Cost and profit efficiency of the Czech commercial banks

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***Abstract*—**This paper estimates the cost and profit efficiency of the Czech commercial banks in the period 2001-2010. The paper employs the parametric approach, in particular the Stochastic Frontier Approach, to estimate the cost and profit efficiency of commercial banks in the Czech Republic. Estimates of the average cost efficiency ranged the value 78-91% and the average profit efficiency ranged from 64-99%. We revealed that size of a bank is a key factor that should be taken into account in calculation as well as interpretation of results. The highest average cost efficiency achieved the group of the medium-sized banks following by the group of small banks and the highest average profit efficiency achieved the group of the small banks. The largest banks were the lowest efficient in the case of the cost and profit efficiency. The development of the average efficiency in three groups of banks is practically similar. Average cost and average profit efficiency achieved higher value than size-adjusted cost and profit efficiency. Thus it confirms that the largest banks had lower efficiency than small and medium-sized banks. The Czech commercial banks were more profit efficient then cost efficient in the most of the estimated period. The reason of the inefficiency of the Czech banks is mainly an excess of client deposits in balance sheet of banks and improperly chosen size (range of operation) of individual banks (especially the largest banks).

***Keywords*—**Commercial banks, cost efficiency, Czech Republic, profit efficiency, Stochastic Frontier Approach.

I. Introduction

BANKS play an important and central role in the Czech economy. Banks keep the savings of the public and finance the development of business and trade. Empirical studies (e.g. [18]) argue that the efficiency of financial intermediation affects economic growth and others [9] indicate that bank insolvencies can result in systemic crises which have adverse consequences for the economy as a whole. Thus, the efficiency of banks is an issue of major interest for various stakeholders such as depositors, regulators, customers and investors.

In empirical literature the two general approaches are used to assess efficiency of an entity, parametric and non-parametric methods, which employ different techniques to envelop a data set with different assumptions for random noise and for the structure of the production technology. The nonparametric methods are Data Envelopment Analysis (DEA) and Free Disposal Hull, which are based on linear programming tools. The efficiency frontier in nonparametric estimations is formed as a piecewise linear combination of best-practice observations. The main drawback of nonparametric methods is that they are not robust to measurement errors and luck (temporary better performance) observed in the data. In other words, the main disadvantage of DEA is that the frontier is sensitive to extreme observations and measurement errors; the basic assumption is that random errors do not exist and that all deviations from the frontier indicate inefficiency [21]. Other of the drawbacks DEA is the issues of sample size. The sample size has a major impact on the entire result. The DEA model does not provide prediction of the organization performance due to its limitation to prepare a model to be extended outside the database. The analysis of DEA model is not suitable to be compared with a theoretical maximum [11]. DEA cannot discriminate between inefficiency and noise, and tends to produce overestimated (in)efficiency measures, while stochastic frontier models are based on the idea that the data are contaminated with noise. Consequently, on the other hand, there is the stochastic approach, which uses econometric techniques [5].

The parametric methods most widely used in empirical estimations are Stochastic Frontier Approach (SFA), Distribution Free Approach and Thick Frontier Approach, which assume specific functional form for the cost function or production technology and allow for an error term composed from symmetrically distributed random error term and truncated inefficiency term. While parametric methods impose an explicit functional form for both the frontier and the deviations, non-parametric methods, in contrast, do neither impose any assumptions about the functional form of the frontier nor any distributional assumptions [21].

The aim of the paper is to estimate the cost and profit efficiency in the Czech banking sector during the period 2001-2010. For the practical estimation we applied the parametric method, especially the Stochastic Frontier Approach. We use the cost and profit efficiency function to estimate the cost and profit efficiency in the banking industry.

Empirical analyses of the Czech banking efficiency exist several. Most of the empirical studies estimated banking efficiency in 1990s and they investigated the impact of bank privatization, e.g. [31], [8], [15], [19] or [32]. Results of these studies indicated that private banks are more efficient than state-owned banks, but there are differences among private banks. Privatised banks with majority foreign ownership were the most efficient and those with domestic ownership are the

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least. In other words, foreign-owned banks were on average more efficient than the other banks.

Reference [29] and [28] found that the Czech banking sector showed itself as the most aligned banking industry among transition countries. The conclusion was the refutation of the conventional wisdom of higher efficiency form foreign-owned banks than form domestic-owned banks, and size was one of the factors that determine efficiency. To achieve high efficiency, a bank should be large, well known, and easily accessible and offering a wide range of products and services, or if small, must focus on specific market segments, offering special products. Results of [2] showed that the banks in the Czech Republic are inefficient from the perspective of costs. To improve the efficiency banks need to improve the quality of assets owned by improving the lending process and reduce the share of nonperforming loans. However [26] found that efficiency of the Czech banking sector has improved in the last ten years. Also [27] evaluated banking efficiency of Visegrad Countries (Czech Republic, Slovakia, Poland and Hungary) in the period 2000-2010 and concluded that the banking sector of the Czech Republic was evaluated as highly efficient.

Reference [30] simultaneously used two alternative specifications (CCR model and BCC model) that differ in returns to scale assumption. It was found that the differences in estimated efficiency scores of individual banks were quite large up to 70%. The largest banks perform significantly worse than medium-sized and small banks. The average efficiency in the banking sector remained nearly unchanged during the period 2001-2008, but it was observed a deterioration of average efficiency during the crisis period.

The paper is organized as follows. Section 2 presents methodology and data. Empirical analysis and results are reported in Section 3. Finally, section 4 concludes the paper.

II. Methodology and Data

The stochastic frontier approach originated with two papers [20] and [1], which were published nearly simultaneously. Both papers are themselves very similar and they appeared shortly before a third SFA paper by [4]. The SFA approach is one of the structural approaches to study efficiency. It is based on the economics of cost minimization or profit maximization by banks, and thus starts with a standard cost or profit function with factors of input, output, and their respective prices. It estimates the minimal cost or maximum profit based on these functions, and generates distance of its cost or profit to the frontier value. The SFA approach treats the observed inefficiency of a bank as a combination of the inefficiency specific to the bank and a random error, and tries to disentangle the two components by making explicit assumptions about the underlying inefficiency process. The parametric approach has the advantage of allowing noise in the measurement of inefficiency. However, the approach needs to specify the functional form for cost or profit.

A. Cost efficiency

Cost efficiency measures the performance of banks relative to the best-practice banks that produces the same output under the same exogenous conditions. Cost efficiency function is based on a cost equation that relates a bank's cost to variables that incur those expenses, such as output levels and input prices.

The cost equation contains a composite error structure that distinguishes random cost fluctuations from cost inefficiencies. To put it simply, the cost function describes the relationship between the cost with quantities of output and input variables plus the inefficiency and random error. The following cost equation:

$$C_{it} = f(y_{it}, w_{it}, z_{it}) + \varepsilon_{it}, \tag{1}$$

where C_{it} measures the total costs of a bank *i* incurs at time *t*, including operating and financial costs, y_{it} is a vector of outputs, w_{it} is a vector of input prices, z_{it} represents the quantities of fixed bank parameters, such as physical capital and equity and ε_{it} is the error term. The error term ε_{it} is composed of two parts:

$$\varepsilon_{it} = \mu_i + v_{it}, \tag{2}$$

where μ_i represents the inefficiency term that captures the difference between the efficient level of cost for given output levels and input prices and the actual level of cost and v_{it} is the random error. More specifically $\mu_i$and v_{it} are assumed to follow the following distributions:

$$\mu_i \sim N^+(0, \sigma_\mu^2), \tag{3}$$

$$v_{it} \sim N^+(0, \sigma_v^2). \tag{4}$$

We assume μ_i follows a half-normal distribution. Alternatively, μ_i can be modelled to follow a truncated normal distribution or exponential distribution so that it can only take non negative values. It measures the difference of bank's *i* cost compared with that of the frontier $f(y_{it}, w_{it}, z_{it})$.

The cost efficiency of the bank can be written in a natural logarithm form as follows:

$$\ln TC = \ln f(y, w, z) + \ln u_t - \ln v_t, \tag{5}$$

where f denotes a functional form.

After estimating a particular cost function, the cost efficiency for bank *i* is measured as the ratio between the minimum cost ($C_{\min}$) necessary to produce that bank's output and the actual cost (C_i):

$$CE_i = \frac{C_{\min}}{C_i} = \frac{\exp[f(y,w,z)]x\exp(lnu_{\min})}{\exp[f(y,w,z)]x\exp(lnu_i)} = \frac{u_{\min}}{u_i}, \tag{6}$$

where u_{min} is the minimum u_i across all banks in the sample. Under this formulation, an efficiency score of 0.95 for

example, implies that the bank would have incurred only 95 percent of its actual costs had it operated in the frontier.

B. Profit efficiency

Despite the wide agreement on the relevance of profit efficiency analysis, the technical difficulties with the measurement and decomposition of profit inefficiency were the main reasons for the small number of empirical studies on banking profit efficiency. Unlike the cost function, the profit function has an additive structure implying that the Shephard type distance functions, which are radial, are not the appropriate dual model of technology [12]. The profit frontier is derived as follows:

$$P = f(y, w, z) + u + v, \tag{7}$$

where P measures the profit of a bank, including both interest and fee income, less total costs of a bank, y is a vector of outputs, w is a vector of input prices, z represents the quantities of fixed bank parameters, u is the inefficiency term that captures the difference between the efficient level of cost for given output levels and input prices and the actual level of cost, and v is the random error term.

The profit function of the bank can be written in a natural logarithm form as follows:

$$\ln P = f(y, w, z) + \ln u_t - \ln v_t, \tag{8}$$

where f denotes a functional form. Profit efficiency is measured by the ratio between the actual profit of a bank and the maximum possible profit that is achievable by the most efficient bank.

$$PE_i = \frac{P_i}{P_{max}} = \frac{\exp[f(y, w, z)]x\exp(lnu_i)}{\exp[f(y, w, z)]x\exp(ln\, u_{max})} \tag{9}$$

where u_{max} is the maximum u_i across all banks in the sample. For example, if the profit efficiency score of a bank is 90%, it means that the bank is losing about 10% of its potential profits to managerial failure in choosing optimum output quantities and input prices.

C. Data and selection of variables

The data set used in this study was obtained from the annual reports of commercial banks for the period 2001–2010. All the data is reported on unconsolidated basis. The data set consists of data of banks that represent almost 80% of the assets of the national banking sector. We analyzed only commercial banks that are operating as independent legal entities due to the homogeneity of the data set. All foreign branches, building societies, specialized banks or credit unions were excluded from the estimation data set.

In order to conduct SFA estimation, inputs and outputs need to be defined. In the literature in the field, there is no consensus regarding the inputs and outputs that have to be used in the analysis of the efficiency of the activity of commercial banks [6]. In the empirical literature four main approaches have been developed to define the input-output relationship in financial institution behaviour. Firstly, the intermediation approach, which can also be referred to as asset approach, was introduced by [24] and assumes that the banks' main aim is to transform deposits (liabilities) into loans (assets). Secondly, production (service-oriented) approach [25], which can also be referred to as value-added or production approach, focuses on the services banks provide to their clients. It assumes that the banks' aim is to produce liabilities (deposits) as well as loans (assets) and other services. The production approach thus has two main disadvantages that it does not take interest costs into account and second, it requires information about the number of accounts and cost allocation [16]. Third, the asset approach recognizes the primary role of financial institutions as creators of loans. In essence, this stream of thought is a variant of the intermediation approach, but instead defines outputs as the stock of loan and investment assets [13]. Last, the profit approach which is the newest of the approaches. It is based on [7] who stated that use of the profit approach may help take into account unmeasured changes in the quality of banking services by including higher revenues paid for the improved quality, and may help capture the profit maximization goal by including both the costs and revenues. Such changes are expected to occur, in particular, following any significant changes in the disposable income of citizens [16].

The intermediation approach is considered relevant for the banking industry, where the largest share of activity consists of transforming the attracted funds into loans. We adopt intermediation approach which assumes that the banks' main aim is to transform deposits into loans. Consistently with this approach, we assume that banks use the two inputs and produce two outputs.

Total costs are the sum of the interest cost and operation cost. Total profit is the sum of interest income and fee income. We employed two inputs (labor and deposits), and two outputs (loans and net interest income). We measure price of labor (w_l) as a ratio of personnel expenses to number of employees, and price a deposits (w_h) as a ratio of annual interest expenses to total deposits. Loans (y_l) are measured by the net value of loans to customers and other financial institutions and net interest income (y_m) as the difference between interest incomes and interest expenses. Descriptive statistics of variables are in Table 1.

Variable	Mean	Median	Min	Max	St.Dev.
C	8614	2457	36	46017	11958
P	10883	3075	44	57858	14297
w_j	0,7896	0,711	0,3267	2,2623	0,2952
w_h	0,0248	0,020	0,0029	0,1225	0,0188
y_l	77901	29827	107,1	422468	96981
y_m	46889	1230	32,9	28332	6529

Table 1 Descriptive statistics of inputs and outputs variables (in million CZK)

The functional form of the stochastic frontier was determined by testing the adequacy of the Cobb Douglas relative to the less restrictive translog. As in e.g. [7], [22], [17] or [14], we normalize dependent variable (cost or profit) with all output quantities y by equity capital Z to account for heterogeneity. The frontier models estimated are defined as:

$$\ln\left(\frac{P}{Z}\right)_{it} = \alpha_1 + \sum_{l=1}^{2}\beta_l \ln\frac{y_l}{Z} + \frac{1}{2}\sum_{l=1}^{2}\sum_{m=1}^{2}\beta_{lm}\ln\frac{y_l}{Z}$$
$$\ln\frac{y_m}{Z} + \sum_{j=1}^{2}\gamma_j \ln w_j + \frac{1}{2}\sum_{j=1}^{2}\sum_{h=1}^{2}\gamma_{jh}\ln w_j \ln w_h +$$
$$\sum_{l=1}^{2}\sum_{j=1}^{2}\beta_{lj}\ln\frac{y_l}{Z}\ln w_j + \ln u_{it} - \ln v_{it}, \quad (10)$$

where C is total cost, y_l, y_m are the outputs l or m, w_j, w_h are the price of inputs, u_{it} is the random error, v_{it} is the inefficiency term, i denotes the bank (i = 1, ..., N) and t denotes time (t = 1, …, T).

$$\ln\left(\frac{C}{Z}\right)_{it} = \alpha_1 + \sum_{l=1}^{2}\beta_l \ln\frac{y_l}{Z} + \frac{1}{2}\sum_{l=1}^{2}\sum_{m=1}^{2}\beta_{lm}\ln\frac{y_l}{Z}$$
$$\ln\frac{y_m}{Z} + \sum_{j=1}^{2}\gamma_j \ln w_j + \frac{1}{2}\sum_{j=1}^{2}\sum_{h=1}^{2}\gamma_{jh}\ln w_j \ln w_h +$$
$$\sum_{l=1}^{2}\sum_{j=1}^{2}\beta_{lj}\ln\frac{y_l}{Z}\ln w_j + \ln u_{it} + \ln v_{it}, \quad (11)$$

where P is total profit.

The use of duality implies the necessity to impose the following homogeneity restrictions:

$$\sum_{l=1}^{2}\beta_l = 1, \sum_{j=1}^{2}\gamma_j = 0, \sum_{h=1}^{2}\sum_{k=1}^{2}\gamma_{hk} = 0.$$

Reference [7] indicated that normalization by equity capital has economic meaning. The dependent variable (profit) becomes the return on equity (ROE) or a measure of how well banks are using their scarce financial capital. Banking is the most highly financially leveraged industry. Shareholders are mostly interested in their rate of return on equity (ROE), which is a measure closer to the goal of the bank than maximising the level of profits. Normalization by the financial equity capital also follows from the choice of equity capital as a fixed input quantity. Equity capital is very difficult and costly to change substantially except over the long run. Equity capital is preferred as a normalization variable besides being the fixed input quantity. Furthermore, if equity was not specified as fixed, the largest banks may be measured as the most profit efficient simply because their higher capital levels allow them to have the most loans [22].

III. EMPIRICAL ANALYSIS AND RESULTS

The cost and profit efficiency function is estimated using the maximum likelihood estimation of parameters in the Cobb-Douglas [3]. The computer programme FRONTIER 4.1 developed by [10] has been used to obtain the maximum likelihood estimates of parameters in estimating the technical efficiency. The programme can accommodate cross sectional and panel data; cost and production function; half-normal and truncated normal distributions; time-varying and invariant efficiency; and functional forms which have a dependent variable in logged or original units.

Year	Mean	Median	Min	Max	St.Dev.
2001	85	88	55	100	14,31
2002	83	87	41	100	15,76
2003	86	89	67	100	10,78
2004	88	89	62	100	10,61
2005	90	93	62	100	9,78
2006	88	90	64	100	8,55
2007	84	85	66	96	9,38
2008	90	94	51	100	13,44
2009	91	91	75	100	6,55
2010	78	75	55	97	15

Table 2 Descriptive statistics of the cost efficiency estimation of Czech banks (in %)

Table 2 presents descriptive statistics of the cost efficiency in period 2001–2010. The value of average cost efficiency was in the range 78-91%. The development of the average efficiency show that the efficiency score was increasing in the period 2001–2009. As [26] argued the increasing average efficiency in the Czech banking sector is influenced by better banks' management. He supported this argument the ownership structures has experienced considerable development in the Czech banking sector. Large Czech banks were privatized in the period 1999–2001, it is probably that the new owners and managers learnt to adapt in the new environment. Reflection of this process is the gradual increase of the efficiency in the Czech banking sector. In 2010 the average efficiency was decreasing, we can suppose that this development is as a result of the financial crisis. Because the

analyzed outputs (loans and net interest income) decreased in the balance sheet of the individual banks.

Bank	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
CSOB	76	64	67	61	62	64
CS	100	83	90	70	100	97
KB	95	86	75	100	88	83
HVB	81	93	77	88	95	92
UNIC						
ZIBA	77	90	91	93	97	85
GEM	88	100	100	97	88	87
RB	96	100	90	95	92	100
IC		93	94	90	99	97
POPO						
JTB	99	88	86	88	99	91
DRES	62	99	98			
BAW				82	83	93
LBBW						
PMB	55	70				
PPF			70	84	80	81
VOLK	98	75	89	85	90	90
CITI	100	83	73	98	97	87
EBAN	82	41	100	98	94	90
Bank	**2007**	**2008**	**2009**	**2010**	***Mean***	**Rank**
CSOB	66	51	91	65	*67*	18
CS	96	100	100	75	*91*	3
KB	84	94	97	90	*89*	6
HVB					*88*	9
UNIC	93	96	85	95	*92*	2
ZIBA					*89*	6
GEM	86	89	75	97	*91*	3
RB	92	97	91	55	*91*	3
IC					*95*	1
POPO	93	98	97	63	*88*	9
JTB	76	80	91	66	*87*	11
DRES					*86*	12
BAW	84				*86*	12
LBBW		93	91	69	*84*	16
PMB		98	93	95	*62*	19
PPF	79	92	89	93	*85*	15
VOLK	89				*89*	6
CITI	66				*86*	12
EBAN	85				*84*	16

Table 3 Cost efficiency of the Czech commercial banks (in %)

The results of the cost efficiency scores of the Czech commercial banks during the period 2001-2010 are presented in Table 3. IC bank reached the high value of the cost efficiency, the second most efficient bank was UniCredit Bank (UNIC) and the third most efficient bank was Česká spořitelna (CS). Česká spořitelna operated at the 100% score of the cost efficiency in four years (2001, 2005, 2008 and 2009), thus 100% of the costs incurred were necessary for the production. In contrast, the lowest average cost efficient bank was Československá obchodní banka (CSOB), which reached the average cost efficiency 67%, thus 33% of the cost was not required for the outputs. Persistently low efficiency of the Československá obchodní banka (one of the largest banks in the Czech banking industry) is surprising findings of this paper. Robust and reliable estimation results should require appropriate number of inputs and outputs involved in the estimation in relation to the number of banks in dataset. The Czech banking sector is relatively small and consisted of limited number of banks, which restricts comprehensiveness of the model. Two inputs and two outputs cannot capture the banking business completely. We can observe that the increasing of total deposits is not accompanied increasing total loans in balance sheet of CSOB over the whole analyzed period. In addition, net interest income, as a second output variable during the last four analyzed years has stagnated.

Year	**Large banks**	**Medium-sized banks**	**Small banks**
2001	90	84	84
2002	81	94	73
2003	77	90	88
2004	80	92	90
2005	86	91	93
2006	84	90	90
2007	85	81	84
2008	85	93	91
2009	93	83	92
2010	81	76	73
Mean	*84*	*87*	*86*

Table 4 Average cost efficiency of banks' groups (in %)

Next, we calculate average efficiency scores derived from model for three groups of banks classified according to volume of total assets (Table 4). We adopt the categorization system applied by the Czech National Bank (CNB) and on distinguish between large, medium-sized and small banks. Large banks seem to be frequently most efficient. The development of the average efficiency in three groups of banks is practically similar. In the period 2001–2009 the cost efficiency was slightly increasing. In 2010 the average efficiency decreased in all groups of banks, and the highest decrease was estimated in the small banks. Generally, we can conclude that the medium-sized banks in the market appeared to be more efficient. Considerable inefficiency was also revealed in large banks.

Large banks have chosen inappropriate scale of operation and simply use too many inputs or produce too few outputs.

Year	Mean	Median	Min	Max	St.Dev.
2001	85	88	62	100	14,21
2002	91	94	78	100	8,23
2003	76	79	48	100	19,05
2004	94	95	85	100	5,26
2005	99	99	98	100	0,65
2006	93	93	92	94	0,69
2007	89	89	87	90	0,89
2008	97	99	86	100	3,77
2009	80	80	65	91	8,65
2010	64	63	33	92	20,46

Table 5 Descriptive statistics of the profit efficiency estimation of Czech banks (in %)

Table 5 presents descriptive statistics of the profit efficiency in the period 2001–2010. The value of the average profit efficiency was in the range 64-99%, thus the Czech commercial banks are high level of the average profit efficiency. This suggests that an average of about 64% to 99% of potential maximum profit was gained due to profit efficiency. The development of the average efficiency shows that the efficiency score was increasing in the period 2001–2008. In 2009 and 2010 the average profit efficiency slight decreased, we can suppose that this development is as a result of the financial crisis in the Czech Republic. The decrease in the net profit was registered in the balance sheet of the most Czech banks (e.g. LBBW, J&T Bank), or e.g. Banco Popolare Bank (POPO) achieved the loss in 2009 and 2010. The large Czech banks did not reach significant decrease of the profit efficiency, because their net profit did not affected by the financial crisis.

The results of the profit efficiency scores of each bank during the period 2001-2010 are presented in Table 6. The highest value of the cost efficiency achieved První městká banka (however, the bank was operated in the Czech banking industry only at the beginning of the analyzed period and then it was transformed into PPF Bank) with the mean efficiency 100%, and IC Bank was the average profit efficiency 99% and eBank reached the average profit efficiency 98%. BAWAG, Dresdner Bank, Živnostenská bank and Volksbank also reached the average profit efficiency higher than 90%. The lowest average profit efficiency reached Banco Popolare, LBBW, HVB and CSOB.

Average profit efficiency had higher value than average cost efficiency in the most analyzed years (except 2003 and 2010). In 2003, large banks reached low values of the profit efficiency, especially profit of the CSOB decreased due to a decline in interest rates. CNB reduces the basic interest rate in 2003. Following the expected development of the economy, CNB lowered its key interest rate by a total of 0.75 percentage points (limit repo rate stood at 2% p.a., discount rate of 1% p.a. and the Lombard rate 3% p.a.) Also Komerční banka registered the decrease of the interest income, which was probably also caused by a reduction in interest rates. Development in year 2010 was probably caused by a decrease in profits in medium-sized and small banks as a result of the financial crisis.

Bank	2001	2002	2003	2004	2005	2006
CSOB	62	78	49	86	98	92
CS	66	80	50	86	98	92
KB	66	79	48	85	98	92
HVB	73	85	60	90	99	92
UNIC						
ZIBA	88	93	78	95	99	93
GEM	77	86	62	90	99	92
RB	96	95	80	95	99	93
IC		100	100	100	100	94
POPO						
JTB	98	100	93	99	100	93
DRES	98	95	87			
BAW				95	100	93
LBBW						
PMB	100	100				
PPF			94	99	100	93
VOLK	100	100	97	100	100	93
CITI	81	88	67	92	99	93
EBAN	100	100	100	100	100	94
Bank	**2007**	**2008**	**2009**	**2010**	***Mean***	**Rank**
CSOB	87	100	91	89	*83*	16
CS	87	100	90	91	*84*	14
KB	87	100	91	92	*84*	14
HVB					*83*	16
UNIC	88	99	85	77	*87*	10
ZIBA					*91*	6
GEM	88	99	84	73	*85*	13
RB	89	99	80	63	*89*	8
IC					*99*	2
POPO	90	86	65	33	*69*	19
JTB	89	97	72	45	*89*	8
DRES					*93*	5
BAW	89				*94*	4
LBBW		97	71	43	*70*	18
PMB					*100*	1
PPF	89	95	72	47	*86*	12
VOLK	89	98	75	50	*90*	7
CITI	89				*87*	10
EBAN	90				*98*	3

Table 6 Profit efficiency of the Czech commercial banks (in %)

Next, we calculate average profit efficiency scores derived from model for three groups of banks classified according to volume of total assets (Table 7). We adopt the categorization system applied by the CNB and on distinguish between large, medium-sized and small banks.

Year	Large banks	Medium-sized banks	Small banks
2001	65	86	99
2002	80	92	100
2003	52	79	97
2004	87	94	99
2005	98	99	100
2006	92	93	94
2007	87	88	89
2008	99	99	95
2009	89	82	71
2010	87	68	44
Mean	*84*	*88*	*89*

Table 7 Average profit efficiency of banks' groups (in %)

Small banks seem to be frequently most efficient. The least efficient was estimated in the group of the large banks. The mean efficiency score in the small banks was 89%, the mean efficiency in the medium-sized banks was estimated 88% and the mean efficiency in the large banks was found 84%. The development of the average profit efficiency in three groups of banks is practically similar. The average profit efficiency was increasing in the period 2001–2008. In 2009 and 2010 the average efficiency was decreasing in the group of small banks and medium-sized banks. Generally, we can conclude that the small banks in the market appeared to be more profit efficient.

We are aware of the fact that averaging without any respect to the size of banks causes loss of information, and therefore, we implemented in our analysis a size-adjusted average efficiency (SEA) calculated as:

$$SEA = \sum_{i=1}^{n} w_i \Theta_i, \tag{12}$$

where *SEA* is the size-adjusted average efficiency, w_j is the weight computed as a share of j^{th} bank's assets on total assets of all estimated banks, Θ_i is the observed efficiency for the j^{th} bank, and *j* indicates the different *n* banks.

Results of the SEA calculation for cost and profit efficiency are presented in Figure 1.

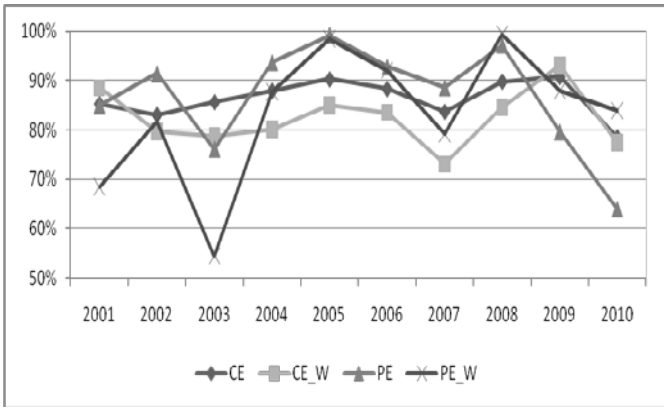

Figure 1 Average cost and profit efficiency of the Czech commercial banks (in %)

The average cost efficiency (CE) achieves the higher value than the average size-adjusted cost efficiency (CE_W). Thus, large banks register lower cost efficiency than small and medium-sized banks. The average profit efficiency (PE) also reached higher values than size-adjusted profit efficiency (PE_W) until 2007, but in the period 2008-2010 the value of simple efficiency lower than the size-adjusted profit efficiency, which confirms the already mentioned high average profit efficiency of large banks during this period. It is particularly caused the fact, that the large banks did not observe the decline in a profit as small and medium-sized banks in the period 2009-2010.

IV. Conclusion

The aim of the paper was to estimate the level of the cost and profit efficiency in the Czech banking sector during the period 2001–2010. For this purpose, this paper uses Stochastic Frontier Approach, cost and profit efficiency function. The development of the average cost efficiency show that the efficiency score was increasing in the period 2001–2008. We assume that it was influenced by better banks' management. Most of the computed average cost efficiency scores register negative effect of financial crisis, particularly in year 2009 and 2010.

The average cost efficiency ranged the value 78-91%. The highest average cost efficiency achieved IC bank with average efficiency score 100%, which was followed by UniCredit bank and Česká spořitelna. Conversely, the lowest average cost efficiency achieved CSOB, where the average cost efficiency was only 67%. We revealed that size of a bank is a key factor that should be taken into account in calculation as well as interpretation of results. When we divided the banks into three groups of banks by size of total assets, we distinguished between the group of small banks, medium-sized banks and largest banks. It was found that the highest average cost efficiency achieve medium-sized banks follow by small banks.

Estimates of the average profit efficiency ranged from 64-99%. The highest value of the profit efficiency achieved První městká banka, IC Bank and eBanka, while the lowest average profit efficiency reached Banco Popolare, LBBW, HVB and CSOB. When we compared three groups of banks,

we found that the highest value of the profit efficiency achieved the group of the small banks and then the group of medium-sized banks. The largest banks were the lowest efficient in the case of the cost and profit efficiency. It can be concluded that the small and medium-sized banks in the market appeared to be more efficient. The development of the average efficiency in three groups of banks is practically similar.

When we calculated the size-adjusted efficiency, we found that average cost and average profit efficiency had higher value than size-adjusted cost and profit efficiency. Thus it can be concluded that largest banks have lower efficiency than small and medium-sized banks.

The Czech commercial banks were more profit efficient then cost efficient in the most of the estimated period. The reason of the inefficiency of the Czech banks is mainly an excess of client deposits in balance sheet of banks and improperly chosen size (range of operation) of individual banks.

We compare the results with the result found by [30] who estimated the efficiency of the Czech banks using DEA. Reference [30] also estimated the increase in the efficiency in the period 2001–2010. It can be reminded that in this paper we estimate cost and profit efficiency, but [30] estimated technical efficiency using DEA. In spite of this fact, the results of efficiency of banks are not significantly different; the most efficient banks in SFA model are also the most efficient in DEA model. This paper also confirms the results estimated by [26] who found the increasing efficiency in the Czech banking sector.

The efficiency of the banking industry is a key factor for the stability of the banking sector. The cost efficiency is a predictor of bank failures that as [23] showed that the risk of bank failure is closely correlated with cost inefficient. Thus [23] suggest the inclusion of cost efficiency in early warning systems.

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