THE WILLIAM DAVIDSON INSTITUTE
AT THE UNIVERSITY OF MICHIGAN

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William Davidson Institute Working Paper Number 998
September 2010

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Abstract

This article provides an empirical insight on the heterogeneity in the estimates of banking efficiency produced by the stochastic frontier approach. Using data from five countries of Central and Eastern Europe, we study the sensitivity of the efficiency score and the efficiency ranking to a change in the design of the frontier. We found that the average scores are significantly smaller when the transcendental logarithmic functional form is used in the profit efficiency measurement and when the scaling effect is neglected in the cost efficiency measurement. The implied bank ranking is robust to changes in the stochastic frontier definition for cost efficiency, but not for profit efficiency.

Keywords: Banking, Efficiency Analysis, Stochastic Frontier Approach, Transitional Countries

JEL Classification: C13; G21; L25

*Acknowledgments: I thank Oldrich Dedek, Petr Jakubik, Michal Mejstrik, and seminar participants at Charles University for helpful comments; and gratefully acknowledge financial support from the Grant Agency of Charles University (grant #89910). All remaining errors are mine.

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1 Introduction

Managers, as well as regulators, need to have accurate information about the effects their decision-making has. The importance of efficiency estimation is backed by an extensive research production in this field. Contrary to the ratio analysis, the frontier approach to efficiency measurement (proposed by Farrell 1957) provides an objective numerical value and ranking of firms. Untill nowadays, researchers have developed several different methodologies applying the frontier approach, the most common of which became the parametric stochastic frontier approach (SFA). However, the estimated efficiency scores, including the exact definition of certain frontier estimation characteristics, differ throughout the studies.

Recently, the literature targeting the efficiency estimation of the banking sector in European transitional countries started to increase in number. The articles applying the SFA deal with technical efficiency including the duality-problem-solving economic efficiency. The examples include Fries & Taci (2005) using translog functional form for the panel of 15 countries in 1994–2001 with cost efficiencies around 75% except the Czech Republic and Romania (50%); Košak & Zajc (2006) applying the intermediation approach on input/output definition with translog cost function for 8 countries through 1996–2003, estimating the average score around 85%; Rossi *et al.* (2004) employing the modified production approach on the unbalanced panel of 9 states during 1995–2002 and Fourier-flexible functional, with average cost and alternative profit scores $75-80\%$ and 40% respectively, subdividing the samples not only according to countries but also bank size and specialization. The works of Mamatzakis *et al.* (2007) and Koutsomanoli-Filippaki *et al.* (2008) are other examples that estimate the efficiency on a regional level; Weill (2003) compares the Eastern European countries to Western Europe and subregional estimates for the years of 1996 and 2000, but with a different number of banks. Authors focusing on a single country include Hasan & Marton (2003) writing about Hungarian banking, Podpiera & Podpiera (2005) about the Czech Republic, or Mertens & Urga (2001) using cross-sectional estimation for the Ukrainian banks.

As it was briefly demonstrated, the studies differ in the final efficiency estimation since they not only use different data samples but also employ diverse approaches toward certain methodological characteristics of the SFA. Therefore, the articles' results are hardly comparable; moreover, the consensus over the sources of differences in estimates and ranking is missing. Following the study of Berger & Mester (1997), this article will focus on the quantitative comparisons of the scores over several proposed definitions of the functional form using the SFA. Moreover, we will observe the changes in ranking of banks caused by the altered methodological design.

The remainder of the article is organized as follows: in Section 2, we briefly describe technicalities behind the SFA; in Section 3, we define and make a summary statistics on the transitional datasets, as well as specify the methodological aspects. Section 4 provides the reader with commentaries on the results, Section 5 concludes the paper.

2 Stochastic Frontier Approach

Benchmarking with the parametric techniques of efficiency estimation is based on the regression analysis. As previously stated, the most common econometric method is the SFA, independently developed by Aigner *et al.* (1977) and Meeusen & van den Broeck (1977). Using explicit assumptions about the inefficiency component's distribution, it decomposes the residual of the frontier into the inefficiency and the noise. Direct estimation of the production function with output as the dependent variable is called *primal approach.* Recently, empirical frontier analysis focuses more on *dual approach* (reasons for which are provided in Battese & Coelli 1995) using cost and profit functions.

In general, firms maximize produced output vector Q_{it} (or maximize observed profit, or minimize costs in the dual approach) generated by input variables matrix $\mathbf{X}$ with sensitivity coefficients β. Ideally, $Q_{it} = f(\mathbf{X}_{it}, \beta)$,[1] but in reality it does not hold because of inefficiencies ξ_{it} and random shocks $\exp(v_{it})$:

$$Q_{it} = f(\mathbf{X}_{it}, \beta)\xi_{it}\exp(v_{it}) \tag{1}$$

If $\xi_{it}|_{\in\langle 0,1\rangle} = 1$, a firm is producing optimally, if $\xi_{it} < 1$, it indicates that a firm with technology embodied in $f(\mathbf{X}_{it}, \beta)$ can do better. Output $Q_{it} > 0$ is strictly positive, therefore the degree of technical efficiency is assumed to be $\xi_{it} > 0$, strictly positive as well.

In the SFA, researchers arbitrarily choose the form of production function. Beginning with Farrell (1957), the Cobb-Douglas functional form was used in the estimation of (1). Later, its generalized form came into usage, the less restrictive transcendental logarithmic (translog) function. An insufficient approximation provided by the translog functional can be cured by adding trigonometric terms (Fourier-flexible functional form); however, specification problem appears (Mitchell & Onvural 1996). According to some authors, the Fourier-flexible functional is considered to be the most appropriate choice for the efficiency estimation in banking sector (as in McAllister & McManus 1993).

Rewriting production function (1) linear in logarithm with N inputs in logarithmic terms yields[2]

$$\ln Q_{it} = \sum_{n=0}^{N} \beta_n \ln X_{nit} + v_{it} - u_{it} \tag{2}$$

$$\text{or } Q_{it} = \underbrace{\exp\left(\sum_{n=0}^{N} \beta_n \ln X_{nit}\right)}_{\text{deterministic component}} \cdot \underbrace{\exp(v_{it})}_{\text{noise}} \cdot \underbrace{\exp(-u_{it})}_{\text{inefficiency}}.$$

The analogy for derivation of production function (2) is the cost functional, the key element of this paper (known as the dual approach, explained in detail by Kumbhakar & Lozano-Vivas 2000). The authors specify the problem as:

$$\ln C_{it} = \beta_0 + \sum_{j=0} \beta_j^y \ln y_{jit} + \sum_{k=0} \beta_k^w \ln w_{kit} + v_{it} - au_{it}, \tag{3}$$

[1] i denotes the cross-sectional dimension, t stands for the dimension of time. These indices are different from the i and t in the equations from Definition 3.2 in the next section.

[2] For $-\ln \xi_{it} = u_{it}$ and $u_{it} \geq 0$ (stemming from u_{it} substracted from $\ln Q_{it}$), $\xi_{it} \in \langle 0, 1\rangle$.

where C_{it} is the cost/profit variable, y_{jit} stands for an output, w_{kit} is the price of an input, $a = 1$ in production functions and $a = -1$ in cost functions [for $a = 1$, we call $f(w, y)$ the alternative profit function and $f(w, p)$ the standard profit function with output prices p instead of output quantity y]. $u_{it} \overset{iid}{\sim} N^+(\mu, \sigma_u^2)$ truncated at 0 is the function of firm-specific factors determining technical inefficiency. $v_{it} \overset{iid}{\sim} N(0, \sigma_v^2)$ represents disturbances (luck, weather, strikes). Therefore, the frontier output from (1) is $X_{it}\beta + v_{it}$ and the observed output is $X_{it}\beta + \varepsilon_{it}$, where ε_{it} represents a composite error equal to $v_{it} - au_{it}$.

Maximization of the likelihood function (8) in Appendix A provides us with the estimates of parameter η (if positively or negatively significant, the efficiency ratio decreases or increases over time), μ (if insignificant, most of the banks lie on or are close to the efficiency frontier), σ_v and σ_u, the output of Stata 10 (see more in the publication of Stata Corporation 2005 and 2007).[3] Knowing these parameters, the estimates of technical efficiency term from equation (3) are obtained via (9) in Appendix A.

The general form of bank-specific efficiency is determined by vector of variables G_{it} (inefficiency determinants, conventionally called the z-variables) and the technological progress (time variables t, t^2) explaining technical inefficiency:

a. First, G- and t-variables can be put in the mean (mean-conditional model), the variance, or both mean and variance of the truncated error term. The mean-conditional model (*one-step procedure*, Coelli 1996) is defined as $E(\mu_{it}|\varepsilon_{it}) = t\tau_{i1} + t^2\tau_{i2} + G_{it}\delta + \omega_{it}$, where variables of G-matrix are expected to be correlated with the mean-inefficiency term μ_{it} from $u_{it} \overset{iid}{\sim} N^+(\mu_{it}, \sigma_u^2)$, and ω_{it} is the white noise error.

b. On the other hand, G- and t-variables can represent a part of the production function as the explanatory variables, along with the output quantities and input prices in (3). Estimating u_{it} in this *two-step procedure* yields $u_{it} = \exp\left(-\eta\left(t - T_i\right)\right) u_i$, where $u_i \overset{iid}{\sim} N^+(\mu, \sigma_u^2)$ for bank i and time $t = 1, \ldots, T$. After estimating the inefficiency term, researchers usually run a second-step individual regression in form of mean-conditional model but with $E(u_{it}|\varepsilon_{it})$ as the dependent variable.

The SFA is not driven by outliers in such an extent as some of the non-parametric methods (for instance, the non-parametric data envelopment analysis may pronounce a bank to be efficient because it is an outlier, and disregard its weak cost management). The cost (profit) function is defined by the behavior of a representative cost-minimizing (profit-maximizing) subject, controlling the amount of every input used to produce a given output. This statement is an implication of a need for properties of linear homogeneity and concavity in input prices (required by the duality theorem), and monotonicity in input prices and output.

The properties of symmetry of the second-order parameters and linear homogeneity in input prices are imposed via parameter restrictions—homogeneity by normalizing C_{it} and w_{it}, and symmetry by conditions of $\beta_{ij}^y = \beta_{ji}^y$ and $\beta_{ij}^w = \beta_{ji}^w$, $\forall i, j$. Standard restrictions of production function as to linear homo-

[3] Note that due to software limitations, only truncated normal distribution will be used for the panel estimates.

geneity would be $\sum_{k=1}^{N} \beta_k^w = 1$, and for translog w-product terms $\sum_{k=1}^{N} \beta_{kl}^w = 0$, here not applied due to price normalization.[4]

If estimating the efficiency of several countries, the cross-country comparisons should be used only in case of the common frontier (pooled panel dataset). Even in this case, countries with similar background or environment, such as transition countries, OECD countries, etc., should be chosen for the comparison. Also, the measurement of bank efficiency *per se* is hardly informative for the owners, the regulators or the bank customers. Therefore, some studies include the regression analysis, where the dependent variable is the (computed) level of efficiency and independent variables are the G-variables such as country-specific macroeconomic variables, structure of banking industry or individual bank characteristics. Statistical significance and polarity of the variables impact is commented. Moreover, the studies focus on ranking of firms according to the computed efficiency score.

3 Data and Methodology

This study uses banks' balance sheet and income statement data for a sample of European banks between the years 1995 and 2006, obtained from the *BankScope* database (Bureau van Dijk Electronic Publishing). The restrictions on the choice of banks were the following: studying transitional countries, we decided for the Central, Eastern Europe and Baltics (CEEB) region—the Czech Republic, Hungary, Poland, the Slovak Republic and Slovenia. Total number of banks' accounts for 221 in this region, with 41 in the Czech Republic, 47 in Hungary, 73 in Poland, 33 in Slovenia, and 27 in the Slovak Republic. Regarding bank types, the selection includes commercial, savings and cooperative banks, real estate and mortgage banks, medium & long term credit banks, investment banks and securities houses.

Let us have a closer look at the variables that will be used (3) [later enlarged with translog and trigonometric terms]. In the literature on banking, there is a controversy regarding the choice of inputs and outputs. We decided for the most common intermediation approach (Sealey & Lindley 1977); a short summary on used variables can be found in Table 1 (more informative statistics is provided in Table 6).

The costs OC and profits OP are reported as operating expenses and operating income of a bank, the output variables cover loans y_1, deposits y_2 and other earning assets y_3 providing us with 3 possible regressors of the Cobb-Douglas specification. Furthermore, there are three inputs to be used: labor x_1, capital x_2 and funds x_3. The prices of labor (personnel on total assets)[5] w_1 and capital w_2 (covering depreciation on fixed assets) are normalized by the price of the funds w_3 (other funds over the sum of interest expenses and deposits). The

[4]The choice of normalizing the prices and C_{it} has some practical reasons as well; it is problematic to assure the price homogeneity for the trigonometric terms of the Fourier-flexible form, which we intend to use in this study. This is not the only kind of normalization to be performed, the cost/profit and output quantities are also going to be normalized by the equity capital to control for a potential heteroscedasticity.

[5]Since the *Bankscope* database does not provide an information on the number of employees, we follow the (Hasan & Marton 2003) approach and define the price of labor as an approximation using total asstets instead of the number of employees.

Table 1: Definition of variables used in regressions of SFA

Regressands		**Description**
OC	Operating costs	Operating expenses
OP	Operating profits	Operating income
Regressors		
Output variables		
y_1	Loans	
y_2	Deposits	
y_3	Other earning assets	
Input price variables		
w_1	Price of labor	Personal expenses over total assets
w_2	Price of capital	Depreciation over fixed assets
w_3	Price of funds	Interest expenses /(deposits + other funds)
Netputs		
z	Equity capital	

intention is to use a multi-product (three inputs[6] & three outputs, and their combinations) functional shapes. The translog production function applies equity capital as one netput variable. Furthermore, we define the correlates with an inefficiency term—the summary statistics on correlates is also presented in Table 6.

Table 6 in Appendix A reports a detailed summary statistics of the variables used in this study. Based on the results of the Kruskal-Wallis equality-of-populations rank test (testing the hypothesis that several samples are drawn from the same population), the heterogeneity among the banks is highly significant. We strongly rejected that the variables' means (i.e., OC, OP, y_i, w_k, and z) are the same across different groups, where by groups we mean the subsamples created by dummies *commb* (group of commercial banks only), *large* (group of banks with total assets over 1 mio USD), *foreign* (banks in which the foreign investor participation on equity is more than 50%), *all* (denoting the Czech Republic, Hungary, Poland, Slovenia and the Slovak Republic), and *years* in the transitional dataset. Almost all the variables' means were significant at 5% level, with an exception of w_1 grouped by *year* and *commb*, w_2 grouped by *foreign*, *commb*, and *large*, y_1 by *commb* and OC by *all*, each of them not statistically significant even at the 10% level.

Another important aspect of the data is the difference between the within and the between standard deviation. For the panel of 1995–2006, the within standard deviation is smaller than between; for the sample of 2003–2006, the difference is even larger. This indicates that the variability in data is almost entirely due to the changes over time for a given bank rather than due to the cross-sectional differences between the banks—consequently, this panel does not behave like a cross-sectional dataset (years are an important identifier) and the panel estimation technique will be an appropriate choice. The dataset is strongly imbalanced and has many missing observations before the year 2000. Moreover, we decided not to weight the individual banks, but to treat each data point equally.

If we take a closer look at Table 2, it illustrates the market representation (by operating profits) of the three and five largest banks (by total assets). There

[6] 2 input prices w_1 and w_2 normalized by the price of the 3$^{\text{rd}}$ input.

is an extremely large portion of the Czech, the Slovak and the Slovenian market occupied by a small number of these financial institutions. Even for the whole transitional dataset at disposal, the numbers of 21% and 30% are quite high. Since we decided not to weight the estimated inefficiencies, it would be more reasonable to focus on the products of the benchmark B model and its deviations deprived of the scaling effect.

Table 2: Market share of banks in countries and regions as of 2006

	Czech Republic	**Hungary**	**Poland**	**Slovenia**	**Slovakia**	**All**
No. of banks	26	31	35	17	16	125
3 largest banks	70%	40%	46%	62%	65%	21%
5 largest banks	77%	52%	57%	71%	76%	30%

Knowing the variables involved in the estimation, we will define the so-called "*benchmark model*", which represents our preferred specification of the functional form and its design (following Berger & Mester 1997). Inspired by a few works written on the fitness of the Fourier-flexible functional form for banking data (McAllister & McManus 1993), we consider this functional form to be an acceptable choice of a benchmark (being aware that many authors in banking efficiency do not have to agree). Moreover, the normalization of costs C and prices w by equity capital z does not only help to get rid of the possible heteroscedasticity presence; also, the economic interpretation of the variables used is more reasonable (if C is profit, the dependent variable changes to return on equity ROE, and so on), and the scale bias is reduced.[7] For this reason, we decided for the two benchmark choices—one not normalized and the other normalized by equity capital z.

From these benchmark models, we will deviate by altering their design–each deviation represents a single methodological change in the benchmark, so that it will be easier to follow and comment on the changes in the final efficiency estimates, and also the respective order correlation between the benchmark and its deviation (or between deviations). In the following lines, we present the two chosen benchmarks, each with five different deviations related to the functional form, the number of outputs, the presence of a netput variable and a different time span.

Definition 3.1 (Benchmark model A). Let us define the model with Fourier-flexible cost/profit functional form, 2 outputs y_1 and y_2 and 2 input prices w_1 and w_2:[8]

[7]Some authors first scale data by dividing each price and output by its sample mean (Mitchell & Onvural 1996). Scaling helps with heteroscedasticity and transforms the variables so that the magnitudes of parameters are closer to each other. For our dataset, an improvement in results by this kind of scaling was not achieved.

[8]Note that the indices denoting cross-sectional and time dimension are not listed; however, we take them as present.

$$
\begin{aligned}
\ln \frac{C}{w_3} = {} & \alpha_0 + \sum_{i=1}^{2} \alpha_i \ln y_i + \sum_{k=1}^{2} \beta_k \ln \frac{w_k}{w_3} + \frac{1}{2} \sum_{i=1}^{2} \sum_{j=1}^{2} \gamma_{ij}^{y} \ln y_i \ln y_j + && (4) \\
& + \frac{1}{2} \sum_{k=1}^{2} \sum_{l=1}^{2} \delta_{kl}^{w} \ln \frac{w_k}{w_3} \ln \frac{w_l}{w_3} + \sum_{i=1}^{2} \sum_{k=1}^{2} \rho_{ik} \ln y_i \ln \frac{w_k}{w_3} \\
& + \sum_{i=1}^{4} [\theta_i \cos q_i + \omega_i \sin q_i] + \sum_{i=1}^{4} \sum_{j=i}^{4} [\theta_{ij} \cos(q_i + q_j) + \omega_{ij} \sin(q_i + q_j)] \\
& + \sum_{i=1}^{4} \sum_{j=i}^{4} \sum_{n=j}^{4} [\theta_{ijn} \cos(q_i + q_j + q_n) + \omega_{ijn} \sin(q_i + q_j + q_n)] + v - au, && (5)
\end{aligned}
$$

where C is the cost (or profit, normalized by w_3), w_k is the price of an input (normalized by w_3) for $k = 1,\ 2$, y_i stands for the output for $i = 1, \ldots, 3$; q-variables are the transformation of $\ln y$'s and $\ln \frac{w}{w_3}$'s according to z-terms from the study of Berger & Humphrey (1997)[9].

The deviations (2) - (6) from the benchmark model A in Definition 3.1 are specified as follows:

(1) The benchmark model A uses Definition 3.1, the Fourier-flexible form is not normalized by z, with 2 outputs and 2 input prices, a panel for the 2003–06 range, without netput z and correlates G; an assumed inefficiency distribution is to be truncated normal;

(2) As the benchmark (1) but the translog specification only, the trigonometric q terms are removed from the cost/profit function;

(3) As the benchmark (1) but the output quantities y and cost/profit variable C are normalized by equity capital z, identical to equation (7);

(4) As the benchmark (1) but with one additional output y_3 and the relevant products of the translog specification are added;

(5) As the benchmark (1) but a panel for the 2004–06 range with one year eliminated from the benchmark (observations eliminated);

(6) As the benchmark (1) but 1 netput variable z, its respective translog regressors and time variable t are included:

$$
\begin{aligned}
& \tau_1 t + \frac{1}{2}\tau_2 t^2 + \sum_{i=1}^{2} \tau_i^{y} t \ln \frac{y_i}{z} + \sum_{k=1}^{2} \tau_k^{w} t \ln \frac{w_k}{w_3} + \tau_1^{z} \ln z + \frac{1}{2} \tau_2^{z} \ln z^2 + && (6) \\
& + \sum_{i=1}^{2} \tau_i^{zy} \ln z \ln \frac{y_i}{z} + \sum_{k=1}^{2} \tau_k^{zw} \ln z \ln \frac{w_k}{w_3},
\end{aligned}
$$

[9] To specify this transformation due to the eligibility of trigonometric terms usage: $\ln y_1 \rightarrow q_1, \ldots, \ln \frac{w_2}{w_3} \rightarrow q_5$, where $q_i = 0.2\pi - \mu a + \mu \ln y_i$ ($\ln \frac{w_i}{w_3}$), $\mu = (0.9 * 2\pi - 0.1 * 2\pi) \,/\, (b - a)$, and $\langle a, b \rangle$ is the range of $\ln y_i$ or $\ln \frac{w_i}{w_3}$ for $i = 1, \ldots, 5$.

where t denotes time variable accounting for the technological change over time.

Definition 3.2 (Benchmark model B). Let us define the model (4), but normalized by the equity capital z as:

$$\begin{aligned}\ln \frac{C}{w_3 z} = {} & \alpha_0 + \sum_{i=1}^{2} \alpha_i \ln \frac{y_i}{z} + \sum_{k=1}^{2} \beta_k \ln \frac{w_k}{w_3} + \frac{1}{2} \sum_{i=1}^{2} \sum_{j=1}^{2} \gamma_{ij}^{y} \ln \frac{y_i}{z} \ln \frac{y_j}{z} \\ & + \frac{1}{2} \sum_{k=1}^{2} \sum_{l=1}^{2} \delta_{kl}^{w} \ln \frac{w_k}{w_3} \ln \frac{w_l}{w_3} + \sum_{i=1}^{2} \sum_{k=1}^{2} \rho_{ik} \ln \frac{y_i}{z} \ln \frac{w_k}{w_3} \\ & + \sum_{i=1}^{4} [\theta_i \cos q_i + \omega_i \sin q_i] + \sum_{i=1}^{4} \sum_{j=i}^{4} [\theta_{ij} \cos(q_i + q_j) + \omega_{ij} \sin(q_i + q_j)] \\ & + \sum_{i=1}^{4} \sum_{j=i}^{4} \sum_{n=j}^{4} [\theta_{ijn} \cos(q_i + q_j + q_n) + \omega_{ijn} \sin(q_i + q_j + q_n)] + v - au,\end{aligned} \tag{7}$$

where the variables' definitions from previous benchmark Definition 3.1 apply and q variables are transformations of normalized y's and w's according to Berger & Humphrey (1997). Unlike in Benchmark A of (3.1), the dependent variable C with all output quantities y are normalized by equity capital z to account for heterogeneity.

The deviations (2) - (6) for benchmark B from Definition 3.2 are specified as follows:

(1) The benchmark model B uses Definition 3.2, Fourier-flexible form is normalized by z, with 2 outputs and 2 input prices, a panel for the 2003–06 range, without netput z and correlates G; an assumed inefficiency distribution is to be truncated normal;

(2) As the benchmark (1) but the translog specification only, the trigonometric terms are removed from the cost/profit function;

(3) As the benchmark (1) but with one additional output y_3 normalized by z, so that also the products of translog specification are added;

(4) As the benchmark (1) but a panel for the 2004–06 range with one year eliminated from the benchmark (observations eliminated);

(5) As the benchmark (1) but time variable t added [see term (6) excluding the z-variables];

(6) As the benchmark (1) but 1 netput variable z and its respective translog regressors included [see term (6) excluding the t-variables].

The price and the cost (profit) variables are normalized in both definitions to ensure the homogeneity of the functional form in prices (since other specifications are considered deviations from the Fourier-flexible, terms of which are not multiplicative). Besides the homogeneity, the symmetry is integrated in the specification of the functional forms. The exact representation of the function would lie in the use of an infinite number of terms but an infinite number of observations as well, which is hardly achievable; therefore, we choose a subset of trigonometric terms. Also, the use of the Fourier form requires all independent variables (to produce trigonometric terms) to be scaled between $\langle 0, 2\pi \rangle$ (more on this subject can be found also in Gallant 1981). In this paper, the transformation of Berger & Humphrey (1997) will be applied. The flexible forms (may) face a problem with the collinearity of variables and even if the convergence is achieved in the model, the estimated production function may still not satisfy the curvature conditions.

Using Stata 10 statistical software, we estimate the random effects model, default for the idiosyncratic error term estimation. The iteration method uses the Newton-Raphson algorithm (see Coelli 1996, who finds the Davidon-Fletcher-Powell algorithm to be the most suitable) and assumes the inefficiency terms of truncated normal distribution.[10] We will also check for the appropriateness of the regression output: among others, the inefficiency term u should be significant, γ parameter should indicate the presence of inefficiency in the composite error term, the polarity of the coefficients of output and price logarithms should make sense, convergence in ML estimation has to be achieved, and the residuals have to have the correct kind of skewness to be consistent with the frontier models.

4 Efficiency Estimation

Often, it is not plausible to restrict the cost or the profit function to be constant over time; especially, in the case of a relatively long time-series panel or a fast evolving technological development. The cost and the (alternative) profit equations are then estimated separately for each year for the whole panel, so that the estimated production frontier coefficients may vary to better reflect the complex environmental, technological, or regulatory states. Applications using the cross-sectional analysis would be a good complement within this sensitivity check; however, we did not find our data sample to be appropriate for the cross-sectional analysis, since the convergence in ML estimation for the benchmark and its variations was not achieved.

Nevertheless, the cross-sectional model does not account for the time variations in efficiency (e.g., when managers learn from previous experiences). Panel estimation offers several advantages over the cross-section; providing a larger sample size and thus more degrees of freedom, accounting for the (unobserved) time variations in efficiency (managerial, regulatory or environmental factors), or generating a more satisfactory solution to biases produced by heterogeneity within the dataset.

Data for the cost efficiency estimation are problematic till 2002, the only suitable data are the panel of 2003–2006 and 2004–2006 (see results in Table 8 in Appendix A). Hence, we limited the research to the period from 2003 till 2006. Data for the profit efficiency estimation are suitable through the whole period of 1995–2006, see Table 9 and Table 10 in Appendix A. We managed to estimate the scores using the profit benchmark A for the period of 1995–

[10]Other distributions have been used as well; for example, the normal-truncated normal distribution in Berger & DeYoung (1997), the normal-exponential distribution in Mester (1996), or the normal-gamma by Greene (1990).

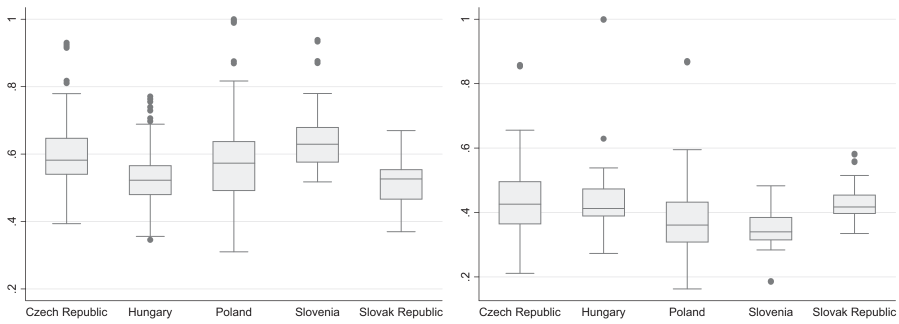

Figure 1: (B) Box plot for cost and profit scores in 2003-2006, resp.

2006 in Table 7; however, we will comment only on the results for the period of 2003–2006, since this period is considered to be relatively stable, thus more suitable for analyzing the sensitivity of the estimates towards the changes in methodological design.

Figure 1 shows the box plot for estimates of the cost and the profit efficiency scores grouped by individual countries [benchmark B or deviation (3) from benchmark A]. The box constitutes the 75$^{\text{th}}$ percentile as the upper hinge and 25$^{\text{th}}$ as the lower hinge, the inside line represents a median value, the lower and the upper adjacent values are marked by lines ending the whiskers and the grayish dots stand for the outside values. We observe the highest simple average (not median) cost efficiency of the banking sector in Slovenia (64.7%), right above the Czech Republic with 60.4%, then 57.7% in Poland (having the largest st. deviation 0.135 of the estimated inefficiency), 53.6 % in Hungary and 51.8% in Slovakia (having the smallest st. deviation 0.076 of the estimate) at the bottom. Regarding the alternative profit efficiency, the largest score from the benchmark B model obtained the Czech Republic with 45% (the highest st. deviation 0.136), next to the Hungarian 44.5%, Slovakia with 43.2% (the lowest st. deviation 0.055), Poland's 39% and at the bottom is Slovenia with 35.4%.

Taking different time sub-panels of the 1995–2006 panel, Figure 2 illustrates the development of estimated alternative profit efficiencies. The kernel density estimates are charted in Figure 3, using the benchmark A and B models (left to right). Figure 4 depicts the development of average profit efficiencies country by country through 1995–2006, Figure 5 and Figure 6 show the development of the cost and the profit scores through 2003–2006 (and their kernel density estimation is sketched by Figure 7 and Figure 8). All figures from Appendix A are paired into the benchmark A and B estimations (left to right), so that the reader can create his/hers own picture about the bias in estimates made by not normalizing the costs/profits and outputs by equity capital. Notice also the vertical shift in the scores and a relatively unchanged trend in the development of scores, apart from the disturbing trend shifts for the cost efficiency of the Slovak Republic and the profit efficiency for Hungary through 2003–2006. Throughout most of the results, we observe a decreasing profit and an increasing cost efficiency over time.

Generally in this paper, the portion of the variance in disturbance due to inefficiency, γ, is around 60% for the cost models, and quite high, 83%, for the alternative profit models. Some of the trigonometric terms needed to be

Table 3: (B) Efficiency scores for 2003-2006

Model specified		**Cost efficiency**			**Alternative profit efficiency**		
		commercial	large	foreign	commercial	large	foreign
(1) Benchmark model:			Mean = 0.575 (0.118)			Mean = 0.416 (0.118)	
Fourier-flexible form normalized	nobs		382			382	
by z with 2 outputs, 2 input							
prices, and frontier between	mean	0.571	0.581	0.561	0.411	0.409	0.439
2003-06; without netput and	st. dev	(0.121)	(0.108)	(0.0954)	(0.112)	(0.0957)	(0.147)
correlates; t-normal panel	nobs	340	215	154	340	215	154
(2) As the benchmark model			Mean = 0.535 (0.119)			Mean = 0.393 (0.119)	
but Translog specification	nobs		382			382	
	mean	0.531	0.541	0.516	0.391	0.403	0.418
	st. dev	(0.122)	(0.10)	(0.0969)	(0.12)	(0.118)	(0.142)
	nobs	340	215	154	340	215	154
Spearman and Kendall corr. of (1) & (2)			0.9656, 0.8545			0.8862, 0.7284	
(3) As the benchmark model			Mean = 0.606 (0.11)			Mean = 0.43 (0.115)	
but with 3 outputs	nobs		382			382	
	mean	0.603	0.61	0.591	0.427	0.426	0.455
	st. dev	(0.114)	(0.1)	(0.0896)	(0.11)	(0.0946)	(0.141)
	nobs	340	215	154	340	215	154
Spearman and Kendall corr. of (1) & (3)			0.9615, 0.8732			0.9301, 0.8299	
(4) As the benchmark model			Mean = 0.592 (0.118)			Mean = 0.416 (0.122)	
but with frontier ranging	nobs		302			302	
from 2004-2006							
	mean	0.589	0.592	0.583	0.413	0.414	0.434
	st. dev	(0.122)	(0.11)	(0.0995)	(0.109)	(0.0953)	(0.151)
	nobs	268	184	123	268	184	123
Spearman and Kendall corr. of (1) & (4)			0.9518, 0.8279			0.9367, 0.7970	
(5) As the benchmark model			Mean = 0.562 (0.12)			Mean = 0.462 (0.126)	
but with time	nobs		382			382	
	mean	0.558	0.57	0.548	0.457	0.449	0.484
	st. dev	(0.124)	(0.11)	(0.1)	(0.116)	(0.0999)	(0.153)
	nobs	340	215	154	340	215	154
Spearman and Kendall corr. of (1) & (5)			0.9601, 0.8343			0.9377, 0.7920	
(6) As the benchmark model			Mean = 0.612 (0.111)			Mean = 0.504 (0.119)	
but with equicap netput	nobs		382			382	
	mean	0.609	0.618	0.602	0.5	0.494	0.52
	st. dev	(0.114)	(0.103)	(0.089)	(0.109)	(0.0963)	(0.139)
	nobs	340	215	154	340	215	154
Spearman and Kendall corr. of (1) & (6)			0.9488, 0.8352			0.9145, 0.7888	

Note: mean = simple mean efficiency score, nobs = number of observations, standard deviation in parenthesis. Rank correlation coefficients significant at the 1% level. Dependent variables are lnocw_z and lnop_w, respectively.

eliminated due to collinearity between the variables; therefore, we could not meet the recommendations of Berger *et al.* (1997) about the number of parameters specifying the cost/profit function. This is, however, of no harm to our results. More interesting is the fact that the joint insignificance of trigonometric terms' coefficients in all-but-one cost models could not be rejected at any statistically appropriate level (although it is not necessarily proof of a wrong specification, since the Fourier functional form is very data demanding).

Even if we take the benchmark B as a preferred specification (results from Table 3), the unscaled benchmark A may still serve as a robustness check (results from Table 11). To compare the particular benchmark A and B specifications, it has to be cleared that the difference between deviation B(2) and the benchmark A(1) as well as B(2) and B(1) is the change of the Fourier functional form to the translog, only scaled in the case of B. B(3) with one additional output is a scaled variation of A(4), B(4) with one less year matches the A(5) model and deviations (6) from both models are quite similar, nevertheless not equally defined specifications. From a simple comparison, we conclude that scaling (by

Table 4: (B) Comparison of efficiency scores in different models

	(4) year	(3) output	(2) tlog	(1) bench	**Profit**
	>	>	>	>	(6) expl
tlog (2)	<	<	>!	>	(4) year
output (3)	>	>	>	>	(3) output
year (4)	>	>	<!	<!	(2) tlog
expl (6)	>!	>	>!	>!	
Cost	(1) bench	(2) tlog	(3) output	(4) year	

equity capital z) markedly increases the cost efficiency but increases much less or even decreases to some extent the alternative profit efficiency.

Overall results of the quantitative scores' comparison are reported in Table 3 (and Table 11), the discussion of it is summarized in Table 4. Symbols $<$ and $>$ denoting "strictly less" and "strictly more" should be read as comparisons of models from rows to columns. The table is divided diagonally into two parts: the white top-right part compares the alternative profit models, the gray bottom-left part concerns the cost efficiencies. The exclamation mark besides the $>$ and $<$ symbols warns about the inconsistency of these symbols through different benchmark A and B variations; however, benchmark B is preferred, therefore the symbol next to the exclamation mark corresponds to the result of B estimates.

We can notice a perfect diagonal symmetry in Table 4; meaning that the variations have the same impact on the direction of change in the cost as well as the profit estimates. The translog specification (2) produces a lower average cost and profit score regardless of the benchmark or its deviation (even if for the profit models, this is true for benchmark B only). It should be noted that while all profit models from Table 14 have the trigonometric terms jointly significant at the 1% level (by F-test and likelihood-ratio test taking into account translog as model nested in Fourier specification), the cost efficiency models in Table 13 were not significant, even at the 10% level, with an exception of deviation (6) which uses an additional netput in the production function.

Turning our attention to the B specification and its variations only, we can conclude the following: the translog functional form (2) behaves throughout all the models as an efficiency-decreasing element—the average efficiencies are smaller in comparison to the other models in both the cost and the profit estimates—and deviates by 3.1% from the cost benchmark and by 1.4% from the profit benchmark. Secondly, a strong claim can be carried from Table 3 about the last specification (6)—inclusion of a netput variable into the production function has a positive effect on efficiency; this specification yields larger scores in comparison to all other models, the change of 3.7% for the cost and high 8.8% for the profit estimation. Interestingly, the inclusion of time variable and its respective translog products defined as B(5) has an opposite influence on the profit and the cost scores [in the majority of models, this specification returns lower scores for the cost and higher for the profit efficiencies; by 1.3% from the cost benchmark and by −4.6% from the profit benchmark]. Finally, the enlargement of the cost functional form by one additional output increases the cost scores, by 1.7% from the cost benchmark, and by 1.4% from the profit benchmark model, although its increasing power is rather equivocal in comparison to other models.

What we cannot exactly interpret are the efficiency estimates by deviation

Table 5: (B) Rank order correlations across models of 2003-06

Spearman	(1) C	(2) C	(3) C	(4) C	(5) C	(6) C	(1) P	(2) P	(3) P	(4) P	(5) P	(6) P
(1) C	1											
(2) C tlog	0.97	1										
(3) C y	0.96	0.93	1									
(4) C year	0.95	0.92	0.92	1								
(5) C explt	0.96	0.93	0.94	0.93	1							
(6) C explz	0.95	0.93	0.92	0.91	0.93	1						
(1) P	-0.54	-0.56	-0.53	-0.57	-0.52	-0.51	1					
(2) P tlog	-0.41	-0.44	-0.40	-0.42	-0.39	-0.40	0.89	1				
(3) P y	-0.43	-0.46	-0.49	-0.45	-0.41	-0.40	0.93	0.84	1			
(4) P year	-0.55	-0.57	-0.53	-0.58	-0.54	-0.51	0.94	0.81	0.89	1		
(5) P explt	-0.56	-0.57	-0.55	-0.59	-0.60	-0.53	0.94	0.80	0.88	0.92	1	
(6) P explz	-0.50	-0.55	-0.49	-0.53	-0.49	-0.52	0.91	0.82	0.88	0.91	0.92	1

(4), which restricts the time range by one year; however, it was expected to behave according to η positive for the cost and negative for the profit models. As mentioned at the beginning of this section, we work with a strongly unbalanced panel dataset. Moreover, the market power of a little number of the large players is huge (even if we partially managed to deal with this problem). The loss of a few highly efficient banks may alter the estimated scores, even if methodologically, the SFA is more robust to outliers than the non-parametric methods. Still, the production frontier and the coefficients are changed, and a loss of the degrees of freedom may have diverse consequences. This phenomenon can be seen in Figure 2, reflecting only slight changes in the estimated development for panels of 1995–2006 to 1999–2006 panel, then almost 8% jump for the 2001–2006 panel and further.

One more issue needs to be addressed when talking about the efficiency value. The estimated efficiencies were divided according to three groups reported in Table 3 (and Table 7, or Table 11). The first one, commercial banks (*commb*), reports almost the average scores less 0.5%, but this population sample has only 11% lower number of observations at the disposal than the full panel. More interesting is the result for *large* and *foreign* banks, defined in Table 6. According to our results, large banks concentrate their efforts in managing costs more effectively, while the profits are only secondary. Foreign-owned banks behave contrary to this attitude, their primary goal is to have high profits by given outputs and input prices; the cost efficient management is secondary.

The efficiency value, however, is not the only concern of this study—the ranking of firms by efficiency value is another important aspect to be discussed. Spearman correlations between the estimated models are conducted (Table 5): all the coefficients are significant at the 1% level (valid for Table 12, as well), the cost-to-cost ones range between 91 and 97%, correlations between estimated profit scores are also high, 80 to 94%. It can be proclaimed from the nature of negative correlation coefficients between the cost and the profit scores that the cost and the alternative profit efficiencies measure different kinds of managerial skills and should be both taken into account in bank x-efficiency valuations. The cost and the profit efficiency, or the economic efficiency, which is a broad concept requiring both allocative and technical efficiency, reflects a managerial decision-making. Due to these negative correlations, we show that the cost and the profit efficiencies are conducted by different managerial skills because the banks are not able to handle low costs and high profits simultaneously.

Regarding the rank-order correlation between the benchmark model and its deviations, it is apparent that accounting for heterogeneity increases the coefficients in Table 5 relatively to Table 12. Ranking of banks in cost efficiency deviations from the benchmark B differs, but only slightly (coefficient between 95–97%), while in the profit efficiency estimation, the differences are more apparent (coefficient reaches 89%). Therefore, in terms of the banks' ranking, the efficiency estimates seem to be quite robust with respect to the differences in the SFA design, especially for the cost functional.

Table 15 to Table 23 provide a similar country-by-country overview of the Spearman and Kendall correlation coefficients. The correlation coefficients between the cost models are high and robust in size for all countries, which indicates that the ranking of firms is robust using different methodological approaches to the cost efficiency estimation. In case of the alternative efficiency scores, the robustness of ranking does not apply to such an extent, especially for Hungary, where the Spearman coefficients range from 50–86%. Interestingly, the most significant managerial problem with keeping low costs and high profits simultaneously can be found in Poland and Slovakia. In Slovenia, this issue is the least problematic, still, the correlation is negative.

5 Concluding Remarks

The paper aims to uncover the sensitivity of a specification change in the stochastic frontier approach—an analysis that is, to the authors knowledge, missing in the present literature on transitional countries banking efficiency frontier estimation (Berger's "black box" with the sources of the substantial variation in measured efficiency, Berger & Mester 1997). We conducted the valuation on a regional level for five Central and Eastern Europe countries, including the Czech Republic, Hungary, Poland, Slovenia and Slovakia. New evidence is provided using an unbalanced panel dataset of about 220 transitional banks for the period of 1995–2006, examining two economic efficiency concepts: the cost and the alternative profit efficiency. Estimations for this panel dataset assuming truncated-normal distribution of inefficiency term differ in the very basic methodological approaches.

We examine several types of variation sources by defining the benchmark model and altering it by deviations such as usage of translog specification instead of Fourier, adding one more output into the functional to have three of them instead of two, adding time trend into the equation to control for technological progress, adding the netput variable z into the functional, and taking a period of time with one less year (which reduces the number of observations but changes the whole dataset, therefore it has only an informative character and is not additive to the sensitivity analysis). Two types of the benchmark model are defined; one normalized by the equity capital to control for scale bias, the other not normalized in this way.

The results for the transitional data sample for the period of 2003-2006 can be resumed in the following: usage of transcendental logarithmic functional decreases on average the cost and profit scores, for the cost efficiency this is valid regardless of the benchmark model or the deviation used. Inclusion of the netput variable into the functional has a positive effect on both efficiencies irrespecitve of the specification (inclusion of one additional output has the same effect on the cost efficiency, only less robust). Scaling (normalization by equity capital) significantly increases the cost efficiency but increases much less or even decreases the alternative profit efficiency. Not accounting for the equity capital normalization makes large, commercial and foreign banks more profit efficient (for large banks, this conclusion is consistent with Berger & Mester 1997, the study on the US banks) but less cost efficient, even if the mean profit efficiency is higher for equity-normalized model.

We found the correlation coefficients of the cost and the alternative profit estimates to be significantly negative. Also, the number of potential correlates has a different relationship for these different measures of efficiency—suggesting that for the efficiency research of banks, both of these measures should be provided by the study on x-efficiency as both of these measures relate to different managerial decision-making; therefore, the raw conclusions about the most efficient institutions may be faulty if not being robust with respect to each of these approaches, which is an outcome supporting the current stream of literature. Also, we found the ranking of firms to be similar especially among the cost efficiency deviations from the benchmark, implying that the estimates are robust to the differences in methodological definitions within the cost efficiency framework.

The largest caveat would be probably addressed to the unbalancedness of the dataset. Moreover, the "transitionality" character of the CEEB countries throughout the investigated period 2003–2006 is questionable; nevertheless, it is not important for the overall results. We would like to emphasize the fact that our findings apply only to the given dataset with chosen assumptions and should be confirmed by the further studies. The future research may concern the alternative assumptions about the efficiency distribution, using a production approach in defining inputs and outputs, or a profit-oriented approach, accompanied by the efficiency estimation using a standard profit functional form, and extending the analysis to the cross-sectional estimates.

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A Appendix

According to Battese & Corra (1977) parametrization, the inefficiency and the noise variances σ_u^2 and σ_v^2 are replaced by $\sigma^2 = \sigma_v^2 + \sigma_u^2$, the variance of composed error ε_{it}. A new variable $\gamma = \sigma_u^2/(\sigma_v^2 + \sigma_u^2)$ is defined, so that $\gamma \in (0,1)$ in ML procedure. For the time-varying model, the log-likelihood function has the form of:

$$\begin{aligned}\ln L = \; & -\frac{1}{2}\left(\ln 2\pi + \ln \sigma^2\right)\sum_{i=0}^{N} T_i - \frac{1}{2}\sum_{i=0}^{N}(T_i - 1)\ln(1-\gamma) \\ & -\frac{1}{2}\sum_{i=0}^{N}\ln\left\{1 + \left(\sum_{t=1}^{T_i}\eta_{it}^2 - 1\right)\gamma\right\} - N\ln\{1-\phi(-\tilde{z})\} - \frac{1}{2}N\tilde{z}^2 \\ & + \sum_{i=1}^{N}\ln\{1-\phi(-z_i^*)\} + \frac{1}{2}\sum_{i=1}^{N} z_i^{*2} - \frac{1}{2}\sum_{i=1}^{N}\sum_{t=1}^{T_i}\frac{\varepsilon_{it}^2}{(1-\gamma\sigma^2)}\end{aligned} \tag{8}$$

where $\eta_{it} = \exp\{-\eta(t - T_i)\}$, $\tilde{z} = \mu/\left(\gamma\sigma^2\right)^{1/2}$, and $\phi(.)$ is the cumulative distribution function of the standard normal distribution, a is the parameter differentiating between the production and the cost functions from (3), and

$$z_i^* = \frac{\mu(1-\gamma) - a\gamma\sum_{t=1}^{T_i}\eta_{it}\varepsilon_{it}}{\left[\gamma(1-\gamma)\sigma^2\left\{1 + \left(\sum_{t=1}^{T_i}\eta_{it}^2 - 1\right)\gamma\right\}\right]^{1/2}}.$$

The estimates of technical efficiency term from (3) are obtained via:

$$E\{\exp(-au_{it})|\varepsilon_{it}\} = \left[\frac{1-\phi\{a\eta_{it}\tilde{\sigma}_i - (\tilde{\mu}_i/\tilde{\sigma}_i)\}}{1-\phi(-\tilde{\mu}_i/\tilde{\sigma}_i)}\right]\exp\left(-a\eta_{it}\tilde{\mu}_i + \frac{1}{2}\eta_{it}^2\tilde{\sigma}_i^2\right), \tag{9}$$

where

$$\tilde{\mu}_i = \frac{\mu\sigma_v^2 - a\sum_{t=1}^{T_i}\eta_{it}\varepsilon_{it}\sigma_u^2}{\sigma_v^2 + \sum_{t=1}^{T_i}\eta_{it}^2\sigma_u^2} \text{ and } \tilde{\sigma}_i^2 = \frac{\sigma_v^2\sigma_u^2}{\sigma_v^2 + \sum_{t=1}^{T_i}\eta_{it}^2\sigma_u^2}.$$

Replacing $\eta_{it} = 1$ and $\eta = 0$ changes the time decay model into the time-invariant model, so that the estimated efficiencies differ only on the cross-sectional level (for banks), not in the time dimension (through years) and $u_{it} = u_i$.

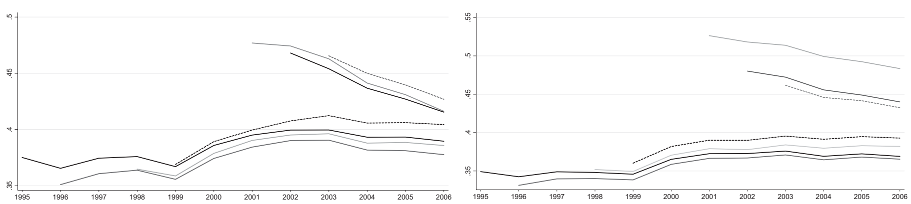

Figure 2: (A, B) Development of profit scores for different panels

Table 6: Descriptive statistics on variables (in ths. USD)

Variables for inputs/outputs	Description	Nobs	Mean	St. dev.	Min	Max
OC	Total Operating Expense	932	98 286.97	192 152.60	1 163	1 498 163
OP	Total Operating Income	932	135 437.10	282 762.30	387	2 632 230
y_1	Total Loans	932	1 220 802.00	2 345 289.00	0	22 700 000
y_2	Other Earning Assets	932	1 134 131.00	2 299 289.00	61	19 100 000
y_3	Deposits	932	2 045 136.00	3 867 016.00	48	30 200 000
z	Equity Capital	932	216 278.40	434 802.60	24	4 113 417
assets	Total Assets	932	2 590 830.00	4 884 916.00	13 304	37 000 000
interexp	Interest Expense	932	93 835.83	152 094.30	67	1 148 314
othfund	Other Funds	932	226 972.60	673 216.40	0	7 430 015
persexp	Personnel Expense	932	34 491.51	72 262.13	0	762 171
deprec	Depreciation	367	13 499.27	25 587.46	77	173 054
fixass	Fixed Assets	925	63 349.54	126 631.70	0	912 214
Bank-specific variables G	**Description**	**Nobs**	**Mean**	**St. dev.**	**Min**	**Max**
llr_gl	Loan Loss Reserve / Gross Loans	669	6.25	8.79	0.200	95
e_ta	Equity / Total Assets	932	10.88	9.21	0.004	88
cf_l	Capital Funds / Liabilities	809	15.88	35.17	0.004	751
nim	Net Interest Margin	932	4.24	3.30	0.030	29
roaa	Return on Average Assets (ROAA)	932	1.70	2.86	0.010	38
cir	Cost to Income Ratio	923	71.42	45.64	12.686	932
nl_ta	Net Loans / Total Assets	932	46.72	19.72	0.100	98
nl_dep	Net Loans / Customer & ST Funding	914	62.94	45.38	0.020	732
Country-specific variables	**Description**	**CZ**	**HU**	**PL**	**SLO**	**SVK**
Observations of commb	= 1 if commercial bank; = 0 if otherwise	204	155	233	139	132
Observations of large	= 1 if total assets over 1 billion USD; = 0 if otherwise	126	49	80	59	59
Observations of foreign	= 1 if shareholder if > 50 % foreign shareholders; = 0 if otherwise	112	65	64	37	71
Total number of observations		**225**	**189**	**245**	**139**	**134**

Table 7: (A) Profit efficiency scores for 1995-2006

Model	**Alternative profit efficiency**			**Model**	**Alternative profit efficiency**		
	commercial	large	foreign		commercial	large	foreign
(1)	Mean = 0.386 (.101)			(2)	Mean = 0.351 (0.105)		
nobs	932			nobs	932		
mean	0.383	0.38	0.392	mean	0.349	0.343	0.357
st. dev	(0.0988)	(0.0717)	(0.0897)	st. dev	(0.104)	(0.0755)	(0.0944)
nobs	863	373	349	nobs	863	373	349
spear				spear	0.9113, 0.7599		
(3)	Mean = 0.3698 (0.0844)			(4)	Mean = 0.387 (0.0984)		
nobs	932			nobs	932		
mean	0.367	0.364	0.375	mean	0.386	0.383	0.391
st. dev	(0.0823)	(0.0548)	(0.0729)	st. dev	(0.0971)	(0.0709)	(0.0832)
nobs	863	373	349	nobs	863	373	349
spear	0.8799, 0.7115			spear	0.9819, 0.9126		
(5)	Mean = 0.375 (0.993)			(6)	Mean = 0.371 (0.807)		
nobs	877			nobs	930		
mean	0.372	0.37	0.377	mean	0.428	0.424	0.428
st. dev	(0 .0974)	(0.0711)	(0.0815)	st. dev	(0.0942)	(0.0670)	(0.0935)
nobs	810	355	336	nobs	861	372	348
spear	0.9812, 0.8935			spear	0.8623, 0.6899		

Note: dependent variable lnopw.

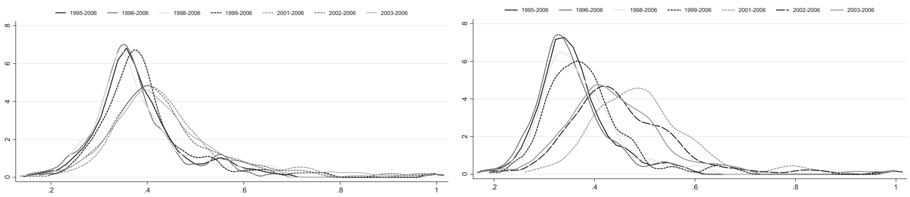

Figure 3: (A, B) Kernel profit density 1995-2006 (epanechnikov, bandwidth 0.0148 & 0.0128)

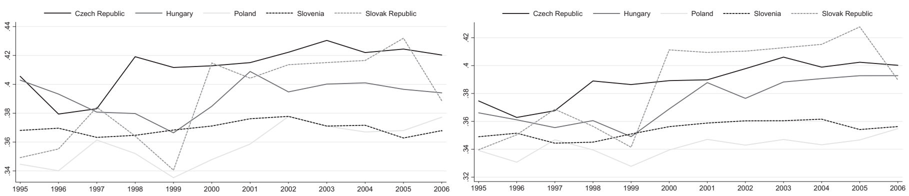

Figure 4: (A, B) Development of profit scores by countries

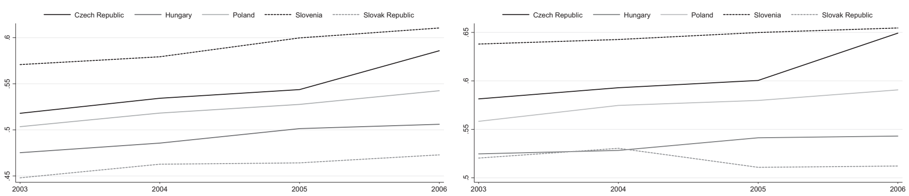

Figure 5: (A, B) Development of cost scores by countries

Table 8: (A, B) Stochastic panel cost frontier by years

lnocw(z) = depvar	(A) 2003-2006	(A) 2004-2006	(B) 2003-2006	(B) 2004-2006
alpha1(_z)	0.0697	−0.530	0.521^{**}	0.416^{**}
	(0.12)	(−0.69)	(6.82)	(4.31)
alpha2(_z)	1.665^{**}	1.672^{**}	0.536^{**}	0.527^{**}
	(5.28)	(4.67)	(8.98)	(6.95)
beta1	2.320^{**}	1.971^{*}	0.811^{**}	0.837^{**}
	(3.30)	(2.48)	(12.80)	(9.78)
gamma11(_z)	0.241^{**}	0.315^{**}	$0.0833^{\dagger}$	0.131^{*}
	(4.28)	(4.30)	(1.88)	(2.38)
gamma12(_z)	-0.215^{**}	-0.252^{**}	-0.0987^{**}	-0.125^{**}
	(−6.61)	(−6.05)	(−4.64)	(−3.97)
gamma22(_z)	0.121^{**}	0.163^{**}	0.123^{**}	0.146^{**}
	(5.78)	(5.00)	(6.47)	(5.56)
delta11	−0.102	−0.0926	0.157^{**}	$0.104^{\dagger}$
	(−0.98)	(−0.85)	(3.01)	(1.82)
rho11(_z)	−0.0740	$-0.0992^{\dagger}$	$0.0593^{\dagger}$	0.0220
	(−1.55)	(−1.73)	(1.65)	(0.45)
rho21(_z)	−0.0455	0.0121	0.105^{**}	0.0975^{*}
	(−1.05)	(0.21)	(3.27)	(2.53)
sq33	0.217	−0.00534	−0.0890	−0.129
	(0.87)	(−0.02)	(−0.46)	(−0.54)
cq111	0.0995	0.165	−0.0896	−0.0550
	(0.75)	(1.13)	(−0.90)	(−0.50)
cq122	0.00187	0.0385	0.0176	0.0549
	(0.01)	(0.13)	(0.08)	(0.21)
cq133	−0.161	−0.362	0.0543	−0.146
	(−0.84)	(−1.62)	(0.41)	(−0.90)
cq222	0.100	−0.0295	0.00851	−0.0967
	(0.61)	(−0.14)	(0.06)	(−0.51)
cq223	-0.435^{*}	-0.637^{*}	−0.115	−0.223
	(−2.54)	(−2.32)	(−0.85)	(−1.10)
cq233	−0.104	0.202	−0.0717	0.163
	(−0.56)	(0.84)	(−0.44)	(0.77)
cq333	−0.00279	0.0266	0.0530	0.0121
	(−0.04)	(0.27)	(0.80)	(0.15)
sq111	0.311	0.647^{*}	0.192	0.352
	(1.44)	(2.15)	(1.03)	(1.41)
sq112	−0.468	$-1.042^{\dagger}$	−0.267	−0.572
	(−1.12)	(−1.71)	(−0.70)	(−1.09)
sq122	0.136	0.550	0.0711	0.304
	(0.49)	(1.29)	(0.27)	(0.83)
sq123	0.431	1.003^{*}	−0.0732	0.226
	(1.52)	(2.43)	(−0.39)	(0.75)
sq133	$0.397^{\dagger}$	0.514^{*}	0.198	$0.327^{\dagger}$
	(1.78)	(2.09)	(1.37)	(1.95)
sq223	0.0627	$-0.526^{\dagger}$	0.0591	−0.316
	(0.34)	(−1.66)	(0.35)	(−1.19)
sq233	$-0.354^{\dagger}$	-0.641^{*}	-0.385^{*}	-0.481^{*}
	(−1.84)	(−2.56)	(−2.33)	(−2.36)
sq333	0.133	0.110	0.0515	0.0467
	(1.44)	(1.07)	(0.67)	(0.54)
constant	−2.583	1.547	1.079^{**}	1.235^{**}
	(−0.64)	(0.31)	(4.82)	(4.26)
$\ln \sigma^2$	-2.239^{**}	-2.305^{**}	-2.534^{**}	-2.578^{**}
	(−23.56)	(−22.37)	(−24.35)	(−22.56)
inverse logit of γ	0.0451	0.0835	0.439^{*}	0.615^{*}
	(0.20)	(0.32)	(2.08)	(2.55)
μ	0.785^{**}	0.773^{**}	0.678^{**}	0.706^{**}
	(3.41)	(3.35)	(3.63)	(2.87)
η	$0.0343^{\dagger}$	$0.0422^{\dagger}$	0.0247	0.0301
	(1.84)	(1.65)	(1.55)	(1.43)
z statistics in parentheses, † $p < 0.10$, * $p < 0.05$, ** $p < 0.01$				
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.107	0.0998	0.0794	0.0759
	(0.0101)	(0.0103)	(0.00826)	(0.00868)
$\gamma = \sigma_u^2/\sigma^2$	0.511	0.521	0.608	0.649
	(0.0554)	(0.0648)	(0.0503)	(0.0549)
σ_u^2	0.233	0.228	0.220	0.222
	(0.01)	(0.0106)	(0.00834)	(0.00903)
σ_v^2	0.228	0.219	0.176	0.163
	(0.0047)	(0.00529)	(0.00284)	(0.00301)
Efficiency score	0.522	0.559	0.575	0.592
	(0.117)	(0.116)	(0.118)	(0.118)
Observations	382	302	382	302

Standard errors in parentheses, ML computed using heteroscedasticity robust z statistics. If $\mu = 0$, most of the banks lie on or are close to the efficient frontier. Inefficiency decreases over time t if $\eta > 0$, increases if $\eta < 0$, and is steady for $\eta = 0$. γ is a proportion of the variance in disturbance due to inefficiency—if it is too low, it questions the presence of inefficiency.

Table 9: (A) Stochastic panel profit frontier by years

lnopw = depvar	1995-06	1996-06	1998-06	1999-06	2001-06	2002-06	2003-06
alpha1	1.275^{**}	1.304^{**}	1.397^{**}	0.713	0.988^{**}	$0.753^{\dagger}$	0.662
	(6.27)	(5.34)	(5.18)	(1.10)	(2.73)	(1.76)	(1.07)
alpha2	0.874^{*}	1.349^{*}	1.458^{**}	1.290^{*}	1.015^{*}	1.745^{**}	1.053^{**}
	(1.97)	(2.27)	(4.45)	(2.01)	(2.48)	(3.07)	(3.15)
beta1	0.106	1.109^{**}	1.015^{**}	0.962^{**}	0.891^{*}	1.879^{**}	0.775^{*}
	(0.23)	(4.53)	(3.77)	(2.60)	(1.97)	(2.71)	(2.01)
gamma11	0.149^{**}	0.128^{**}	0.128^{**}	0.179^{**}	0.164^{**}	0.168^{**}	0.136^{*}
	(10.78)	(7.47)	(7.55)	(4.21)	(5.46)	(5.12)	(2.01)
gamma12	-0.192^{**}	-0.184^{**}	-0.201^{**}	-0.201^{**}	-0.201^{**}	-0.191^{**}	-0.166^{**}
	(−8.79)	(−7.26)	(−10.60)	(−8.19)	(−8.88)	(−5.60)	(−5.90)
gamma22	0.183^{**}	0.115^{**}	0.124^{**}	0.134^{**}	0.192^{**}	0.0892^{*}	0.118^{**}
	(5.94)	(3.33)	(8.85)	(3.39)	(5.84)	(2.41)	(8.04)
delta11	0.307^{*}	0.0726	0.0493	−0.0212	0.116	-0.148^{*}	0.0550
	(2.52)	(1.59)	(0.98)	(−0.32)	(1.56)	(−2.26)	(1.05)
rho11	−0.00606	−0.00251	−0.0267	0.00554	−0.0304	-0.0956^{*}	−0.0118
	(−0.42)	(−0.20)	(−1.55)	(0.18)	(−0.82)	(−2.35)	(−0.56)
rho21	0.145^{*}	0.00538	0.0211	−0.0206	0.0664	0.00496	0.0189
	(2.41)	(0.15)	(0.88)	(−1.05)	(1.54)	(0.17)	(0.56)
sq113	0.360^{*}	0.216	0.219^{*}	0.156	$0.264^{\dagger}$	0.407^{**}	
	(2.01)	(1.37)	(2.25)	(0.99)	(1.95)	(3.17)	
sq22	-0.395^{**}	-0.509^{**}	-0.574^{**}	-0.666^{*}		−0.413	−0.265
	(−3.45)	(−3.01)	(−3.20)	(−2.09)		(−1.35)	(−1.31)
cq133	0.395^{*}	0.0972	−0.0156	0.0886		-0.352^{**}	
	(2.37)	(1.20)	(−0.28)	(0.85)		(−3.13)	
cq11	0.557^{*}	0.397	0.505^{*}	0.367^{*}			
	(2.06)	(1.11)	(1.97)	(2.35)			
cq123	$-0.613^{\dagger}$	−0.303	-0.460^{**}		−0.105	-0.561^{*}	
	(−1.93)	(−1.24)	(−3.40)		(−0.43)	(−2.27)	
sq111	0.204	0.0684	0.0996		-0.151^{*}		−0.176
	(1.20)	(0.42)	(0.92)		(−2.08)		(−1.42)
cq111	0.0821	−0.0825				0.144	$0.482^{\dagger}$
	(0.98)	(−0.57)				(1.32)	(1.73)
cq13	1.452^{**}	0.716^{*}					
	(2.85)	(2.29)					
sq233	−0.230				−0.192	−0.176	-0.290^{**}
	(−1.05)				(−1.30)	(−1.58)	(−2.60)
cq33	−0.111					-0.405^{**}	
	(−0.77)					(−2.93)	
cq23	0.851^{*}	0.192			1.825^{**}		
	(2.34)	(0.53)			(2.82)		
sq223			-0.332^{**}		0.306^{*}	−0.148	$-0.367^{\dagger}$
			(−2.65)		(2.43)	(−1.31)	(−1.86)
cq223				-0.240^{*}	0.124		-0.449^{**}
				(−2.12)	(0.80)		(−3.75)
sq333				0.0827			0.142^{**}
				(1.51)			(3.45)
sq123							0.665^{*}
							(2.54)
constant	-6.961^{*}	−6.988	-7.733^{*}	−2.144	−5.509	−4.982	0.836
	(−2.13)	(−1.32)	(−2.09)	(−0.30)	(−1.56)	(−1.17)	(0.22)
$\ln \sigma^2$	-1.560^{**}	-1.529^{**}	-1.669^{**}	-1.732^{**}	-1.860^{**}	-2.085^{**}	-2.032^{**}
	(−23.67)	(−22.42)	(−22.89)	(−22.52)	(−19.42)	(−18.04)	(−16.40)
inverse logit of γ	-0.462^{*}	-0.442^{*}	$-0.340^{\dagger}$	−0.294	0.249	1.287^{**}	1.546^{**}
	(−2.53)	(−2.32)	(−1.79)	(−1.47)	(1.25)	(7.19)	(8.09)
μ	1.254^{**}	1.247^{**}	1.176^{**}	1.125^{**}	$1.186^{\dagger}$	1.028^{**}	1.050^{**}
	(2.78)	(3.52)	(4.22)	(4.29)	(1.86)	(6.76)	(4.95)
η	0.00332	0.00513	0.00832	0.0105	−0.0230	-0.0209^{*}	$-0.0168^{\dagger}$
	(0.72)	(0.99)	(1.25)	(1.30)	(−1.52)	(−2.35)	(−1.65)
z statistics in parentheses, † $p < 0.10$, * $p < 0.05$, ** $p < 0.01$							
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.210	0.217	0.188	0.177	0.156	0.124	0.131
	(0.0139)	(0.0148)	(0.0137)	(0.0136)	(0.0149)	(0.0144)	(0.0162)
$\gamma = \sigma_u^2/\sigma^2$	0.387	0.391	0.416	0.427	0.562	0.784	0.824
	(0.0433)	(0.0454)	(0.0462)	(0.0489)	(0.0492)	(0.0303)	(0.0277)
σ_u^2	0.285	0.291	0.280	0.275	0.296	0.312	0.329
	(0.0134)	(0.0145)	(0.0133)	(0.0134)	(0.0150)	(0.0145)	(0.0165)
σ_v^2	0.359	0.363	0.332	0.318	0.261	0.164	0.152
	(0.00674)	(0.00719)	(0.00656)	(0.00645)	(0.00505)	(0.00218)	(0.00214)
Efficiency score	0.386	0.375	0.384	0.4004	0.447	0.438	0.445
	(0.101)	(0.0993)	(0.108)	(0.111)	(0.127)	(0.129)	(0.139)
Observations	932	877	735	666	523	457	382

St. errors in parentheses, ML computed using heteroscedasticity robust (observed information matrix) z statistics. Only significant trigonometric coefficients reported. All frontier equations are Fourier-flexible using 2 outputs and 2 input prices.

Table 10: (B) Stochastic panel profit frontier by years

lnopw_z = depvar	1995-06	1996-06	1998-06	1999-06	2001-06	2002-06	2003-06
alpha1_z	0.0828	0.0725	0.129†	0.133†	0.270*	0.0844	0.0845
	(1.26)	(1.08)	(1.84)	(1.81)	(2.32)	(0.85)	(0.76)
alpha2_z	0.483**	0.498**	0.441**	0.515**	0.370**	0.400**	0.405**
	(7.59)	(7.61)	(6.39)	(7.20)	(3.61)	(4.81)	(4.19)
beta1	0.701**	0.695**	0.888**	0.887**	0.808**	0.534**	0.389**
	(8.81)	(8.56)	(8.72)	(7.98)	(7.08)	(4.65)	(3.02)
gamma11_z	0.139**	0.131**	0.109**	0.106**	0.102*	0.221**	0.226**
	(6.53)	(5.92)	(3.99)	(3.48)	(2.25)	(5.79)	(5.29)
gamma12_z	−0.0922**	−0.0906**	−0.0831**	−0.0917**	−0.0825**	−0.0839**	−0.0761**
	(−7.61)	(−7.24)	(−5.47)	(−5.53)	(−3.53)	(−4.15)	(−3.17)
gamma22_z	0.128**	0.132**	0.133**	0.146**	0.108**	0.0701**	0.0634*
	(8.49)	(8.42)	(8.13)	(8.71)	(4.86)	(3.39)	(2.31)
delta11	0.0454	0.0500	0.00657	0.0277	−0.114†	−0.109†	−0.0762
	(0.86)	(0.93)	(0.12)	(0.45)	(−1.71)	(−1.92)	(−1.12)
rho11_z	−0.0217	−0.0212	−0.0576*	−0.0433	−0.0612†	−0.0333	−0.00986
	(−0.94)	(−0.89)	(−2.29)	(−1.59)	(−1.67)	(−0.78)	(−0.19)
rho21_z	0.0490†	0.0552*	0.0690**	0.0757**	0.00214	0.0384	0.0603
	(1.92)	(2.10)	(2.62)	(2.75)	(0.06)	(1.29)	(1.54)
cq11	−0.395†	−0.459*	0.252	0.164	0.827*	−0.120	−0.323
	(−1.82)	(−2.05)	(0.90)	(0.55)	(2.04)	(−0.31)	(−0.69)
cq12	−0.337*	−0.290†	−1.154**	−0.999**	−1.547**	−0.450	−0.0701
	(−2.03)	(−1.70)	(−4.06)	(−3.32)	(−3.61)	(−1.14)	(−0.14)
cq13	−0.639**	−0.692**	−0.0814	−0.167	0.114	−0.429	−0.502
	(−2.60)	(−2.75)	(−0.25)	(−0.47)	(0.28)	(−1.21)	(−1.10)
cq33	−0.255*	−0.266*	−0.389**	−0.330*	−0.606**	−0.609**	−0.565**
	(−2.18)	(−2.21)	(−3.19)	(−2.39)	(−4.33)	(−5.53)	(−4.49)
cq23	0.593**	0.620**	0.623**	0.800**	0.687**	0.291	0.169
	(2.74)	(2.80)	(2.89)	(3.61)	(2.83)	(1.57)	(0.81)
sq22	−0.133†	−0.122	−0.232**	−0.205*	−0.270**	−0.135†	−0.121
	(−1.78)	(−1.58)	(−2.58)	(−2.20)	(−2.81)	(−1.70)	(−1.36)
sq23	−0.558	−0.557	−0.573	−0.536	−1.236*	−0.921	−0.770
	(−1.57)	(−1.52)	(−1.46)	(−1.15)	(−2.12)	(−1.63)	(−1.07)
sq33	0.0186	−0.00992	−0.128	−0.103	−0.102	−0.00923	0.174
	(0.18)	(−0.09)	(−1.09)	(−0.78)	(−0.73)	(−0.08)	(1.15)
cq111	0.0130	0.00288	0.125	0.153†	0.242**	0.188**	0.213*
	(0.17)	(0.04)	(1.50)	(1.75)	(2.58)	(2.63)	(2.44)
cq113	−0.416**	−0.399**	−0.170	−0.107	−0.0254	−0.196	−0.186
	(−2.96)	(−2.78)	(−1.11)	(−0.59)	(−0.12)	(−0.99)	(−0.66)
cq123	0.274	0.242	−0.105	−0.127	0.200	0.330	0.369
	(1.21)	(1.05)	(−0.41)	(−0.40)	(0.53)	(0.99)	(0.81)
cq133	−0.142	−0.112	−0.00859	−0.0224	−0.0973	−0.325*	−0.506**
	(−1.36)	(−1.04)	(−0.06)	(−0.14)	(−0.54)	(−2.41)	(−2.68)
sq111	−0.0249	−0.0608	0.261†	0.0986	0.342	−0.0763	−0.107
	(−0.25)	(−0.59)	(1.86)	(0.64)	(1.56)	(−0.38)	(−0.44)
sq112	−0.260*	−0.229*	−0.583**	−0.437**	−0.777**	−0.255	−0.183
	(−2.55)	(−2.17)	(−3.72)	(−2.64)	(−3.20)	(−1.18)	(−0.66)
sq113	0.0761	0.0506	0.373*	0.490**	0.711**	0.346*	0.376*
	(0.55)	(0.36)	(2.39)	(2.76)	(3.60)	(2.30)	(2.00)
sq233	−0.343*	−0.373*	−0.513**	−0.476*	−0.593**	−0.540**	−0.470**
	(−2.11)	(−2.23)	(−3.02)	(−2.48)	(−3.08)	(−3.41)	(−2.58)
constant	3.916**	3.891**	4.090**	3.953**	4.278**	3.970**	3.830**
	(9.41)	(10.26)	(11.24)	(10.04)	(5.55)	(10.33)	(7.47)
$\ln \sigma^2$	−1.885**	−1.855**	−1.967**	−1.975**	−2.119**	−2.330**	−2.354**
	(−29.03)	(−27.66)	(−27.31)	(−25.82)	(−22.47)	(−19.81)	(−19.19)
inverse logit of γ	−0.473**	−0.436*	−0.388*	−0.290	0.0359	1.340**	1.466**
	(−2.64)	(−2.37)	(−2.01)	(−1.47)	(0.16)	(7.40)	(7.53)
μ	1.250**	1.238**	1.159**	1.144**	0.994	0.939**	0.997**
	(3.78)	(4.51)	(4.94)	(4.56)	(1.41)	(6.48)	(4.95)
η	0.00400	0.00615	0.00874	0.00750	−0.0175	−0.0187*	−0.0139
	(1.02)	(1.40)	(1.48)	(1.10)	(−1.14)	(−2.25)	(−1.52)
z statistics in parentheses, † $p < 0.10$, * $p < 0.05$, ** $p < 0.01$							
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.152	0.156	0.140	0.139	0.120	0.0973	0.0950
	(0.00986)	(0.0105)	(0.0101)	(0.0106)	(0.0113)	(0.0114)	(0.0117)
$\gamma = \sigma_u^2/\sigma^2$	0.384	0.393	0.404	0.428	0.509	0.792	0.812
	(0.0425)	(0.0439)	(0.0464)	(0.0484)	(0.055)	(0.0298)	(0.0297)
σ_u^2	0.241	0.248	0.238	0.244	0.247	0.278	0.278
	(0.00949)	(0.0102)	(0.00975)	(0.0104)	(0.0116)	(0.0116)	(0.0119)
σ_v^2	0.306	0.308	0.289	0.282	0.243	0.142	0.133
	(0.00487)	(0.00515)	(0.00496)	(0.00504)	(0.00442)	(0.00164)	(0.00167)
Efficiency score	0.362	0.357	0.374	0.388	0.503	0.458	0.445
	(0.0861)	(0.0886)	(0.0936)	(0.0998)	(0.116)	(0.119)	(0.118)
Observations	932	877	735	666	523	457	382

St. errors in parentheses, ML computed using heteroscedasticity robust (observed information matrix) z statistics.

Table 11: (A) Efficiency scores for 2003-2006

Model specified		**Cost efficiency**			**Alternative profit efficiency**		
		commercial	large	foreign	commercial	large	foreign
(1) Benchmark model:			Mean = 0.522 (0.117)			Mean = 0.386 (.101)	
Fourier-flexible form with 2	nobs		382			382	
outputs, 2 input prices, and							
frontier between 2003-2006;	mean	0.519	0.528	0.508	0.430	0.423	0.443
without equity capital and	sd	(0.120)	(0.106)	(0.0872)	(0.119)	(0.104)	(0.135)
correlates; panel estimation	nobs	340	215	154	340	215	154
(2) As the benchmark model			Mean = 0.469 (0.119)			Mean = 0.411 (0.135)	
but Translog specification	nobs		382			382	
	mean	0.465	0.471	0.448	0.407	0.399	0.429
	sd	(0.122)	(0.107)	(0.0904)	(0.131)	(0.115)	(0.149)
	nobs	340	215	154	340	215	154
Spearman and Kendall corr. of (1) & (2)			0.9417, 0.8104			0.9188, 0.7743	
(3) As the benchmark model			Mean = 0.575 (0.118)			Mean = 0.416 (0.118)	
but with equity capital	nobs		382			382	
normalization							
	mean	0.571	0.581	0.561	0.411	0.409	0.439
	sd	(0.121)	(0.108)	(0.954)	(0.112)	(0.0957)	(0.147)
	nobs	340	215	154	340	215	154
Spearman and Kendall corr. of (1) & (3)			0.9386, 0.8053			0.8157, 0.6386	
(4) As the benchmark model			Mean = 0.553 (0.111)			Mean = 0.435 (0.13)	
but with 3 outputs	nobs		382			382	
	mean	0.552	0.559	0.54	0.43	0.423	0.448
	sd	(0.115)	(0.101)	(0.0787)	(0.123)	(0.104)	(0.134)
	nobs	340	215	154	340	215	154
Spearman and Kendall corr. of (1) & (4)			0.9566, 0.8627			0.9665, 0.8710	
(5) As the benchmark model			Mean = 0.559 (0.116)			Mean = 0.399 (0.127)	
but with frontier ranging	nobs		302			302	
from 2004-2006							
	mean	0.557	0.558	0.55	0.398	0.397	0.409
	sd	(0.119)	(0.109)	(0.0926)	(0.117)	(0.107)	(0.145)
	nobs	268	184	123	268	184	123
Spearman and Kendall corr. of (1) & (5)			0.9494, 0.8350			0.9286, 0.7923	
(6) As the benchmark model			Mean = 0.484 (0.114)			Mean = 0.447 (0.126)	
but with other explanatory	nobs		382			382	
variables (with gray							
part in Def. 3.1)	mean	0.479	0.487	0.474	0.444	0.436	0.463
	sd	(0.116)	(0.0997)	(0.0927)	(0.122)	(0.111)	(0.143)
	nobs	340	215	154	340	215	154
Spearman and Kendall corr. of (1) & (6)			0.8328, 0.6555			0.8599, 0.6942	

Note: mean = simple mean efficiency score, nobs = number of observations, standard deviation in parenthesis. Rank correlation coefficients significant on 1% level.

Table 12: (A) Rank order correlations across models of 2003-06

Spearman	(1) C	(2) C	(3) C	(4) C	(5) C	(6) C	(1) P	(2) P	(3) P	(4) P	(5) P	(6) P
(1) C	1											
(2) C tlog	0.94	1										
(3) C z	0.94	0.94	1									
(4) C y	0.96	0.88	0.91	1								
(5) C year	0.95	0.88	0.88	0.91	1							
(6) C expl	0.83	0.83	0.79	0.80	0.82	1						
(1) P	-0.48	-0.49	-0.46	-0.47	-0.48	-0.37	1					
(2) P tlog	-0.40	-0.50	-0.42	-0.40	-0.39	-0.33	0.92	1				
(3) P z	-0.49	-0.54	-0.54	-0.49	-0.50	-0.37	0.82	0.81	1			
(4) P y	-0.41	-0.41	-0.39	-0.44	-0.40	-0.30	0.97	0.90	0.80	1		
(5) P year	-0.48	-0.52	-0.45	-0.45	-0.50	-0.42	0.93	0.86	0.78	0.88	1	
(6) P expl	-0.45	-0.55	-0.48	-0.45	-0.45	-0.43	0.86	0.92	0.87	0.82	0.81	1

Table 13: (B) Cost efficiency by models (2003-06)

lnocw_z = depvar	(1)	(2)	(3)	(4)	(5)	(6)
alpha1_z	0.521^{**}	0.478^{**}	0.325^{**}	0.416^{**}	0.495^{**}	-0.306
	(6.82)	(7.98)	(3.19)	(4.31)	(3.31)	(-0.60)
alpha2_z	0.536^{**}	0.437^{**}	0.423^{**}	0.527^{**}	0.535^{**}	1.757^{**}
	(8.98)	(11.42)	(6.33)	(6.95)	(3.83)	(6.29)
beta1	0.811^{**}	0.713^{**}	0.909^{**}	0.837^{**}	1.012^{**}	2.911^{**}
	(12.80)	(16.11)	(13.32)	(9.78)	(5.65)	(4.91)
gamma11_z	$0.0833^{\dagger}$	0.105^{**}	0.184^{*}	0.131^{*}	0.0694	0.145^{**}
	(1.88)	(2.84)	(2.57)	(2.38)	(1.56)	(2.61)
gamma12_z	-0.0987^{**}	-0.0745^{**}	-0.0334	-0.125^{**}	-0.0870^{**}	-0.168^{**}
	(-4.64)	(-4.96)	(-0.91)	(-3.97)	(-3.89)	(-5.94)
gamma22_z	0.123^{**}	0.0881^{**}	0.134^{**}	0.146^{**}	0.115^{**}	0.125^{**}
	(6.47)	(9.30)	(5.67)	(5.56)	(5.77)	(6.28)
delta11	0.157^{**}	0.124^{**}	$0.118^{\dagger}$	$0.104^{\dagger}$	0.185^{**}	-0.00641
	(3.01)	(5.52)	(1.81)	(1.82)	(3.14)	(-0.08)
rho11_z	$0.0593^{\dagger}$	0.0719^{**}	-0.00866	0.0220	$0.0637^{\dagger}$	-0.0379
	(1.65)	(2.97)	(-0.15)	(0.45)	(1.74)	(-0.87)
rho21_z	0.105^{**}	0.0640^{**}	0.147^{**}	0.0975^{*}	0.0909^{**}	-0.00601
	(3.27)	(3.44)	(3.96)	(2.53)	(2.83)	(-0.16)
alpha3_z			0.330^{**}			
			(3.77)			
gamma23_z			-0.0177			
			(-0.70)			
gamma33_z			0.00842			
			(0.40)			
gamma13_z			-0.107^{*}			
			(-2.23)			
rho31_z			-0.00237			
			(-0.05)			
tau1					0.264	
					(0.98)	
tau2					-0.0187	
					(-0.95)	
tauy1					0.00182	
					(0.20)	
tauy2					-0.00277	
					(-0.31)	
tauy3					0.00281	
					(1.33)	
tauw1					-0.0126	
					(-0.97)	
tau1_z						0.192
						(0.35)
tau2_z						-0.0299
						(-0.70)
tauy1_z						0.0570
						(1.43)
tauy2_z						-0.107^{**}
						(-4.60)
tauy3_z						0.00574^{*}
						(2.53)
tauw1_z						-0.183^{**}
						(-3.50)
constant	1.079^{**}	1.033^{**}	1.121^{**}	1.235^{**}	-1.147	1.218
	(4.82)	(5.30)	(4.24)	(4.26)	(-0.60)	(0.34)
$\ln \sigma^2$	-2.534^{**}	-2.444^{**}	-2.649^{**}	-2.578^{**}	-2.625^{**}	-2.670^{**}
	(-24.35)	(-23.16)	(-26.69)	(-22.56)	(-24.61)	(-26.57)
inverse logit of γ	0.439^{*}	0.561^{**}	0.205	0.615^{*}	0.335	0.226
	(2.08)	(2.73)	(0.92)	(2.55)	(1.52)	(1.01)
μ	0.678^{**}	0.748^{**}	0.677^{**}	0.706^{**}	0.661^{**}	0.639^{**}
	(3.63)	(3.73)	(3.08)	(2.87)	(3.95)	(2.93)
η	0.0247	$0.0251^{\dagger}$	0.0219	0.0301	0.0844^{*}	$0.0305^{\dagger}$
	(1.55)	(1.80)	(1.33)	(1.43)	(2.49)	(1.70)
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.0794	0.0868	0.0707	0.0759	0.0725	0.0693
$\gamma = \sigma_u^2/\sigma^2$	0.608	0.637	0.551	0.649	0.583	0.556
σ_u^2	0.220	0.235	0.197	0.222	0.206	0.196
σ_v^2	0.176	0.178	0.178	0.163	0.174	0.175
log L	10.12	0.898	18.17	12.96	14.01	22.50
Efficiency score	0.575	0.535	0.606	0.592	0.562	0.612
st. dev	(0.118)	(0.119)	(0.11)	(0.118)	(0.121)	(0.111)
Observations	382	382	382	302	382	382

t statistics in parentheses, ML computed using heteroscedasticity robust (observed information matrix) z statistics. Trigonometric coefficients not reported.

Table 14: (B) Profit efficiency by models (2003-06)

lnopw_z = depvar	(1)	(2)	(3)	(4)	(5)	(6)
alpha1_z	0.236**	0.441**	−0.00374	0.287**	0.265*	0.246
	(3.32)	(7.58)	(−0.04)	(3.33)	(2.22)	(0.55)
alpha2_z	0.286**	0.381**	0.185**	0.248**	0.214*	1.355**
	(5.39)	(10.33)	(3.17)	(3.97)	(1.97)	(5.44)
beta1	0.584**	0.481**	0.742**	0.570**	0.649**	1.619**
	(10.48)	(11.69)	(12.33)	(7.41)	(4.56)	(3.23)
gamma11_z	0.183**	0.157**	0.349**	0.193**	0.201**	0.272**
	(4.26)	(4.42)	(5.40)	(3.72)	(4.74)	(5.49)
gamma12_z	−0.0529**	−0.0663**	0.0284	−0.0622*	−0.0615**	−0.146**
	(−2.67)	(−5.05)	(0.88)	(−2.19)	(−3.06)	(−5.55)
gamma22_z	0.0578**	0.0592**	0.103**	0.0649**	0.0712**	0.0822**
	(3.62)	(6.91)	(5.04)	(2.91)	(4.23)	(5.73)
delta11	0.183**	0.0864**	0.0665	0.127**	0.225**	0.125†
	(3.89)	(4.05)	(1.20)	(2.62)	(4.37)	(1.84)
rho11_z	0.0754*	0.122**	−0.0312	0.0778†	0.0805**	0.0287
	(2.52)	(5.62)	(−0.69)	(1.95)	(2.65)	(0.88)
rho21_z	0.00162	0.0677**	0.0731*	−0.0324	−0.000381	−0.0743*
	(0.06)	(3.91)	(2.36)	(−1.03)	(−0.01)	(−2.57)
alpha3_z			0.464**			
			(6.12)			
gamma23_z			−0.0414†			
			(−1.89)			
gamma33_z			−0.00109			
			(−0.06)			
gamma13_z			−0.154**			
			(−3.66)			
rho31_z			0.0131			
			(0.35)			
tau1					0.442*	
					(2.27)	
tau2					−0.0378*	
					(−2.55)	
tauy1					0.000304	
					(0.04)	
tauy2					0.00829	
					(1.20)	
tauy3					0.000608	
					(0.35)	
tauw1					0.00189	
					(0.18)	
tau1_z						1.527**
						(3.18)
tau2_z						−0.117**
						(−3.14)
tauy1_z						−0.0000235
						(−0.00)
tauy2_z						−0.0843**
						(−4.11)
tauy3_z						0.00256
						(1.47)
tauw1_z						−0.0784†
						(−1.77)
constant	3.458**	3.314**	3.543**	3.540**	−0.858	−6.637*
	(8.72)	(5.50)	(8.97)	(3.35)	(−0.65)	(−2.15)
$\ln \sigma^2$	−2.313**	−2.132**	−2.442**	−2.329**	−2.308**	−2.473**
	(−18.48)	(−17.70)	(−19.61)	(−17.27)	(−17.62)	(−19.81)
inverse logit of γ	1.578**	1.621**	1.536**	1.925**	1.642**	1.390**
	(8.00)	(8.85)	(7.79)	(9.03)	(8.28)	(6.92)
μ	1.098**	1.207*	1.054**	1.143	0.987**	0.854**
	(3.04)	(2.01)	(2.91)	(1.10)	(5.46)	(5.40)
η	−0.00581	−0.000346	−0.00424	−0.0249	−0.0651*	−0.0207†
	(−0.71)	(−0.05)	(−0.52)	(−1.06)	(−2.33)	(−1.87)
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.0990	0.119	0.0870	0.0974	0.0995	0.0843
$\gamma = \sigma_u^2/\sigma^2$	0.829	0.835	0.823	0.873	0.838	0.801
σ_u^2	0.286	0.315	0.268	0.291	0.289	0.260
σ_v^2	0.130	0.140	0.124	0.111	0.127	0.130
logL	65.06	34.35	85.49	60.49	77.42	79.67
Efficiency score	0.416	0.394	0.43	0.416	0.462	0.504
st. dev	(0.118)	(0.119)	(0.115)	(0.122)	(0.126)	(0.119)
Observations	382	382	382	302	382	382

t statistics in parentheses, ML computed using heteroscedasticity robust (observed information matrix) z statistics. Trigonometric coefficients not reported.

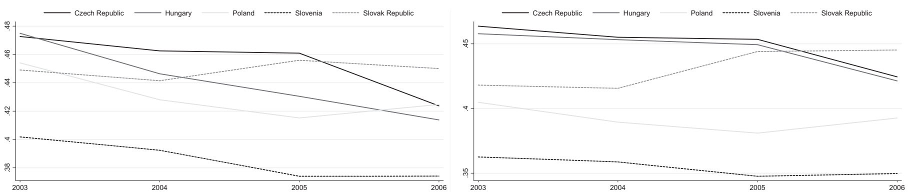

Figure 6: (A, B) Development of profit scores by countries

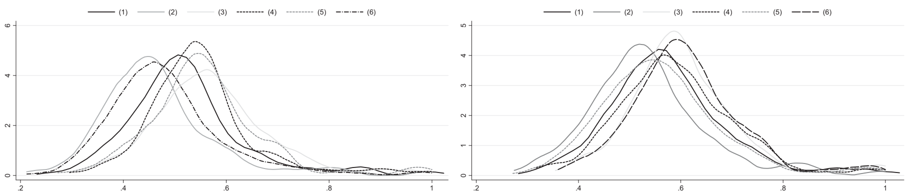

Figure 7: (A, B) Kernel cost density (epanechnikov, bandw. 0.023)

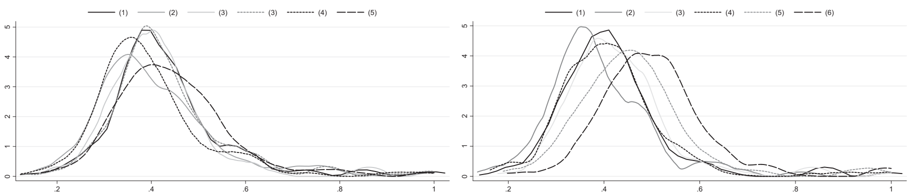

Figure 8: (A, B) Kernel profit density (epanechnikov, bandw. 0.023)

Table 15: (B) Spearman correlations, the Czech Republic in 2003-06

Spearman	(1) C	(2) C	(3) C	(4) C	(5) C	(6) C	(1) P	(2) P	(3) P	(4) P	(5) P	(6) P
(1) C	1											
(2) C tlog	0.93	1										
(3) C y	0.90	0.86	1									
(4) C year	0.91	0.88	0.75	1								
(5) C explt	0.97	0.92	0.88	0.91	1							
(6) C explz	0.92	0.89	0.81	0.84	0.90	1						
(1) P	-0.32	-0.38	-0.20	-0.44	-0.31	-0.36	1					
(2) P tlog	-0.31	-0.39	-0.19	-0.45	-0.30	-0.39	0.93	1				
(3) P y	-0.23	-0.32	-0.31	-0.29	-0.24	-0.27	0.88	0.82	1			
(4) P year	-0.27	-0.33	-0.11	-0.44	-0.28	-0.25	0.96	0.88	0.81	1		
(5) P explt	-0.40	-0.42	-0.26	-0.50	-0.44	-0.39	0.95	0.86	0.80	0.96	1	
(6) P explz	-0.31	-0.37	-0.17	-0.40	-0.31	-0.36	0.98	0.93	0.85	0.95	0.95	1

Table 16: (B) Spearman correlations, Hungary in 2003-06

Spearman	(1) C	(2) C	(3) C	(4) C	(5) C	(6) C	(1) P	(2) P	(3) P	(4) P	(5) P	(6) P
(1) C	1											
(2) C tlog	0.95	1										
(3) C y	0.96	0.89	1									
(4) C year	0.95	0.95	0.89	1								
(5) C explt	0.92	0.86	0.92	0.88	1							
(6) C explz	0.84	0.84	0.81	0.82	0.79	1						
(1) P	-0.51	-0.45	-0.56	-0.57	-0.51	-0.30	1					
(2) P tlog	-0.36	-0.29	-0.40	-0.41	-0.36	-0.13	0.83	1				
(3) P y	-0.43	-0.36	-0.51	-0.48	-0.39	-0.18	0.83	0.72	1			
(4) P year	-0.70	-0.68	-0.72	-0.72	-0.67	-0.55	0.81	0.61	0.80	1		
(5) P explt	-0.50	-0.46	-0.54	-0.59	-0.60	-0.34	0.86	0.76	0.78	0.73	1	
(6) P explz	-0.38	-0.48	-0.36	-0.57	-0.35	-0.48	0.51	0.52	0.50	0.62	0.65	1

Table 17: (B) Spearman correlations, Poland in 2003-06

Spearman	(1) C	(2) C	(3) C	(4) C	(5) C	(6) C	(1) P	(2) P	(3) P	(4) P	(5) P	(6) P
(1) C	1											
(2) C tlog	0.98	1										
(3) C y	0.99	0.96	1									
(4) C year	0.97	0.94	0.97	1								
(5) C explt	0.98	0.96	0.97	0.96	1							
(6) C explz	0.98	0.97	0.98	0.94	0.96	1						
(1) P	-0.57	-0.55	-0.57	-0.58	-0.55	-0.55	1					
(2) P tlog	-0.54	-0.55	-0.55	-0.48	-0.51	-0.54	0.87	1				
(3) P y	-0.52	-0.50	-0.54	-0.55	-0.51	-0.50	0.98	0.85	1			
(4) P year	-0.58	-0.55	-0.58	-0.63	-0.58	-0.52	0.95	0.79	0.95	1		
(5) P explt	-0.60	-0.59	-0.60	-0.64	-0.62	-0.56	0.95	0.79	0.94	0.97	1	
(6) P explz	-0.61	-0.61	-0.60	-0.61	-0.59	-0.58	0.98	0.88	0.96	0.95	0.96	1

Table 18: (B) Spearman correlations, Slovenia in 2003-06

Spearman	(1) C	(2) C	(3) C	(4) C	(5) C	(6) C	(1) P	(2) P	(3) P	(4) P	(5) P	(6) P
(1) C	1											
(2) C tlog	0.98	1										
(3) C y	0.99	0.97	1									
(4) C year	0.93	0.87	0.95	1								
(5) C explt	0.93	0.91	0.94	0.93	1							
(6) C explz	0.98	0.96	0.99	0.95	0.94	1						
(1) P	-0.25	-0.19	-0.25	-0.20	-0.24	-0.29	1					
(2) P tlog	-0.16	-0.09	-0.16	-0.05	-0.17	-0.18	0.89	1				
(3) P y	-0.24	-0.19	-0.25	-0.19	-0.22	-0.30	0.98	0.88	1			
(4) P year	-0.24	-0.16	-0.24	-0.20	-0.23	-0.28	0.98	0.85	0.96	1		
(5) P explt	-0.25	-0.22	-0.25	-0.19	-0.35	-0.30	0.90	0.81	0.88	0.93	1	
(6) P explz	-0.18	-0.17	-0.19	-0.14	-0.20	-0.24	0.89	0.74	0.89	0.89	0.93	1

Table 19: (B) Spearman correlations, Slovakia in 2003-06

Spearman	(1) C	(2) C	(3) C	(4) C	(5) C	(6) C	(1) P	(2) P	(3) P	(4) P	(5) P	(6) P
(1) C	1											
(2) C tlog	0.96	1										
(3) C y	0.97	0.91	1									
(4) C year	0.94	0.87	0.98	1								
(5) C explt	0.93	0.92	0.92	0.91	1							
(6) C explz	0.98	0.92	0.98	0.97	0.93	1						
(1) P	-0.59	-0.66	-0.62	-0.64	-0.59	-0.59	1					
(2) P tlog	-0.17	-0.24	-0.20	-0.31	-0.23	-0.18	0.71	1				
(3) P y	-0.44	-0.51	-0.48	-0.52	-0.44	-0.44	0.96	0.78	1			
(4) P year	-0.56	-0.64	-0.56	-0.59	-0.63	-0.58	0.86	0.75	0.76	1		
(5) P explt	-0.60	-0.69	-0.62	-0.61	-0.72	-0.58	0.89	0.65	0.85	0.83	1	
(6) P explz	-0.62	-0.71	-0.62	-0.62	-0.64	-0.61	0.97	0.61	0.92	0.84	0.91	1

Table 20: (B) Kendall correlations, the Czech Republic in 2003-06

Spearman	(1) C	(2) C	(3) C	(4) C	(5) C	(6) C	(1) P	(2) P	(3) P	(4) P	(5) P	(6) P
(1) C	1											
(2) C tlog	0.81	1										
(3) C y	0.80	0.70	1									
(4) C year	0.77	0.72	0.61	1								
(5) C explt	0.86	0.77	0.75	0.76	1							
(6) C explz	0.80	0.74	0.69	0.68	0.76	1						
(1) P	-0.27	-0.35	-0.16	-0.37	-0.25	-0.29	1					
(2) P tlog	-0.24	-0.32	-0.16	-0.35	-0.24	-0.30	0.78	1				
(3) P y	-0.19	-0.30	-0.27	-0.23	-0.19	-0.24	0.80	0.69	1			
(4) P year	-0.21	-0.30	-0.07	-0.35	-0.22	-0.20	0.86	0.72	0.70	1		
(5) P explt	-0.33	-0.37	-0.20	-0.43	-0.37	-0.31	0.83	0.69	0.67	0.85	1	
(6) P explz	-0.25	-0.34	-0.13	-0.33	-0.26	-0.31	0.92	0.79	0.77	0.84	0.82	1

Table 21: (B) Kendall correlations, Hungary in 2003-06

Spearman	(1) C	(2) C	(3) C	(4) C	(5) C	(6) C	(1) P	(2) P	(3) P	(4) P	(5) P	(6) P
(1) C	1											
(2) C tlog	0.84	1										
(3) C y	0.86	0.76	1									
(4) C year	0.84	0.83	0.77	1								
(5) C explt	0.78	0.69	0.76	0.73	1							
(6) C explz	0.67	0.67	0.64	0.68	0.62	1						
(1) P	-0.39	-0.36	-0.43	-0.43	-0.37	-0.21	1					
(2) P tlog	-0.28	-0.23	-0.31	-0.32	-0.27	-0.14	0.66	1				
(3) P y	-0.35	-0.30	-0.40	-0.40	-0.29	-0.15	0.72	0.57	1			
(4) P year	-0.53	-0.52	-0.57	-0.55	-0.50	-0.42	0.66	0.48	0.69	1		
(5) P explt	-0.39	-0.35	-0.42	-0.44	-0.45	-0.25	0.71	0.57	0.62	0.58	1	
(6) P explz	-0.29	-0.37	-0.27	-0.43	-0.25	-0.37	0.40	0.42	0.41	0.51	0.49	1

Table 22: (B) Kendall correlations, Poland in 2003-06

Spearman	(1) C	(2) C	(3) C	(4) C	(5) C	(6) C	(1) P	(2) P	(3) P	(4) P	(5) P	(6) P
(1) C	1											
(2) C tlog	0.90	1										
(3) C y	0.94	0.89	1									
(4) C year	0.86	0.82	0.88	1								
(5) C explt	0.88	0.86	0.87	0.84	1							
(6) C explz	0.91	0.87	0.89	0.82	0.85	1						
(1) P	-0.43	-0.42	-0.43	-0.43	-0.41	-0.41	1					
(2) P tlog	-0.42	-0.42	-0.42	-0.36	-0.39	-0.41	0.75	1				
(3) P y	-0.40	-0.38	-0.42	-0.41	-0.38	-0.38	0.91	0.72	1			
(4) P year	-0.45	-0.43	-0.46	-0.48	-0.45	-0.41	0.83	0.63	0.83	1		
(5) P explt	-0.46	-0.44	-0.46	-0.48	-0.48	-0.42	0.82	0.64	0.80	0.85	1	
(6) P explz	-0.47	-0.47	-0.47	-0.46	-0.45	-0.45	0.89	0.73	0.87	0.83	0.83	1

Table 23: (B) Kendall correlations, Slovenia in 2003-06

Spearman	(1) C	(2) C	(3) C	(4) C	(5) C	(6) C	(1) P	(2) P	(3) P	(4) P	(5) P	(6) P
(1) C	1											
(2) C tlog	0.91	1										
(3) C y	0.93	0.90	1									
(4) C year	0.82	0.76	0.85	1								
(5) C explt	0.81	0.78	0.81	0.80	1							
(6) C explz	0.91	0.89	0.93	0.84	0.82	1						
(1) P	-0.24	-0.17	-0.24	-0.22	-0.22	-0.26	1					
(2) P tlog	-0.12	-0.05	-0.12	-0.05	-0.14	-0.13	0.76	1				
(3) P y	-0.22	-0.17	-0.24	-0.21	-0.20	-0.26	0.92	0.73	1			
(4) P year	-0.21	-0.14	-0.22	-0.21	-0.20	-0.25	0.90	0.74	0.85	1		
(5) P explt	-0.20	-0.17	-0.21	-0.19	-0.28	-0.25	0.75	0.65	0.73	0.80	1	
(6) P explz	-0.15	-0.14	-0.16	-0.15	-0.18	-0.20	0.81	0.62	0.80	0.80	0.80	1

Table 24: (B) Kendall correlations, Slovakia in 2003-06

Spearman	(1) C	(2) C	(3) C	(4) C	(5) C	(6) C	(1) P	(2) P	(3) P	(4) P	(5) P	(6) P
(1) C	1											
(2) C tlog	0.85	1										
(3) C y	0.87	0.77	1									
(4) C year	0.84	0.75	0.90	1								
(5) C explt	0.79	0.77	0.78	0.80	1							
(6) C explz	0.88	0.78	0.89	0.88	0.79	1						
(1) P	-0.47	-0.51	-0.49	-0.51	-0.45	-0.47	1					
(2) P tlog	-0.11	-0.20	-0.17	-0.22	-0.16	-0.13	0.57	1				
(3) P y	-0.35	-0.39	-0.37	-0.42	-0.32	-0.35	0.87	0.62	1			
(4) P year	-0.42	-0.49	-0.42	-0.45	-0.47	-0.44	0.71	0.58	0.62	1		
(5) P explt	-0.44	-0.53	-0.47	-0.46	-0.55	-0.43	0.73	0.49	0.68	0.66	1	
(6) P explz	-0.50	-0.55	-0.50	-0.47	-0.49	-0.52	0.88	0.49	0.79	0.68	0.75	1

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