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Efficiency in Banking: Empirical Evidence from the Czech Republic

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Abstract. The paper examines the cost efficiency of the Czech-banking system in the 1990s by applying the distribution free approach model. Reported results indicate that foreign banks were on average more efficient than the other banks, although their efficiency was comparable with the 'good' small banks' efficiency in early years of their operation. Based on the estimated results it is argued that early privatisation of state-owned commercial banks and more liberal policy towards foreign banks in the early stage of transition would have enhanced the efficiency in the banking system.

JEL Classification Numbers: G21, G34, P20

Key words: banks, Czech Republic, efficiency, transition economies

1. Introduction

The banking sector in transition countries has attracted the particular attention because of its non-standard 'transitory behaviour'. Questions concerning how efficient banks are, what factors cause their inefficiency and whether or not bank inefficiency is liable for industry problems are central to studies of banking sectors in those countries.

A large number of studies have been conducted on measuring efficiency in the banking industry. The geographical focus has prevailed on USA, EU countries and Japan. However, there is a significant gap in the current economic literature as for transition economies.

The analyses of banking efficiency in transition economies gain importance not only because of persistent changes in the environment of competition and regulation in the banking but also in the context of the EU enlargement. The study compares the performance of different banks groups and exams the consequences of postponed banking privatisation in the

★ The views and opinions are those of the author and not necessarily those of the EBRD.

Czech-banking sector. Reported results indicate that foreign banks were on average over six years more efficient than the other banks, although their efficiency has been comparable with the good small banks' efficiency in early years of their operation. It is argued that the entry of foreign banks, mainly from the EU countries, might spur in increasing the overall efficiency. The foreign banks may have entered the domestic credit market earlier, a phenomenon that happened only recently. This entry would have increased competition in the credit market and therefore increase the efficiency. If the Central Bank had allowed foreign banks to enter into the market earlier and the government had not postponed the privatisation process of partially state owned commercial banks then the overall efficiency of the Czech-banking sector would have been higher.

Big banks have been less efficient than the good small banks in the early years of our analysis. However, on average over six years their efficiency level does not differ significantly from the good small banks. This result may suggest that the pressure of competition to gain market share and survive may have pushed good small banks to minimise costs as well or even better than big banks. Big state-owned banks have suffered, among other, from overstaffing and irresponsible management. The latter is induced by government soft budget constraint, subsequent to political pressure to lend to politically important enterprises. The early privatisation of big state-owned banks and a consequent increase in competition would have contributed to the improvement of the performance of banks in terms of cost minimisation.

The study is organised as follows. Section 2 summaries and review the transition conditions in the process of banking development. Section 3 assesses the method used for measuring efficiency and for estimating the cost function. Section 4 describes the econometric model and the data. Section 5 provides a discussion on empirical results and Section 6 concludes.

2. A brief overview of the development of the Czech-banking system in the 1990s

In the first stage of transition a two-tier banking system was created from a monobank that performed both central and commercial banking activities under a command economy. A separation of central and commercial banking was identical for most of the former communist countries undergoing banking sector transformation. Commercial banking operations were carved out of the monobank and its asset and liabilities transferred to newly created commercial banks (Buch, 1996). This process went along with further expansion and openness of banking systems. However, several shortcomings can be identified in applied measures.

When the Czech Republic and other transition economies began to establish a two-tier banking system, it was believed that the more banks operating within the financial market the better and the banking system as a whole becomes more competitive and efficient. The rapid growth of new commercial banks in the first stage of transition brought a certain degree of competition into the financial market but afterward the financial position of the new established banks was considerably impaired.

Building an efficient banking system requires, among other, two policies to be carried out simultaneously, i.e., liberalization of the sector and the prudentially regulated entry of new banks. The licensing policy applied by the Czech National Bank that evolved from a lax to strict was inappropriate. The almost free entry into the banking sector in the early 1990s, excluded from foreign banks, mainly adopted because of the perceived benefits of competition, has in fact been detrimental. Partly unrestrained access induced a situation where too many domestic banks served a limited market.

One can observe that newly created banking systems in transition countries faced several disturbances. In the Czech Republic, a deterioration of the portfolios within the group of state-owned banks (SOBs) that inherited loans from the Central Bank needed to be resolved in the early stage of transition. SOBs were either technically or actually insolvent. The liberalisation of entry for small and medium sized banks (SMBs) that were significantly undercapitalised in the first half of the 1990s created additional problems within the banking sector, testifying further to risks as described by Davis (1999).

The Czech-banking sector has remained highly concentrated (Figure 1) and four state-owned largest banks had limited credit exposure to enterprises. Lending activities had been concentrated on the interbank market. *Komerční banka* (KB), *Investiční a Poštovní banka* (IPB) and *Československá Obchodní banka* (CSOB) had a small share of personal deposits compared to corporate clients. Particularly activities of KB and IPB were concentrated on lending to business firms at the outset of transition. *Česká Spořitelna* (Savings bank – CS) remained the primary collector of households' deposits.

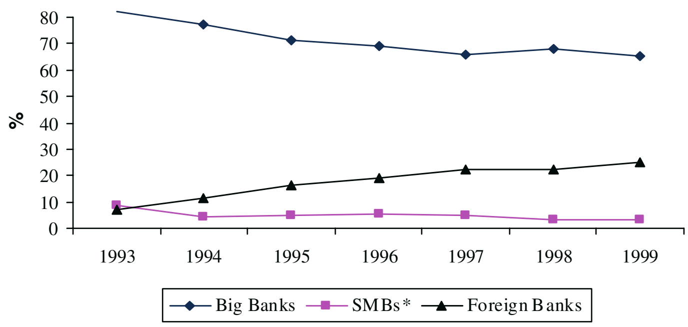

Figure 1. Share of banks in total assets (%). *SMBs – small and medium sized banks. *Source*: Czech National Bank.

Further, the 'big' banks had a high proportion of non-performing loans (26.7% of total non-performing loans (NPLs) as a percentage of total loans at the end of 1998) and 47% of NPLs was in the portfolio of two large banks, which counted for about 40% of the loan market. NPLs were not only inherited from the past but also generated as a result of bad management and political intervention for serving the loss making big enterprises.

A higher expectation was placed with newly established domestic private banks, as they did not suffer from 'old' NPLs, overstaffing and high expectation of future government bailouts. Conversely, a considerable number of these banks in the early 1990s faced solvency problems after a few years of operation. Most of SMBs had been closed or taken over by other institutions (Matoušek, 2002).

After 14 years of transformation, foreign banks now control the domestic market as a result of their gradual penetration into the market and the privatisation process. All former state or partially state-owned banks were bought by the foreign banks. Their market share has continually increased and foreign banks have extended activities to allocating credit to domestic companies and households.

3. Efficiency measure methodologies – a literature review

The issue of efficiency in the banking industry has extensively been tackled in a number of studies that have focused primarily on developed economies. Measurement of inefficiency in banking literature has been undertaken mainly through estimating a cost function. The cost inefficiency is measured as the amount by which a firm lies above its cost *frontier*. Farrell (1957), as summarized in Ferrier and Lovell (1990), distinguished two sources of productive inefficiency: technical and allocative. Both inefficiencies create costs to the firm. Technical and allocative efficiencies are necessary and sufficient conditions for cost minimization.

Technical inefficiency is due to excessive use of inputs. Suppose a firm produces output y^0 with inputs x^0 (a vector where $x^0 = x_1,\ldots,x_n$) and the frontier production function is described by $\varphi(\bullet)$. The firm is technically efficient if $y^0 = \varphi(x^0)$ and technically inefficient when $y^0 < \varphi(x^0)$. Allocative inefficiency arises from employing the sub-optimal proportion of inputs that does not reflect the ratio of relative prices and hence the total costs of the firm increase. Let p_m be the price of input m, then the firm is allocatively efficient if $\varphi_m(x^0)/\varphi_n(x^0) = p_m/p_n$, i.e., the ratio of derivatives of frontier production function, $\varphi(\bullet)$, with respect to input m and input n, is equal to the ratio of prices of input m and n (assuming that $K(\bullet)$ is differentiable). On the contrary the firm is allocative inefficient if $\varphi_m(x^0)/\varphi_n(x^0) \neq p_m/p_n$.

Since production technologies are unknown, inefficiencies must be measured relative to some cost or production frontier, which is estimated from the data. Therefore, measurements of inefficiency are measures of deviations away from some minimal levels found in the data rather than from any true technologically based frontier. Bank cost X-efficiency can be defined as the percentage difference between observed costs and predicted minimum costs, holding scale and output mix constant (Hunter and Timme, 1995).

The estimation of a cost function, however, allows an examination of input inefficiencies only that is the cost effect of wrong levels or mixes of inputs. Berger et al. (1993) argue in favour of a profit function for examining banking inefficiency. However, it is difficult to implement the profit function approach in transition economies because of the data quality. The data on profits are extremely unreliable highly affected from the sub-optimal level of loan provisions, resulting in only 'paper' profits. Moreover, since the profit function specifies both inputs and outputs, the number of parameters is significantly higher than that for a cost function. Thus, degrees of freedom become a more severe constraint, given the small sample of banks under consideration. Therefore, given present data availability, estimating the cost function is the most feasible approach.

Different techniques have been developed in the literature to measure firms' cost or production efficiency. The difference between these techniques reflects the different underlying assumptions used in estimating the frontiers. Four approaches have been utilised to estimate cost efficiency for commercial banks: the stochastic frontier approach, the data envelopment analysis, the thick frontier approach and the distribution free approach.

The stochastic frontiers approach (SFA) applied in banking industry by Ferrier and Lovell (1990) modifies the standard cost function to allow inefficiencies to be included in the error term. The predicted value of a standard cost function is assumed to characterise the frontier, while inefficiency enters through the error term, which is by construction orthogonal to the predicted frontier. As Berger and Humphrey (1991) mention these assumptions force the measured inefficiencies to be uncorrelated with the regressors. In order to distinguish the inefficiency from the random components of the error term it is assumed that inefficiencies are drawn from an asymmetric half normal distribution and the random fluctuations are drawn from a symmetric normal distribution. However, as discussed, for example, by Greene (1999) or Stevenson (1980) the half-normal assumption is often violated.

The second approach is the data envelopment analysis (DEA) which uses linear programming techniques to estimate piecewise linear cost or production frontiers. Firms on the vertices of this linear frontier are considered to be fully efficient and the inefficiencies of other firm are measured relative to this frontier. The problem with this approach is that there is no random error and all variations are treated as reflecting inefficiencies. A small change in the measurement error or luck of the firm on the frontier may have large cumulative effect on the aggregate inefficiencies, as all the other firms are measured against these few 'efficient' firms. The measurement of inefficiency is then biased upward. Another difficulty is that the inefficiency measure is sensitive to the number of exogenous constraints, which reduce the number of observations, biasing measured inefficiency downward by eliminating some potentially more efficient firms from the comparisons.

A third approach is the thick frontier approach (TFA). In this procedure instead of estimating a precise frontier bound, a cost function is estimated for the lowest average cost quartile of banks, which may be thought of as a 'thick frontier', where the firms exhibit an efficiency greater than the sample average. A cost function for the highest average cost quartile is also estimated. The difference between these two cost functions can be split into two factors. First is explained by market factors related to the available exogenous variables and the second factor cannot be explained, the 'inefficiency residual'. The necessary assumption is that the error terms within the lowest and highest cost quartiles reflect only random measurement error and luck, while the differences between the lowest and highest cost quartiles reflect only inefficiencies and market factors. These assumptions do not hold exactly, and this approach may not yield precise estimates of the overall level of inefficiencies in banking. Another problem is that dividing the data into quartiles may impose skewing and heteroskedasticity of the error terms. The main gain is that there is no assumption needed that the inefficiencies are orthogonal to the outputs and other regressors.

Finally, the last approach developed in banking studies to derive measures of bank efficiency is the distribution free approach (DFA) by Berger (1993). DFA assumes that the difference in actual and predicted cost for a given cross-sectional period is a combination of a persistent inefficiency component and a random component. It is possible to obtain the persistent inefficiency component by averaging out these differences over time see for example, Schmidt and Sickles (1984) and Berger (1993).

There are a number of studies focusing on bank efficiency performed mostly for standard market economies Bauer et al. (1993), Berger (1993) and Hunter and Timme (1995), to mention only few, perform efficiency studies on banking sector of the United States. Molyneux et al. (1996) present a detailed analysis of efficiency in European banking. Allen and Anoop (1996) compared the operational efficiency of 15 western countries, including US, find that input X-inefficiencies outweigh the output inefficiencies. Carbo et al. (2002) estimate the efficiency in the savings banks in European Union by using the Fourier-flexible functional form and stochastic cost frontier methodologies. Drake and Hall (2003) apply the non-parametric frontier approach, data envelopment analysis, for estimating the technical and scale efficiency in Japanese banking.

Empirical research on the efficiency of commercial banks in transition economies is still rather limited. Studies recently published have been mostly focused only on one or two countries with a limited number of observations. Konopielko (1997) employs a translog cost function to analyse the change of costs resulting from a potential Polish banking consolidation process including 65 banks. He concludes that consolidation of the Polish banking sector contributed to the banking sectors in terms of the increase in return to scale. Kraft and Tirtiroglu (1998) analyse the bank efficiency in Croatia in 1994 and 1995 by using stochastic frontier analysis. The analysis compares the efficiency of 'old' and 'new' banks, and state and private banks. Results indicate that new banks are less cost efficient than established banks. Weill (2003) applies the stochastic approach to estimate efficiency in the Czech Republic and Poland. The result is mixed in evidence in favour of Polish banks.

4. Data and model specification

The privatisation process of the state or partially state owned commercial banks started in 1998–1999 and the analysis is confined to the period 1993–1998. Banks' privatisation has been accompanied by restructuring and consolidation. The government interventions through capital injections influenced balance sheets and income statements of state-owned banks significantly. They therefore do not reflect a true picture about the real performance of formerly state-owned banks during this period. Further, bank differences in the level of (in)efficiency observed could arise because of the differences in the functions they perform. The analysed sample includes all operating commercial banks for which data was available in the Czech Republic. Data are taken from the banks' Annual Reports and covers almost 95% of all banks. Banks are divided into three groups: big, small and foreign banks. The criteria for separating big banks and foreign banks are the total amount of assets and the ownership structure. Big banks had partial state ownership. The state retained significant shares: 45% in *Česká Spořitelna*, 48.7% in *Komerční banka* and, 67.5% in CSOB until the end of 1998.

Small banks are split into two groups: the problematic banks that are those that ceased their activity due to solvency problems and the remaining small banks are defined as 'good' small banks. The foreign banks are in a different group to allow comparison with the domestic banks. Branches of foreign banks, the specialised banks and the banks without official license are excluded from the sample. Data are in nominal terms in local currency.

The original data contains 38 commercial banks. The number of banks in our sample decreases over time since failing 'problematic' banks drop out.

This unbalanced data sample represents a drawback for the results of our analysis since it introduces a sample selection bias. To conserve the benefit of a longer sample from earlier years and to compare the change of efficiency over years, we perform several estimations across different time periods from three to six years on varying samples containing banks that were in operation during the whole time period under consideration. Therefore, our sample has 38 banks over 1993–1994, 36 banks over 1993–1995, 30 banks over 1993–1996, 28 banks over period 1993–1997 and only 22 banks over six years 1993–1998.

The Distribution Free Approach (DFA) is applied and it is assumed that the difference in the actual and predicted cost for a given cross-sectional period is a combination of a persistent inefficiency component and a random component (Berger, 1993). It is possible to obtain the persistent inefficiency component by averaging out these differences over time. Following Hunter and Timme (1995), the error term bank i in time t can be expressed as

$$\varepsilon_{i,t} = \ln(v_{i,t}) + \ln(u_i), \tag{1}$$

where $\ln(v_{i,t})$ is a random error component that varies with time and is distributed with a zero mean over time, and $\ln(u_i)$ is the core efficiency or average efficiency for each bank which is time-independent while random error tends to average out over time. In order to be consistent with this error term specification, the cost function can then be expressed with a residual in the multiplicative form:

$$\mathrm{Cost}_{i,t} = C_t(Q_{i,t}, P_{i,t})v_{i,t}u_i, \tag{2}$$

where C_t is a cost function and $Q_{i,t}$ and $P_{i,t}$ are outputs and input prices, respectively. This cost function in logarithm is

$$\ln\mathrm{Cost}_{i,t} = \ln C_t(Q_{i,t}, P_{i,t}) + \ln(v_{i,t}) + \ln(u_i). \tag{3}$$

The term $\ln(u_i)$ is assumed to be orthogonal to the regressors in the cost function. The error term $\varepsilon_{i,t}$ can be estimated for each bank for each year. In this way the parameters in the cost function and the random error term $\ln(v_{i,t})$ are allowed to change for each year while $\ln(u_i)$ remains constant over time.

The next step is to average the estimated cost function, Equation (6), error term ϵ_{it} for each bank over n years in order to obtain an estimate of $\ln(u_i)$, that is, $\ln(u_i) = \sum_t \varepsilon_{it}/n$. For each bank then the percentage efficiency measure can be expressed as

$$\mathrm{EFF}_i = \exp[\ln(u_{\min}) - \ln(u_i)], \tag{4}$$

where $\ln(u_{\min})$ is the lowest value of $\ln(u_i)$. From this formulation an efficiency value of 1 corresponds to the most efficient bank while all other banks have values between 1 and 0.

An issue of the efficiency measure in Equation (4) could be that for any sample period the random error component $\ln(v_{i,t})$ may not cancel out completely for all banks. It is possible to calculate an additional measure for efficiency from truncated distributions of $\ln(u_i)$ suggested by Hunter and Timme (1995). In this case banks that lie above the $(1 - q\text{th})$ quartile take an efficiency value of 1 and those below take the same efficiency measure as the bank representing the qth quartile. The efficiency measure for the qth quartile then becomes

$$\mathrm{EFF}_i = \exp[\ln(u_{1-q}) - \ln(u_q)]. \tag{5}$$

where $\ln\left(u_{1-q}\right)$ and $\ln\left(u_q\right)$ are the estimates of $\ln(u_i)$ for the banks in the $(1 - q\text{th})$ and qth quartile, respectively.

Besides the zero truncation, the estimated measures of bank efficiency are derived and reported by using 1% and 5% truncation of the distribution of average efficiency terms, $\ln(u_i)$.

However, DFA does not specify a particular form of the cost function. The cost function used in earlier bank cost studies is log-linear based on the assumptions of a Cobb–Douglas production function and the exogenously determined firm's output. Since the 1980s a different approach has been developed. Hunter and Timme (1986) used a translogarithmic cost function in order to estimate U-shaped average cost functions. This specification conveys more generalised results with fewer restrictions than the Cobb–Douglas functional form.

A standard second order, non-homothetic translog approximation to the multiproduct total cost function is adopted for the estimation.[1] The cost function can be written as

$$\begin{aligned}\ln TC_t = {} & \alpha_0 + \Sigma_m \alpha_m \ln P_{m,t} + (1/2)\Sigma_m \Sigma_n \alpha_{m,n} \ln P_{m,t} \ln P_{n,t} + \Sigma_i \beta_i \ln Q_{j,t} \\ & + (1/2)\Sigma_i \Sigma_j \beta_{i,j} \ln Q_{i,t} \ln Q_{j,t} + \Sigma_i \Sigma_m \phi_{i,m} \ln Q_{i,t} \ln P_{m,t} + \varepsilon_{i,t}.\end{aligned} \tag{6}$$

where ln TC is the natural logarithm of total costs, $\ln P_{m,t}$ is the natural logarithm of annual salary per employee, price of capital, price of funds, $\ln Q_{i,t}$ is the natural logarithm of loans, investments, securities, demand deposits.

In the literature there are two approaches to measure bank outputs and costs (Berger and Humphrey, 1997). The production approach considers that banks produce accounts of various size by processing deposits and loans, incurring in capital and labour costs. Operating costs are thus specified in the cost function and output is measured as number of deposits and loans accounts. The intermediation approach considers banks as transforming deposits and purchased funds into loans and other assets. Costs are expressed as total operating plus interest cost and output is measured in money units.

These two approaches have been applied in different ways depending on the availability of data and the purpose of the study.

The intermediation approach is applied since competitive and thus efficient firms minimise the total of operating and interest costs for any given output. Interest expenses on average account for about 60% of total costs in the Czech-banking sector for the analysed period. Moreover, the production approach would have been difficult to apply because the number of accounts is unavailable. We specified total cost as the sum of interest expenses, general operating expenses and depreciation. To determine which bank products to include as outputs we employed the criterion of value added. Banking functions that produce a flow of banking services associated with a substantial labour or physical capital expenditure are identified as outputs.

Three control variables are included to control for non-traditional banks activities and their risk difference. The measured efficiency may reflect some changes in the product quality between banks. As suggested by the data low costs banks have smaller amount of non-interest income, suggesting that they may offer less fee-type services and hold more non-loan assets or off balance sheet activities, which may have different cost characteristics. As a proxy for product differences the fee to assets ratio (OffB) and non-loan to assets ratio (Nol) are employed. To control for the change in risk strategy between banks when bank may choose high risk high return-high cost strategy as was the case for small banks in the Czech Republic. We include the variable *risk*, which is calculated as ratio of provisions over average loan balance. Berger and Humphrey (1991) stress that the 'big' banks may have different products, which have different cost structure from the small banks.

Three input prices are defined. The price of labour (P_L) equals total salaries divided by the average number of employees, and is used as a proxy for average unit wage cost. The price of physical capital (P_k) was the most difficult to specify. We employed the replacement cost as a proxy for the price of physical capital because of unfeasibility to find a more precise measure, for example, fix assets expenses. The unit price of capital is defined as the ratio between depreciation and average balance of tangible and intangible assets. The price of funds (P_F) was calculated as the average interest rate on all funds used by the banks. It has not been possible for us to distinguish the different fund rates, as they are not available on the balance sheet.

We also present results where demand deposits are specified as inputs as suggested by Hunter and Timme (1995). Demand and saving deposits exhibit both output and input property. In this way we provide more insight into the sensitivity of efficiency measure to the treatment of deposits as variable input and outputs. For comparison purpose we estimated both types of models. From now on TC-DI refers to the specification of cost function when deposits are considered as inputs and TC-DO to the one where deposits are considered as outputs.

The following variables are used:

Inputs	Outputs	Dummy variables
P_L: average annual salary per employee;	Q_{LS}: average crown volume of loans, investments and securities;	D_B: dummy for big banks;
P_K: average price of capital;	Q_D: average crown volume of demand deposits;	Risk: loan loss provisions over total loans (loan loss provisions$_{i,t}$ /loans$_{i,t}$);
P_F: average price of funds;		OffB: fee incomes over total assets (fee income$_{i,t}$ /assets$_{i,t}$);
		NoI = non-loan assets over total assets (non-loan assets$_{i,t}$/assets$_{i,t-1}$).

In estimating Equation (6) constraints on the symmetry ($\alpha_{m,n} = \alpha_{n,m}$ and $\beta_{i,j} = \beta_{j,i}$), homogeneity in prices and adding-up ($\Sigma_m \alpha_m = 1$ and $\Sigma_m \alpha_{m,n} = \Sigma_n \alpha_{m,n} = \Sigma_m \varphi_{i,m} = 0$) are imposed and tested against a Cobb–Douglas functional form; the coefficients of cross-production terms are all zero, i.e. $\alpha_{m,n} = \beta_{i,j} = \varphi_{i,m} = 0$.[2]

Two basic models are estimated: Deposits treated as outputs (TC-DO) and deposits treated as inputs (TC-DI). When deposits are specified as inputs, the following restrictions are imposed on the parameter estimation of Equation (6), $\beta_I = \beta_{i,j} = \varphi_{i,m} = 0$ for i = D and j = LS.

Using DFA the inefficiency of a given bank is calculated as percentage change of this bank's efficiency with the efficiency frontier estimated for all the different sets of data. To calculate the cost frontier for banks in 1993–1996, for example, we run cross-section regressions by year on a sample of banks containing all the banks that are still in operation in 1996. That is, the number of banks included in each year is the same and equal to the number of banks in the last year 1996 (all banks that operate for the whole period 1993–1996). Since the number of banks in 1996 was 30 (eight banks of our sample failed since 1993) to calculate the cost frontier for period 1993–1996 we estimate the cost function with the 30 banks remained in 1996, for each of four years from 1993 through 1996. The efficiency frontier is then calculated as the minimum of the average residuals over 1993–1996. We follow the same method for all periods defined above, 1993–1994, 1993–1995, 1993–1996, 1993–1997 and, 1993–1998.

The method of measuring inefficiency by cross-section estimation embodies the assumption that X-inefficiencies are orthogonal with the cost function regressors. To test the hypothesis that X-inefficiency is orthogonal with the cost function regressors four steps are taken: First, a bank specific effect is retrieved similar to the Within method used by Schmidt and Sickles (1984) that also measures the technical inefficiency. Second, for each year there is the regression of the deviation from bank-means of total cost on the deviation from bank-means of all the regressors. Third, the coefficients of this regression on the variables without the means are taken away. Fourth, the bank specific effects as an average of the residuals of the last coefficients' application are retrieved

$$\hat{\theta}_i = \sum_{t=1}^{6} \frac{\ln TC_{it} - Z'_{it}\delta^*_t}{6}, \tag{7}$$

where Z represents the regressors in cost equation (6) and δ^*_t represents the coefficient estimates using deviations from bank specific means.

Further, we regress above retrieved bank specific effects $\hat{\theta}_i$ on the means of the regressors of the cost equation and tests the hypothesis that all coefficients are zero.[3]

$$\hat{\theta}_i = \bar{Z}'_i\gamma + \varepsilon_i, \tag{8}$$

where $\bar{Z}_i$ is a vector of the means of the cost function from Equation (6) for bank i.

This assumption is tested for last dataset containing 22 banks over 6 years, 1993–1998. The result of the F-test for the hypothesis that joint coefficients are zero is highly significant. It is found $\chi^2_{15} = 3961$ for model TC-DO and $\chi^2_{14} = 5733$ TC-DI, implying the rejection of this hypothesis.[4] It may be concluded that the hypothesis that the X-inefficiencies in cost function Equation (6) are not correlated with the regressors can be rejected.

5. Empirical results

The errors are retrieved from the estimated equations and used for the calculation of the DFA efficiency measure for two models.[5] The random error components may not cancel out completely when calculating the efficiency measure. In order to gain significance of our results 1% and 5% truncations of average residuals are chosen. Truncation measures of 1% and 5% are calculated in the same way as Equation (4).

The models TC-DO and TC-DI, for no truncation, indicate overall efficiency in the range of about 58–89% and 69–90%, respectively, during the period 1994–1998 (Tables I and II). Since efficiency measures are only relative to the best-practice bank, the increase in efficiency of banks shows that the banks become more alike over time.

Table I. TC-DO (total cost estimation of a single equation where deposits are treated as outputs) – %

	1995 Truncation			1996 Truncation			1997 Truncation			1998 Truncation		
	0%	1%	5%	0%	1%	5%	0%	1%	5%	0%	1%	5%
Banking groups												
Big banks	64.9	66.3	73.6	79.0	79.5	81.8	80.0	81.3	85.0	87.9	88.0	88.5
Small banks	63.6	65.0	71.5	76.9	77.4	79.3	78.2	79.3	82.4	86.0	86.1	86.5
Of which: good banks	68.9	70.1	76.0	77.6	78.0	80.3	82.1	83.1	86.1	86.0	86.1	86.5
Problematic banks	58.4	59.9	67.0	76.3	76.7	78.4	74.2	75.4	78.8			
Foreign banks	70.5	72.1	80.0	82.9	83.4	86.0	82.8	84.2	88.1	89.7	89.9	90.5
Overall	66.1	67.5	74.6	79.6	80.1	82.4	80.5	81.7	85.3	88.1	88.3	88.8

Table II. TC-DI (total cost estimation of a single equation where deposits are treated as inputs) – %

	1995 Truncation			1996 Truncation			1997 Truncation			1998 Truncation		
	0%	1%	5%	0%	1%	5%	0%	1%	5%	0%	1%	5%
Banking groups												
Big banks	76.6	78.3	82.3	82.6	83.1	85.3	83.7	84.5	86.9	87.3	87.7	89.5
Small banks	78.8	80.4	84.5	84.8	85.6	88.6	85.9	86.7	89.3	89.7	90.1	91.9
Of which: good banks	80.2	81.7	85.3	82.5	83.4	86.4	85.6	86.4	89.1	89.7	90.1	91.9
Problematic banks	77.5	79.2	83.6	87.0	87.8	90.8	86.1	86.9	89.5			
Foreign banks	73.9	75.5	79.6	80.0	80.7	83.6	81.8	82.6	85.1	85.9	86.3	88.1
Overall	76.9	78.5	82.5	82.5	83.2	86.0	83.7	84.5	87.0	87.4	87.9	89.7

The estimated efficiency/inefficiency of banks and therefore the policy implications may depend on the type of specification used for estimation. Two types of cost function models are estimated. Firstly, bank deposits are taken as inputs. Secondly, the demand deposits are considered as inputs. Several tests are applied to test the hypothesis that the resulted efficiency measures depend on the cost function specification. A test for equality of mean efficiency is applied in order to compare models pair wise by using *t*-test. The test is performed in two points in time, for the efficiency measures for the period 1993–1995 and for the efficiency measures for the whole six years period 1993–1998.

Taking the measured efficiencies from a given model specification we test how significant the differences in average efficiency for different groups are using pair wise *t*-tests. In order to distinguish good and problematic banks in the group of small banks the differences in measured efficiency between banks' groups are checked. We perform the pair wise *t*-tests for the measured efficiencies of different groups during the period of 1993–1995. This is because in 1996 and thereafter, the group of problematic small banks becomes insignificantly small going to nil in 1998. The group of small banks is reduced to only 'good' small banks for the period 1993–1998. Afterwards we perform the tests for the resulted efficiency measures of three banks' groups for six years (1993–1998) in order to see the evolution of efficiency differences between groups (Table III).

The foreign banks take the first place ranged by the levels of efficiency in average of six years. Foreign banks do not show higher levels of efficiency than the domestic good small banks on an average over three years 1993–1995. This outcome may be explained by high replacement costs of foreign banks at the beginning of their operations in the Czech Republic. Newly established small banks do not show significantly different levels of efficiency from the old 'big' banks, proving not to be exactly the expected severe competitors.

A test for differences in efficiency means between groups of banks shows that the foreign banks take the first place in average of six years. Nevertheless, on average over three years 1993–1995 foreign banks do not show higher levels of efficiency than the domestic good small banks. This result may be explained by the high physical capital and adjustment costs of foreign banks at the beginning of their operations.

New small domestic banks show levels of efficiency not significantly different from old big banks, proving not to be exactly the expected competitors. Although the difference in efficiency between banks does not seem to be very significant. Results indicate that the X-efficiency levels at good small have been actually above comparative levels at old big banks. The good small banks on an average during the years 1993–1995 have performed better than big banks, although not very significantly better only at 7% confidence interval. However, as the *t*-test on the mean efficiency shows for 1993–1998 (Table IV), these good banks have performed on average not significantly different from big banks over a six years period. This shows the importance of competitive pressures in gaining market share and surviving in the first years of operation of small banks. The fact that the big banks showed even

Table III. Tests for comparing the resulted efficiency measures from different methods used

	TC-DO	TC-DI	*t*-Stat.	*t*-Stat. between groups in TC-DI
Cross-section estimation for 3 years (1993–1995)				
Big banks	64.90	76.60	0.08	Big–good small: 1.12
Good small banks	68.90	80.20	0.70	Good–prbl small: 1.12
Problem banks	58.40	77.50	0.71	Prbl–foreign: −3.06
Foreign banks	70.50	73.90	0.60	Big–prbl: 1.98
Overall	66.10	76.90	1.20	Big–foreign: −0.59

The *t*-statistics are the *t*-statistics that pair wise efficiency means are the same. The approximate critical values at the 0.05 level are: Big banks $t(8) = 1.86$, Small banks $t(12) = 1.78$, Foreign banks $t(18) = 1.73$, Overall $t(42) = 1.69$, Big–small $t(10) = 1.81$, Small–foreign $t(15) = 1.75$ and Big–foreign $t(13) = 1.77$.

Table IV. Tests for comparing the resulted efficiency measures from different methods used

	TC-DO	TC-DI	t-Stat.	t-Stat. between groups in TC-DI
Cross-section estimation for 3 years (1993–1998)				
Big banks	87.9	87.3	0.24	Big–small: 0.57
Small banks	86.0	89.7	−0.85	Small–foreign.: −3.63
Foreign banks	89.7	85.9	1.20	Big–foreign: −0.47
Overall	88.1	87.4	0.35	

The t-statistics are the t-statistics that pair wise efficiency means are the same. The approximate critical values at the 0.05 level are: Big banks $t(8) = 1.86$, Small banks $t(12) = 1.78$, Foreign banks $t(18) = 1.73$, Overall $t(42) = 1.69$, Big–small $t(10) = 1.81$, Small–foreign $t(15) = 1.75$ and Big–foreign $t(13) = 1.77$.

lower levels of efficiency than the good small banks can be explained by the government control on their activity, that is, there are inner interests other than market forces to guide the behaviour of these banks.

When looking at the group of problematic small banks in the measured efficiency levels for years 1993–1995, the levels of X-efficiency are significantly below compared to all the other banks (Tables I and II). The efficiency level increases in 1996 and declines again relative to 1996, in 1997, reflecting the exit of most problematic banks leaving this group with the 'better' banks. This increase in efficiency measures can also be explained by flaws in reported data after the banks were already in forced administration or in the process of liquidation. The problematic banks group is compound mostly from the so-called zero banks. These banks were created from the start of their activities to serve special interest of their shareholders. Taking advantage of the weak supervision and legislative environment the managers of problematic banks often served special interests of their shareholders in the short run, without being concerned with long run cost minimisation. The results point to the importance of the supervision and regulatory capacity when liberalising new entry. Only a strong supervision and legislative environment discourages the entry of inefficient banks.

The main source of funds for small banks was the interbank market given the traditional role of *Česká Spořitelna* (Czech Savings Bank) in gathering retail deposits. The small banks were turned to offering very high deposits rates in order to attract depositors and charging a high loan rate. That connected to the adverse selection problem at the end caused the failure of a number of such banks. Thus, specifically the banks with lower efficiency offered higher interest on deposits in order to attract depositors – the bank would not bear the cost of failure to pay the insured deposits as it was the case when several small banks failed in the Czech Republic. The results from truncation increase the efficiency measures but leaves the ranking of bank' groups according to efficiency unchanged although the difference in efficiency between groups tends to decrease.

The bank efficiency increased for the period 1993–1995 and then deteriorated in 1996 reflecting the problems in the sector. However, there is a general increase in overall level of efficiency when compared for the period 1993–1996 and then to 1998. The increase in banks' efficiency reflects to some degree liquidation of the 'bad' small banks, which already left the market or merged with other banks. These results are robust to the choice of specifications of the deposits being inputs or outputs.

The estimated bank efficiency and test for correlation[6] with a set of variables is used to describe the bank characteristics such as: profitability described as return on assets (ROA), calculated as before-tax profits over total assets, and return on equity (ROE), calculated as before-tax profits over total bank equity; bank risk measured by the standard deviation of ROA over the sample period; bank size such as the logarithm of total assets; average cost ratios, such as total cost on assets ratio and operating cost on assets ratio; deposit's market concentration measured by bank's share in deposit's market.

Table V shows the correlation of measures of banks' efficiency derived from cross-section estimation.

While the efficiency levels of big and foreign banks' groups show a positive correlation with return to assets and return to equity, indicating that the efficiency measures do not involve the difference in product quality, the small banks efficiency measure is negatively correlated with the return to assets. Further, we observe a positive correlation of efficiency measures for small banks with the risk (standard deviation of ROA) indicating that the high efficiency for small banks is associated with a higher risk. The negative correlation with the return to assets and equity for problematic banks suggests that high inefficiency in these banks associated with high risk is translated into higher return. A higher efficiency level is associated with lower profitability and higher risk taking by banks.

The same can be said for the correlation with the cost ratios. Whilst all banks groups' efficiency is negatively correlated to the total cost to asset ratio, the small banks' efficiency is positively related to the operating cost to asset ratio, suggesting that bank managers at the small banks are less efficient in controlling operating costs. The positive correlation with the bank size suggests that big banks are more efficient. Moreover, the correlation with market share generates mixed results for different bank groups but concluding however for the overall banks a negative correlation. Market share has an unexpected positive sign with efficiency levels for big banks, supporting the theory that banks operating in more concentrated markets like in the Czech Republic and have higher market power are more efficient.

Table V. Correlations between group mean efficiency measures from cross-section estimation, and selected variables

Variable	Efficiency measures				
	Deposits as inputs 1995	Deposits as inputs 1998			
	Problem banks	Big banks	Small banks	Foreign banks	Total banks
Return on assets (ROA)	−0.737**	0.513*	−0.071*	0.415*	0.153*
Standard deviation of (ROA)	0.727**	−0.677*	0.384*	−0.467*	−0.118*
Return on Equity (ROE)	−0.326*	0.538*	0.100*	0.086*	0.011*
Total Cost/total Assets	−0.114*	−0.180**	−0.740**	−0.626**	−0.345*
Operating costs/total assets	0.179*	0.247*	0.075*	−0.083*	0.179*
Log of total assets	−0.297*	0.179*	−0.206*	0.017*	−0.056*
Share of market deposits	−0.285*	−0.029*	−0.288*	0.090*	−0.025*

*Statistics significantly different from zero at 5% level.
**Statistics significantly different from zero at 1% level.

Correlations for the efficiency measures of big banks imply that the cost structure of big banks is different from the one of other banks. The cost function does not fit as well for the big banks as for the other banks although we tried to control for it through the dummy variable for big banks. Moreover, the resulted positive correlation with market power may also suggest that our measures of efficiency may reflect some elements of market power as well as efficiency. However, the negative correlation of market share with the level of efficiency for small and foreign banks seems to support the theory that banks in less competitive markets can charge higher prices for their services but might feel less pressure to keep costs down.

The correlation test with profitability ratios did not pass mostly for the small banks for return on assets in the case when we consider deposits as inputs. This result may be explained from the fact that the accuracy of the loan loss provision is very doubtful to be used for accounting for risk behaviour of the bank since the provisions for loan losses are not accurately made in the big and small banks. This is particularly true for small banks where the problem of bad loans has been more severe.

6. Conclusions

The reported results indicate that the efficiency of the Czech-banking sector increases during the analysed period. Since efficiency measures are only relative to the best-practice bank, the increase in efficiency of banks shows that the banks become more alike over time. In the Czech case theses results reflect the forced exit of less efficient banks from the market, which left the market with the ‘better’ banks.

The efficiency measures of foreign banks are on average over six years higher than those for the domestic banks both small and big banks although, comparable with the 'good' small banks in the early years of their operation. On the other hand, the small domestic banks do not show significantly higher levels of efficiency compared to the big banks, thus failing to be the expected strong competitors. This conclusion is robust to both specifications of models, that is, when deposits are used as inputs or outputs. The difference in efficiency between these banks does not seem to be very significant. Our estimations indicate that the X-efficiency levels of 'good' small banks have been above the cost efficiency of big state-owned banks. This result seems to support the theory that emphasises the importance of competition, which may have pushed these banks to manage their resources and minimise costs better than the big banks. Yet, the competition in the Czech Republic was not strong enough to make 'good' small banks to perform better than big banks over the whole six years period.

The group of 'problematic' small banks shows that the levels of X-efficiency are far below compared to all the other banks in the period 1994–1997. The low efficiency levels of these banks were mostly caused as the result of myopic behaviour of incumbent management. These banks were often created to serve special interests of their shareholders with the managers not concerned with cost minimisation issues. Our results may point to the importance of the supervision and regulatory capacity when liberalising new entry. Only a strong supervision and legislative environment discourages the entry of inefficient banks. At the same time the low efficiency of problematic banks could also have served as warning signal about the problems in this segment of banking sector.

The results also imply that an increase in competition through privatisation of the remaining big banks and further entry of foreign banks accompanied by strong supervision and regulation holds the promise to increase the efficiency in the banking sector. The privatisation and foreign entry are likely to pressure banks to reduce costs and to merge with more efficient banks or to exit the industry.

As for the group of small problematic banks the low efficiency may suggest that an increase in competition through new entry is desirable but has to go in pace with an improvement in banking supervision and regulation capacity so that fraud in banking activities will not be allowed.

A further research in this area should take into account the differences in the banks' risk, defined as the excessive growth of loans. Moreover, given the high concentration of the loan and deposit market in the Czech-banking sector, accounting for the endogeneity of input prices is another important issue to be considered while measuring efficiency.

Notes

1. This form of the cost function was chosen because of its flexibility. In this specification there is no need to impose a priori restrictions on the substitution elasticities as in the Cobb–Douglas specification, where the substitution elasticities between inputs are all equal to one.
2. Other constraints can be imposed on the parameters corresponding to restrictions on the underlying technology. For the translog cost function to be homothetic it is necessary and sufficient that $\varphi_{i,m} = 0$ for every i and m. Homogeneity of a constant degree in output occurring if $\beta_{i,I} = \beta_{j,j} = 0$ is also imposed. The homogeneity constraints are not satisfied by our data thus we did not impose these constraints on our estimated cost function.
3. The results of this test may be impacted from the fact that the residuals used as a dependent variable in this estimation are estimated values, which may be heteroskedastic. In the estimation above we do not account for their standard deviations.
4. The residuals of this estimation were also used for calculating the X-inefficiency. The results show higher inefficiency than the ones calculated before.
5. Estimated parameters for models are not reported, but the regressions' fit are high. The adjusted R-squares are in the range of 0.81–0.93.
6. Since causation may go in both directions we avoid using the regression analysis to regress the measured efficiency level on the given variables. We use the simple correlation analysis instead.

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