variables. To control for potential disequilibrium effects of merger activities, an interaction term with a dummy variable *merger* is included. Individual disturbance vectors u_k are assumed to have zero means $E(u_k) = 0$, variances $E(u_k u_k') = \sigma^2 I_t$ and zero covariances $E(u_k u_l') = 0$, $k \neq l$, across banks. To ensure symmetry and linear homogeneity in input prices, the following restrictions are imposed:

$$a_{ij} = a_{ji} \quad i,j = 1,2,3 \qquad b_{mn} = b_{nm} \quad m,n = 1,\dots,6$$

$$\sum_{i=1}^{3} a_i = 1 \qquad \sum_{i=1}^{3} d_i = 0 \qquad \sum_{i=1}^{3} f_i = 0 \qquad \sum_{i=1}^{3} g_i = 0$$

$$\sum_{j=1}^{3} a_{ij} = 0 \quad i = 1,2,3 \qquad \sum_{i=1}^{3} g_{im} = 0 \quad m = 1,\dots,6$$

As the cost function indicates, we work under the assumption that intercepts vary across individual banks, whereas slope coefficients are identical. In addition we assume that regression coefficients do not vary over time. Individual effects which will be used to measure differences in cost efficiency are therefore captured by the μ_k terms in the cost function. Given our specification, two alternative estimation procedures for panel data can be applied: If individual effects μ_k are assumed to be fixed, i.e., non-stochastic, a fixed effects model is appropriate. If, on the other hand, individual effects are assumed to be random, a random effects technique has to be used. Under the former approach, the data are treated as being representative only for the banks in the dataset. In a strict sense the model therefore does not apply to banks outside the sample. In the latter case, however, the sample is treated as if it represented a larger population and allowed conclusions on banks outside the sample (cf. *Greene, 1993, p. 469*). In the following, we pursue both approaches in order to check the robustness of our results (for details of the estimators see e.g. *Greene, 1993, ch. 16*).

2.2. Economies of Scale and Scope, Cost Efficiency and Technical Progress

From the estimated cost function measures of economies of scale and scope, overall cost efficiency, and the rate of technical progress will be calculated. Scale economies can arise from improved division of labor and specialization in larger firms. In addition, there is a bank-specific reason for increasing returns to scale: Depositors face a lower risk at a larger bank. They are therefore willing to hold larger balances in their accounts which reduces the bank's costs per currency unit deposited (see *Sheldon, 1993, S. 356*).

The ray scale elasticity

$$RSCE(y) = \left.\frac{\partial \ln C(\lambda y)}{\partial \ln \lambda}\right|_{\lambda=1} = \sum_{m=1}^{6} \frac{\partial \ln C(y)}{\partial \ln y_m} = \sum_{m=1}^{6} \frac{\partial C(y)}{\partial y_m} \frac{y_m}{C(y)}$$

is used to measure economies of scale. *RSCE* is the relative cost increase caused by a relative increase in outputs where the levels of all outputs are raised proportionately. Values of *RSCE* of less than one indicate cost increases which are less than proportionate to output increases. A given output vector can then be produced at a lower cost within one big firm compared to several smaller firms with the same composition of outputs.

To avoid using the assumption of proportionate changes in all outputs, *Berger et al. (1987)* presented an alternative measure of scale economies. They compare two firms *A* and *B* which are immediate neighbors in the size distribution but do not necessarily share the same output structure. An expansion path scale elasticity is calculated as

$$EPSCE(y^A, y^B) = \sum_m \frac{(y_m^B - y_m^A)/y_m^B}{(C(y^B) - C(y^A))/C(y^B)} \frac{\partial \ln C(y^B)}{\partial \ln y_m^B}.$$

EPSCE indicates the cost advantage or disadvantage of a (larger) bank *B* compared to a (smaller) bank *A* by measuring the elasticity of costs with respect to output changes from vector y^A to y^B. For values of *EPSCE* of less than one the larger bank *B* enjoys a cost advantage over bank *A*.

Economies of scope in banking can arise from a variety of factors (cf. *Berger et al., 1987, pp. 504-505Y* (a) fixed costs, e.g. of branch offices, computer equipment, or collection of information on the financial status of customers can be spread across several products; (b) diversification and adjustment of maturities of deposits and loans can be used to reduce the portfolio and the interest rate risks; (c) customers enjoy an advantage from being served with several products at one bank, which allows banks to extract some of this additional consumer surplus by charging higher fees for their sendees. Our cost function is able to capture effects of type (a). The traditional measure for economies of scope, used for example in *Mester (1987),* gives the relative cost increase from producing a firm's output vector in two or more different firms which specialize in some of the outputs. To calculate this measure, some components of the output vectors have to be set to zero which can be criticized in our framework for at least two reasons. Firstly, we do not find banks in the dataset and in the economy in general which are completely specialized. We can rather expect banks to differ in their degree of specialization. Evaluating the cost function in those regions of full specialization is therefore equivalent to extrapolating the estimated function far beyond the range of output vectors covered by the data. Secondly, output levels of zero which are used to measure economies of scope are in conflict with the specification of a translog cost function, since the log of zero does not exist. There are a number of „solutions“ for this problem in the literature (see e.g. *Mester, 1987, p. 439, Berger et al., 1987, p. 513,* or *Pulley und Braunstein,* *1992, p. 227*), but none of them is very convincing.[1] We therefore employ a modified measure of economies of scope (see *Kolari and Zardkoohi, 1987*):

$$MSCOPE_T(y^B, y^A) = \left[\left(C\left(y_T^B, y_{-T}^A\right) - C\left(y_T^A, y_{-T}^A\right)\right) + \left(C\left(y_T^A, y_{-T}^B\right) - C\left(y_T^A, y_{-T}^A\right)\right)\right.$$
$$\left. -\left(C\left(y_T^B, y_{-T}^B\right) - C\left(y_T^A, y_{-T}^A\right)\right)\right] \cdot \left[C\left(y_T^B, y_{-T}^B\right) - C\left(y_T^A, y_{-T}^A\right)\right]^{-1},$$
$$\text{where} \quad T \subset \{1,\ldots,6\}, \quad -T = \{1,\ldots,6\} \setminus T.$$

y_T^B (y_T^A) denotes the output vector of bank *B* (*A*) in which all outputs which are not covered by the index set *T* are set equal to zero. Analogously, y_{-T}^B (y_{-T}^A) is the output vector of bank *B* (*A*) in which all outputs belonging to *T* are set equal to zero. We compare a (larger) bank *B* to a (smaller) bank *A*. If $MSCOPE_T$ is greater (less) than zero, the difference between output vectors y^B and y^A can be produced at a lower (higher) cost within a single bank as opposed to production in several specialized firms. If there are economies of scope, a bank of type *A* which increases only outputs in *T* or in *-T* is at a cost disadvantage compared to a bank of type *B* or a bank of type *A* which increases its outputs according to the proportions suggested by the output structure of bank *B*. As for the index set, we analyze six cases with $T = \{m\}$, $m = 1,\ldots,6$. In addition, we follow the example of *Sheldon (1993)* and evaluate economies of scope for two groups of outputs. As it turns out in our dataset, it is interesting to ask whether or not there are economies of joint production of loans and other services offered by the banks. For this reason we also use $T = \{5,6\}$ and $-T = \{1,2,3,4\}$.

Berger et al. (1987) suggested expansion path subadditivity as yet another measure of economies of scope. Again a (larger) bank *B* and a (smaller) bank *A* are considered. Define the output of a hypothetical bank *D* as the difference $(y^B - y^A)$ of the output vectors of banks *B* and *A*. We then calculate

$$EPSUB(y^B, y^A) = \frac{C(y^A) + C(y^D) - C(y^B)}{C(y^B)}.$$

This is the relative cost increase or decrease arising from producing bank *B*'s outputs in bank *A* and in the complementary bank *D*. Positive (negative) values of *EPSUB* indicate economies (diseconomies) of scope. Notice, however, that *EPSUB* and $MSCOPE_T$ include both economies of scope and scale.

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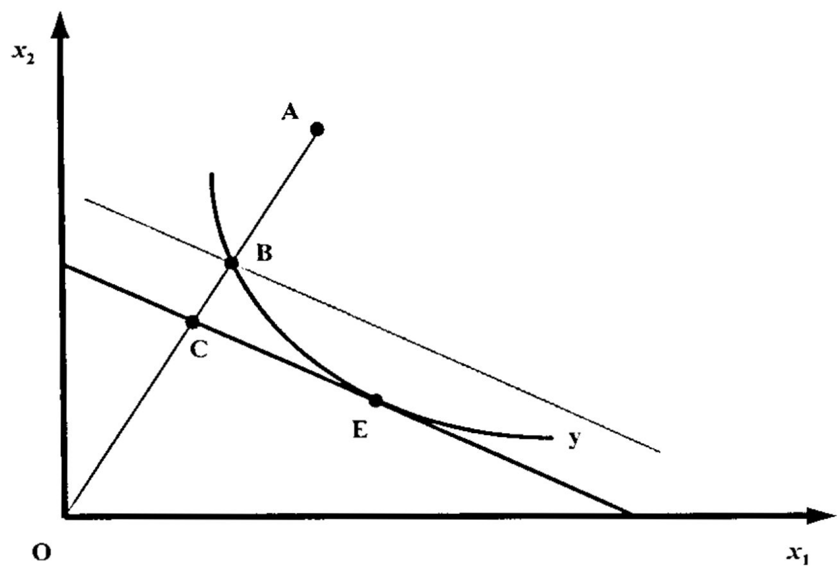
1 In fact, we also used replacement values like DM 1,000 instead of zero outputs, but the traditional measure of economies of scope turned out to be rather sensitive to changes in the hypothetical output value.

The intuition of a measure of overall cost efficiency proposed by *Farrell (1957)* can be seen from figure 1. For two inputs x_1 and x_2 and a given level y of a single output, E denotes the most efficient point. If the firm instead uses the input combination given by point A to produce y, it suffers from two types of inefficiencies: (a) It is inefficient in a technical sense, since by moving to point B it could produce the same output with less inputs. The ratio OB:OA provides a measure of technical efficiency. (b) It is allocatively inefficient, since by moving from B to point E and thereby adjusting to the given factor prices it could produce the same output at a lower total cost. The ratio OC:OB provides a measure of allocative efficiency. Overall cost efficiency can be defined by the ratio OC:OA which corresponds to the product of technical efficiency OB:OA and allocative efficiency OC:OB. All three ratios are in the interval (0,1], where a value of one indicates full efficiency.

Figure 1

Technical, allocative, and overall cost efficiency



In our translog cost function the individual effects μ_k, which are calculated both for the fixed and the random effects model, can be used as indicators of cost efficiency (see *Bauer et al. 1993, p. 392*). The bank with the lowest intercept is the most efficient bank in the sample, and all other banks are assigned an efficiency measure relative to this bank. More precisely, overall cost efficiency of bank k is calculated as

$$\rho_k = \exp\left[\min(a_0 + \mu_1, \ldots, a_0 + \mu_k, \ldots, a_0 + \mu_K) - (a_0 + \mu_k)\right].$$

Finally, to account for the fact that costs are not only influenced by output levels and factor prices but also by technical progress, linear and squared time trends were included in the specification of the cost function. Aggregate technical progress ε_t can then be calculated as the elasticity of total cost C with respect to time t, i.e., $\varepsilon_t = \partial \ln C / \partial t = (\partial C / \partial t)/(1/C)$.

3. Data

The study is based on a combined times series and cross-sectional dataset for 757 Bavarian co-operative banks over the period 1989-1992. In particular, we had access to the balance sheets and the income statements of all Bavarian co-operative banks,[2] and were also given information on the number of employees, the number of branch offices, and on merger activity, if there was any. This segment of the German banking industry which covers less than 20% of all banks in Germany is characterized by low absolute firm sizes, relatively high numbers of branch offices, and by a volume of loans which in many cases is significantly lower than the volume of deposits.

To model the banks we follow the majority of the literature and rely on the intermediation approach which treats deposits as inputs and loans as outputs (cf. *Sealey and Lindley, 1977*). As *Berger et al. (1987)* have shown, the alternative technique of the production approach, where both deposits and loans are interpreted as outputs which are produced with the non-interest bearing factors labor and physical capital, leads to biased scale and scope measures, because larger banks employ a higher proportion of interbanking deposits.

Table 1 gives the minimum, maximum, mean values, and the standard deviations of the variables for the year 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 nominal 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 investment goods employed, where we approximate this expectation by the growth rate of the producer price index for investment goods in the German economy. While this approximation of a price of physical capital is far from perfect, we feel rather confident that our approach is more reliable than what can be found in related work in

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2 About ten banks were excluded from the estimations because their data were not consistent with the data of the other banks.

the literature, where rents for office space, depreciation, spending on furniture etc. are used as proxies for the quantity of physical capital and a price is generated by dividing quantity by the volume of deposits or the number of employees (see e.g. *Mester, 1987, Sheldon and Haegler, 1993*). Total costs C are finally calculated as the sum over $w_i x_i$, $i = 1,2,3$.

Table 1

Description of the data, 1992

Variable	Description	Mean Value	Standard Deviation	Minimum	Maximum
C	total cost (million DM)	12.43	15.09	1.04	177.55
w_1	price of labor (thousand DM/employee)	77.91	9.27	50.38	133.00
w_2	price of capital (%)	16.78	5.06	7.93	81.89
w_3	price of deposits (%)	5.66	0.48	3.57	8.34
x_1	volume of labor (number of employees)	37.19	42.20	3	566
x_2	volume of capital (fixed assets in million DM)	3.94	4.42	0.05	43.30
x_3	volume of deposits (million DM))	153.51	184.76	13.33	2479.65
y_1	short-term loans to non-banks (million DM)	22.07	34.55	0.45	431.00
y_2	long-term loans to non-banks (million DM)	80.22	95.84	3.15	1003.08
y_3	loans to banks (million DM)	18.48	32.63	0.30	671.78
y_4	bonds, cash, real estate investments (million DM)	47.76	58.48	2.96	1033.66
y_5	fees and commissions (million DM)	0.88	1.20	0.006	15.93
y_6	revenue from sales of commodities (million DM)	2.52	3.94	0.001	33.22
br	number of offices	6.06	5.66	1	39
merger	dummy for merger	0.178	0.383	0	1

Numbers of observed banks: 757

We consider six outputs $y_i, i = 1,\ldots,6$: 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); fees and commissions (y_5); revenue from sales of commodities (y_6). Long-term loans are defined as having a duration of at least one year. The residual output variable includes bonds, cash holdings and other assets not covered by outputs y_1 to y_3. Income from fees and commissions is a consequence of the universal banking system in the German financial sec tor. Revenues from selling commodities, on the other hand, are a specific characteristic of the co-operative banks in our dataset which often operate in rural areas. Since 269 of our 757 banks do not engage in these activities. j'_6 takes the value of zero for these banks which implies that the translog function is not defined. To avoid this problem, we use a substitute value of DM 1,000 in these cases. All other output variables only take strictly positive values for all banks in the dataset.

A familiar problem of panel data is the exiting and entering of micro-units over time. In the case of our co-operative banks the observed fluctuations were rather strong because of significant merger activities. One possibility to deal with this fact would be to eliminate all banks which took part in a merger during the years covered by our panel. This would, however, reduce the sample by 135 observations per year, and could create a selection bias. We therefore decided to proceed in the following way: If two or more banks merged in the period from 1989 until 1992. the relevant data were aggregated into a single bank for each year of our sample period. In a second step we calculated input prices for these hypothetical firms. In short, we treated all mergers as if they had happened already before 1989. To control for potential disequilibrium effects in these cases, a dummy variable *merger* was used.

4. Empirical Results

4.1. Fixed and Random Effects Estimations

Table A-l in the appendix contains the parameter estimates both for the fixed and the random effects model of the translog cost function. Since the *Breusch-Pagan* test led to a rejection of the null hypothesis of homoscedastic errors, we used *White's (1980)* correction for the standard errors. Under both estimation approaches R^2 takes a very high value and the majority of the parameters are significant. To test whether individual effects are present, we also ran an F-test for the fixed effects model and a *Lagrange multiplier* test by *Breusch and Pagan (1980)* for the random effects model. In both cases the null hypothesis of no individual effects was rejected at the 1%-level. Table A-2 in the appendix gives summary information on the bank-specific intercepts.

Before drawing conclusions on the underlying technology of the banks, we have to check whether our estimated function meets the theoretical requirements for a cost function. Table 2 provides information on four criteria which are examined for even' observation in the dataset. There are some violations, in particular for concavity under the random effects approach, but compared to other studies with translog specifications our data perform rather well. We therefore feel encouraged to proceed with our analysis.[3]

Table 2

Properties of the estimated cost function

Criterion	Actual Violations		Potential Violations
	Fixed Effects	Random Effects	
increasing in outputs:	2355	1046	18168
increasing in input prices:	57	80	9084
concave in input prices:	516	1304	3028
negative own-price elasticity:	239	977	9084

In reaction to a recent paper by *McAllister and McManus (1993)* who pointed at parameter instability as a potential reason for a rightward shift of the minimum efficient size in U.S. banking studies when smaller banks are excluded from the sample, we also ran *Chow*-tests, using total assets to split our sample in two subsamples in six different ways. For all tests the null hypothesis of identical parameters in both subsamples was rejected at the 1%-level. We then calculated our main indicators of technology both for parameter estimates based on the full sample and for estimates based on two separate regressions using banks with up to DM 100 million and more than DM 100 million in assets. Since we found neither qualitatively nor quantitatively significant differences between these approaches, we restrict our presentation in the following to results from the full sample.[4]

4.2. Characteristics of the Banking Technology

We follow *Berger et al. (1987)* and use total assets in 1992 to divide our sample in ten size classes which are defined in table A-3 in the appendix. For each class a „typical" bank with the class means of input prices, outputs, branches and merger activity is generated and averaged over all years. For these ten banks we then evaluate our measures of technology.

Table 3 contains the measures *RSCE* and *EPSCE* for scale economies under both the fixed and the random effects models.

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3 In previous work with a translog cost function and two cost share equations for the year 1992 we found almost no violations of theoretical requirements (see *Lang and Welzel, 1994*).

4 Results based on the subsamples are available from the authors upon request.

Table 3
RSCE and *EPSCE*

	Fixed Effects		Random Effects	
	RSCE	*EPSCE*	*RSCE*	*EPSCE*
class 1	0.8370	-	0.9565	-
class 2	0.8318	0.8122	0.9521	0.8781
class 3	0.8354	0.8135	0.9546	0.9168
class 4	0.8319	0.8307	0.9512	0.9640
class 5	0.8367	0.7993	0.9552	0.8719
class 6	0.8388	0.8155	0.9582	0.8653
class 7	0.8377	0.8145	0.9566	0.9366
class 8	0.8378	0.8812	0.9564	1.2498
class 9	0.8363	-	0.9545	-
class 10	0.8267	0.8190	0.9448	0.9435

Note that due to the definition of *EPSCE* this indicator can not be calculated for class 1. In addition, there is no value of *EPSCE* for class 9 because not all outputs of the average bank in this class are greater than the corresponding outputs of the typical bank in class 8. Both *RSCE* and *EPSCE* indicate the existence of scale economies for all classes and both estimation methods. There are, however, quantitative differences between the fixed and the random effects approach. Under the former, cost advantages from increasing bank size are higher. Notice that for a given estimation method *RSCE* and *EPSCE* take rather similar values with *EPSCE* being a little smaller. This suggests that only small gains from non-proportional growth exist. Furthermore, there is no evidence of a size trend, i.e., all size classes seem to enjoy almost the same cost advantages from output growth. This result differs from the findings in other studies where larger banks were often seen as facing declining scale economies or even diseconomies of scale (see e.g. *Berger et al., 1987*).

In table 4 we collect results for $MSCOPE_{5,6}$ and *EPSUB*. Again, the measures can not be calculated for classes 1 and 9. Recall from the previous definition that $MSCOPE_{5,6}$ is an indicator of cost advantages from joint production of loans (outputs 1 to 4) and other services (outputs 5 to 6). Both for the fixed and the random effects model we can conclude that joint production of loans and other services is efficient. This can even be interpreted as empirical support for the German system of universal banking. As for *EPSUB* we see that the results from the two estimation methods are contradictory. The random effects model suggests that there are diseconomies of scope.

Table 4

$MSCOPE_{5,6}$ and $EPSUB$

	Fixed Effects		Random Effects	
	$MSCOPE_{5,6}$	$EPSUB$	$MSCPOE_{5,6}$	$EPSUB$
class 1	-	-	-	-
class 2	0.1510	0.0689	0.1018	-0.0271
class 3	0.1550	0.0511	0.0620	-0.0181
class 4	0.1397	0.0757	0.0164	0.0098
class 5	0.1796	0.0459	0.1114	-0.0285
class 6	0.1609	0.0385	0.1201	-0.0358
class 7	0.1601	0.0362	0.0460	-0.0113
class 8	0.0946	0.0530	0.2729	0.0470
class 9	-	-	-	-
class 10	0.1148	0.0044	0.0115	-0.0207

Tables A-4 and A-5 in the appendix contain the results for the disaggregated measures $MSCOPE_T$. For the fixed effects model all values are positive, and there are no significant differences between size classes. Increasing only production of one output or of its complementary output therefore puts a bank at a cost disadvantage compared to the reference bank in the next size class. Under the random effects approach the values of $MSCOPE_T$ are more erratic, but in most cases they also indicate economies of scope.

Table 5

Degree of cost efficiency ρ_k, and technical progress ε_t

	Fixed Effects	Fixed Effects	Random Effects	Random Effects
	ρ_k	ε_t	ρ_k	ε_t
class 1	0.87	-0.0247	0.58	-0.0354
class 2	0.80	-0.0208	0.55	-0.0310
class 3	0.75	-0.0189	0.54	-0.0289
class 4	0.72	-0.0173	0.55	-0.0270
class 5	0.69	-0.0171	0.54	-0.0267
class 6	0.66	-0.0162	0.51	-0.0257
class 7	0.63	-0.0155	0.51	-0.0249
class 8	0.63	-0.0153	0.55	-0.0246
class 9	0.60	-0.0148	0.53	-0.0241
class 10	0.57	-0.0138	0.54	-0.0230

In table 5 we present results on cost efficiency ρ_k and technical progress ε_t. For the former we compare the typical firm of each class to the most efficient bank in the dataset. Values of less than one indicate inefficiency.

The results from the two estimation methods differ significantly: Under the random effects model relative efficiency is lower, but does not exhibit a size trend which can be observed for the fixed effects approach. The decrease in ρ_k in the fixed effects model could be the result of a positive correlation between part of our exogenous variables - in particular outputs 1 to 4 - and individual effects μ_k. This in turn would provide an argument in favor of the fixed effects approach because the random effects model is based on the assumption of no correlation between individual effects and the exogenous variables. In addition we know from comparing theoretical input quantities $\hat{x}_i$ which can be derived from the cost function to actual input quantities x_i that the banks in the dataset tend to use too much labor and too small amounts of deposits. This indicates that at least part of the observed inefficiency is of the allocative type. As for technical progress, both estimation methods yield numerically plausible rates of growth in total factor productivity, and both indicate that technical progress is somewhat stronger for smaller banks in the dataset.

5. Conclusions

In our empirical investigation of a panel of 757 German co-operative banks in the years 1989 to 1992 we found evidence of moderate scale economies for all size classes in the sample. This finding contrasts with results in the literature which point to diseconomies for larger banks. An explanation for this discrepancy can probably be found in the relatively small size of the banks in our dataset. We also found signs for economies of scope. Overall cost efficiency was shown to deviate considerably from the optimum. Finally, we found that all banks enjoy cost reductions due to technical progress which seems to be stronger for the smaller banks. In most cases the fixed and the random effects models led to the same conclusions.

Further research should deal with the considerable number of mergers taking place in this part of the German banking industry, following e.g. the lines of *Berger and Humphrey (1992)* or *Shaffer (1993a)*. In addition, the problem of zero outputs ought to be solved in order to avoid the use of an arbitrary substitute value. One could either think of applying a *Box-Cox* transformation or of a specification suggested recently by *Pulley and Braunstein (1992)* which is quadratic in outputs and log-quadratic in input prices.

From a broader perspective a similar study should be done with a more comprehensive dataset to generate results representative for the German banking sector as a whole. With such a dataset it would also be attractive to examine the technology of banking and the interactions of banks jointly, thereby endogenizing output quantities and estimating conjectural variations as proxies of the kind of competition in the industry (for the basic concepts see *Bresnahan, 1989*). *Shaffer (1989, 1993b)* took first steps in this direction with aggregate data of the USA and Canada, whereas *Berg and Kim (1993, 1994)* used micro data to estimate an oligopoly model of multi-product banks.

Appendix

Estimated parameters, their *White (1980)* heteroscedasticity-consistent *t*-statistics, and goodness-of-fit measures of the translog cost function are given in table A-1 for both the fixed and the random effects model. *, ** and *** represent a significance level of 90%, 95% and 99%, respectively. All calculations were run on Gauss386-i VM, version 3.01.

Table A-1

Parameter estimates

	Fixed Effects Model		**Random Effects Model**	
Parameter	**Estimate**	***t*-ratio**	**Estimate**	***t*-ratio**
a_1	0.583320	6.401 ***	0.557340	5.129 ***
a_2	-0.118511	-1.838 *	-0.153016	-1.691 *
a_3	0.535191	5.423 ***	0.595676	4.607 ***
b_1	0.171708	4.123 ***	0.210212	4.716 ***
b_2	0.245876	3.100 ***	0.214157	2.609 ***
b_3	0.238299	9.932 ***	0.242017	8.709 ***
b_4	0.177854	3.644 ***	0.152433	3.286 ***
b_5	-0.011927	-0.352	0.085733	2.164 **
b_6	0.015533	2.763 ***	0.031801	5.630 ***
a_{11}	-0.295079	-5.319 ***	-0.322177	-4.999 ***
a_{12}	0.060921	2.221 **	0.049755	1.400
a_{13}	0.234158	4.522 ***	0.272422	4.470 ***
a_{22}	0.017669	0.999	0.041055	1.359
a_{23}	-0.078590	-2.617 ***	-0.090810	-2.257 **
a_{33}	-0.155568	-2.522 **	-0.181613	-2.437 **
g_{11}	0.028742	1.816 *	0.004832	0.252
g_{12}	-0.106089	-4.541 ***	-0.067950	-2.483 **
g_{13}	-0.006184	-0.706	-0.007090	-0.684
g_{14}	0.042045	2.986 ***	0.031800	1.868 *
g_{15}	0.054233	3.848 ***	0.050413	3.028 ***
g_{16}	0.001256	0.830	-0.000702	-0.400
g_{21}	-0.014363	-1.449	0.007119	0.551
g_{22}	0.049593	3.261 ***	0.038365	2.234 **
g_{23}	-0.004251	-0.702	-0.005310	-0.777
g_{24}	-0.011338	-1.103	-0.007074	-0.591
g_{25}	-0.014052	-1.401	-0.024636	-1.826 *
g_{26}	0.003841	3.423 ***	0.004559	3.439 ***

g_{31}	-0.014379	-1.015	-0.011952	-0.681
g_{32}	0.056496	2.690 ***	0.029586	1.168
g_{33}	0.010435	1.224	0.012400	1.188
g_{34}	-0.030707	-2.310 **	-0.024726	-1.491
g_{35}	-0.040181	-3.050 ***	-0.025777	-1.492
g_{36}	-0.005097	-3.759 ***	-0.003857	-2.309 **
b_{11}	0.059868	4.645 ***	0.086833	7.190 ***
b_{12}	-0.004784	-0.272	-0.033207	-2.118 **
b_{13}	-0.008954	-1.872 *	-0.006236	-1.227
b_{14}	-0.049222	-4.634 ***	-0.049431	-5.089 ***
b_{15}	-0.003775	-0.519	-0.008840	-1.043
b_{16}	0.002018	2.021 **	0.002613	2.803 ***
b_{22}	0.078797	2.722 ***	0.120546	4.419 ***
b_{23}	-0.015914	-2.486 **	-0.022317	-2.912 ***
b_{24}	-0.031216	-2.211 **	-0.041462	-3.019 ***
b_{25}	0.000764	0.059	0.003825	0.268
b_{26}	-0.002998	-1.975 **	-0.004841	-3.267 ***
b_{33}	0.018161	6.915 ***	0.022232	6.590 ***
b_{34}	-0.026943	-5.643 ***	-0.022482	-3.984 ***
b_{35}	0.009501	2.603 ***	0.004970	1.083
b_{36}	0.000758	1.647 *	0.000439	0.815
b_{44}	0.098915	9.311 ***	0.123454	10.876 ***
b_{45}	-0.002995	-0.424	-0.012298	-1.557
b_{46}	0.000809	0.883	0.000418	0.424
b_{55}	0.004196	0.769	0.017681	2.910 ***
b_{56}	-0.001432	-1.755 *	-0.001311	-1.415
b_{66}	0.004875	6.567 ***	0.007568	13.501 ***
c_0	-0.039483	-2.622 ***	0.020277	1.402
c_1	0.047479	5.156 ***	0.014626	2.710 ***
d_1	-0.001114	-0.097	0.005684	0.451
d_2	0.007512	0.773	-0.002343	-0.192
d_3	-0.006398	-0.610	-0.003341	-0.253
e_0	-0.012815	-1.863 *	-0.019949	-2.229 **
e_1	0.004711	3.319 ***	0.004550	2.568 **
f_1	-0.042142	-6.773 ***	-0.048430	-6.361 ***
f_2	0.000989	0.325	0.001376	0.358
f_3	0.041153	6.083 ***	0.047054	5.472 ***
g_1	0.014745	0.938	0.013602	0.732
g_2	-0.023031	-1.727 *	-0.008791	-0.998
g_3	0.008285	0.655	-0.004811	-0.390

SSR	1.615	2.448
$\overline{R}^2$	0.985	0.991
observations	3028	3028
DF	2974	2973

Table A-2 shows minimum, maximum, mean-values and standard deviations of the firm-specific intercepts ($a_0+\mu_k$):

Table A-2

Estimates of intercepts

	Fixed Effects	**Random Effects**
Minimum	1.7780	1.5219
Maximum	3.0237	5.1498
Mean value	2.1680	2.1484
Standard deviation	0.1268	0.2220

Table A-3 contains information on the size classes used to evaluate the estimated cost function.

Table A-3

Description of the size classes

Size Class	**Total Assets (million DM)**	**Number of Banks**	**Size Class**	**Total Assets (million DM)**	**Number of Banks**
class 1	0-25	16	class 6	100-150	140
class 2	25-40	72	class 7	150-200	86
class 3	40-60	96	class 8	200-250	48
class 4	60-80	96	class 9	250-350	65
class 5	80-100	65	class 10	> 350	73

Measures for economies of scope, disaggregated by size-classes and output-variables, are given in table A-4 and table A-5:

Table A-4

$MSCOPE_T$, fixed effects model

	$MSCOPE_1$	$MSCOPE_2$	$MSCOPE_3$	$MSCOPE_4$	$MSCOPE_5$	$MSCOPE_6$
class 1	-	-	-	-	-	-
class 2	0.1573	0.0984	0.1275	0.1349	0.1549	0.1502
class 3	0.1515	0.1062	0.1424	0.1438	0.1587	0.1539
class 4	0.1434	0.1047	0.1314	0.1393	0.1454	0.1398
class 5	0.1745	0.1520	0.1765	0.1791	0.1852	0.1789
class 6	0.1624	0.1260	0.1592	0.1547	0.1666	0.1594
class 7	0.1560	0.1175	0.1517	0.1574	0.1609	0.1596
class 8	0.0919	0.0688	0.0978	0.0984	0.1024	0.0949
class 9	-	-	-	-	-	-
class 10	0.1098	0.0322	0.1171	0.1297	0.1163	0.1208

Table A-5

$MSCOPE_T$, random effects model

	$MSCOPE_1$	$MSCOPE_2$	$MSCOPE_3$	$MSCOPE_4$	$MSCOPE_5$	$MSCOPE_6$
class 1	-	-	-	-	-	-
class 2	0.1138	0.0573	0.0752	0.0796	0.1069	0.1042
class 3	0.0743	0.0240	0.0520	0.0506	0.0670	0.0663
class 4	0.0270	-0.0114	0.0055	0.0108	0.0245	0.0185
class 5	0.1177	0.0922	0.1125	0.1132	0.1188	0.1144
class 6	0.1291	0.0918	0.1215	0.1129	0.1273	0.1217
class 7	0.0507	0.0083	0.0379	0.0399	0.0471	0.0501
class 8	-0.2668	-0.2961	-0.2663	-0.2695	-0.2591	-0.2707
class 9	-	-	-	-	-	-
class 10	0.0190	-0.0636	0.0096	0.0118	0.0136	0.0241

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