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Estimating cost efficiency of Turkish commercial banks under unobserved heterogeneity with stochastic frontier models

Hakan Gunes, Dilem Yildirim*

Department of Economics, Middle East Technical University, 06531, Ankara, Turkey

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ABSTRACT

This study aims to investigate the cost efficiency of Turkish commercial banks over the restructuring period of the Turkish banking system, which coincides with the 2008 financial global crisis and the 2010 European sovereign debt crisis. To this end, within the stochastic frontier framework, we employ true fixed effects model, where the unobserved bank heterogeneity is integrated in the inefficiency distribution at a mean level. To select the cost function with the most appropriate inefficiency correlates, we first adopt a search algorithm and then utilize the model averaging approach to verify that our results are not exposed to model selection bias. Overall, our empirical results reveal that cost efficiencies of Turkish banks have improved over time, with the effects of the 2008 and 2010 crises remaining rather limited. Furthermore, not only the cost efficiency scores but also impacts of the crises on those scores appear to vary with regard to bank size and ownership structure, in accordance with much of the existing literature.

1. Introduction

A stable and efficient banking system is quite important for economic growth and welfare especially for emerging countries like Turkey where the banking sector is the backbone of the economy. The banking system in Turkey has experienced a fundamental change due to the far-reaching reforms implemented in the aftermath of the 2001 local financial crisis. The year of 2001 could well be named as a milestone for the Turkish banking sector. In that year, the banking sector faced with a very deep and devastating crisis and a substantial increase in the non-performing loans due to the skyrocketed interest and exchange rates, inadequate level of funding, maturity mismatch, insufficient risk management practices and bad governance. Subsequent to the 2001 financial crisis, a comprehensive restructuring program was implemented with the aims of strengthening state and private banks, solving the problems of troubled banks, addressing regularity and supervisory deficiencies and improving efficiency. With the gradual implementation of the reform package, the Turkish banking sector experienced a rapid and stable financial deepening process during 2002–2007. More recently, the Turkish economy was severely affected by the 2008 global crisis similar to all other emerging economies. The banking sector however, was relatively less affected compared to the banking sectors in many other emerging countries, which was owed to the reforms adopted successfully after the 2001 crisis to strength the Turkish banking system.

In this context, this study aims to measure the efficiency of

* Corresponding author.
E-mail addresses: hgunes@metu.edu.tr (H. Gunes), dilem@metu.edu.tr (D. Yildirim).

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Table 1
Summary of the literature review on bank efficiency in emerging markets.

Author(s)	Country	Data sample	Functional form	Methodology	Efficiency	Average efficiency
Poghosyan and Kumbhakar (2010)	AL, AM, AZ, BG, BY, CZ, EE, GE, HR, HU, KZ, LT, LV, MD, PL, RO, RU, SI, SK, UA	681 Banks, 1993–2004	Translog	SFA	Cost efficiency	0.69
Du and Girma (2011)	CN	14 Banks, 1995–2001	Translog	SFA	Cost inefficiency	1.30–1.56
Williams (2012)	AR, BR, CL, MX	419 Banks, 1985–2010	Translog	SFA	Cost efficiency	0.77
					Profit efficiency	0.50
Kumbhakar and Wang (2007)	CN	14 Banks, 1993–2002	Translog	SFA	Technical efficiency	0.47–0.90
Manlagnit (2011)	PH	31 Banks, 1990–2006	Translog	SFA	Cost inefficiency	1.25
Kasman and Yildirim (2006)	CZ, EE, HU, LV, LT, PL, SK, SI	190 Banks, 1995–2002	Fourier Flexible	SFA	Cost efficiency	0.20
					Profit efficiency	0.36
Kumbhakar and Peresetsky (2013)	KZ, RU	94 Banks, 2002–2006	Translog	SFA	Cost efficiency	0.82–0.83
Demir et al. (2005)	TR	43 Banks, 1995–1998	Translog	SFA	Cost efficiency	0.70–0.87
Yildirim (2002)	TR	38 to 59 Banks, 1988–1999	–	DEA	Technical efficiency	0.89
Denizer et al. (2007)	TR	29 to 53 Banks, 1970–1994	–	DEA	Technical efficiency	0.50–0.86
Ozkan-Gunay (2012)	TR	29 Banks, 2002–2009	–	DEA	Technical efficiency	0.70
Fukuyama and Matousek (2011)	TR	25 Banks, 1991–2007	–	Two-stage network	Cost efficiency	0.55
					Technical efficiency	0.65
					Allocative efficiency	0.83
Isik and Hassan (2002)	TR	36 Banks 1988–1988, 50 Banks 1992–1992, 53 Banks 1996–1996	–	DEA, SFA	Cost efficiency	0.72–0.89
					Profit efficiency	0.83
Kasman (2002)	TR	48 Banks, 1988–1998	Fourier Flexible	SFA	Cost inefficiency	0.23
Assaf et al. (2013)	TR	45 Banks, 2002–2010	Translog	Bayesian	Technical efficiency	0.78
Zaim (1995)	TR	39 Banks, 1981–1981; 56 Banks, 1990–1990	–	DEA	Technical efficiency	0.82–0.92
El-Gamal and Inanoglu (2005)	TR	53 Banks, 1990–2000	Translog	Estimation - Classification	Cost inefficiency	2.28

Notes: SFA Stochastic Frontier Approach, DEA Data envelopment Analysis, AL Albania, AM Armenia, AR Argentina, AZ Azerbaijan, BG Bulgaria, BY Bosnia and Herzegovina, BR Brazil, CL Chile, CN China, CZ Czech Republic, EE Estonia, GE Georgia, HR Croatia, HU Hungary, ID Indonesia, KZ Kazakhstan, LT Lithuania, LV Latvia, MX Mexico, MD Moldova, MK Macedonia, PH Philippines, PL Poland, RO Romania, RU Russia, SI Slovenia, SK Slovakia, TR Turkey, UA Ukraine.

Turkish commercial banks. Although the efficiency of the banking system has been analysed in numerous studies for developed countries, the literature on the efficiency of the banking sector in emerging countries is relatively thin, as summarized in Table 1.[1] When examining the literature for Turkey, it appears that the studies focus essentially on the evolution of bank efficiencies following the financial liberalization that took place in the late 1980s, the restructuring program adopted in 2001 and the 2008 global financial crisis. The conclusions, however, are not unanimous. For instance, while Zaim (1995) and Ertugrul and Zaim (1999) and Demir et al. (2005) reveal that the financial liberalization led to an increase in the efficiency of Turkish banks, Yildirim (2002), Denizer et al. (2007), Isik and Hassan (2002) and Kasman (2002) observe that the liberalization did not provide the anticipated efficiency gains in Turkish banks. More recently, the studies by Fukuyama and Matousek (2011), Ozkan-Gunay (2012) and Assaf et al. (2013) investigate the effect of the restructuring program adopted in 2001 on the Turkish banking system. Fukuyama and Matousek (2011) find that the restructuring program has a positive effect on bank efficiency over the period 2001–2004, though a gradual decline is observed after 2004 when the restructuring reforms are formally ended. Unlike Fukuyama and Matousek (2011), Ozkan-Gunay (2012) reveal a substantial and more importantly a gradual improvement in the bank efficiency following the restructuring program. The analysis of Assaf et al. (2013), on the other hand, indicates a decline in the efficiency of Turkish banks over the period 2002–2010. Furthermore, it is seen that the annual decline in efficiency becomes more prominent in 2009 and 2010 due to the 2008 global financial crisis.

Our study aims to measure the cost efficiency of 22 Turkish commercial banks over the period of 2003Q1-2015Q3. The use of the longest time period allowed by data availability is important to observe the temporal movement of the efficiency of Turkish banks. More specifically, with our data we will be able to provide a long-term empirical assessment of the effectiveness of the restructuring reforms implemented after the 2001 crisis, which remains controversial in the empirical literature. Moreover, although it is partially investigated by Assaf et al. (2013) over the sample

[1] See Erkoc (2012) for a detailed discussion of the efficiency literature and the existing estimation methodologies.

2002–2010, extension of the sample period to 2015 enables us further to attain more reliable inference on how the 2008 global financial crisis has affected the efficiency of Turkish banks. As underlined by Assaf et al. (2013), the time period they examined is not long enough to propose direct conclusions about the impact of the crisis and future stability of the banking sector. Finally, our dataset allows us to investigate the impacts of the 2010 European sovereign debt crisis on the efficiency of Turkish banks, which has not been examined so far to the best of our knowledge.

Methodologically, unlike the previous studies for Turkey, we employ the true fixed effects model of Greene (2005), where the unobserved bank heterogeneity is embedded in the inefficiency distribution at a mean level. Moreover, being aware of the fact that the efficiency analysis could be quite sensitive to the choice of the inefficiency determinants, we adopt an exhaustive search algorithm to specify the cost frontier function with the most appropriate inefficiency correlates. Furthermore, to circumvent any possible problems, including the model uncertainty and omitted variable biases that may arise from relying on only the single (best) model, we perform the model-averaging approach of Huang and Lai (2012).

The rest of the paper is organized as follows. Chapter 2 provides an overview of the Turkish banking sector. Chapter 3 discusses the econometric methodology and Chapter 4 describes the data. Empirical findings are discussed in Chapter 5 and finally Chapter 6 concludes the study.

2. A brief overview of the Turkish banking sector

In the last two decades, the Turkish economy has witnessed several financial crises that were caused mainly by poor macroeconomic conditions and a fragile banking system. 1990s were the starting era of structural problems in the banking system, which had experienced legal, structural and institutional changes with the financial liberalization program adopted in 1980s. In the early 1980s the Turkish government launched a liberalization program that aimed to deregulate the banking system and eliminate restrictions regarding market entry and interest rates. As expected, the launched program increased the competition with the entries of new domestic and foreign banks, which in turn led to a wide variety of banking services, including capital market operations, purchase of government debt securities and Treasury bonds.

In 1990s, banks decreased the amount of traditional banking activities in their portfolios and started to invest more and more in risk free government debt instruments. In other words, the banking sector became the main instrument of government financing by transferring short-term borrowing from domestic and foreign depositors and investors to the government (Akın et al., 2009). High government debt with low levels of maturity eventually led to an environment characterized by high levels of inflation and real interest rates. Increasing risks in the financial system lowered the average maturity of savings and triggered excessively high loan interest rates. The economic and financial conditions deteriorated further due to domestic political instabilities and the Asian and Russian crises in 1997 and 1998, which lowered capital inflows and international borrowing opportunities. Hence, due to inadequate level of funding, maturity mismatch, high amount of nonperforming loans, insufficient risk management practices and bad governance, the Turkish banking system experienced a systemic crisis which reached its peak in 2001. With the 2001 crisis, several banks went bankrupt and transferred to the Saving Deposits Insurance Fund (SDIF), the Turkish financial market ceased to function and the economy contracted drastically.

After the 2001 crisis many reforms were implemented in a timely manner by the Turkish authorities to retrain the impact of the crisis on the structure of the economy and to drive the economy into a more sound and stable pattern in the long term. The bank restructuring program initiated by the Banking Regulation and Supervision Agency was the vital part of these reforms. The program rested on four main pillars: financial restructuring of the state banks, implementation of measures to facilitate the participation of the private capital to strength the private banking system, prompt resolution of the SDIF banks and taking measures for prudential regulation and supervision of the banking sector. With this program substantial achievements were made in the Turkish banking system. More specifically, short-term liabilities of the state banks were terminated and they were reinforced through mergers and privatized, some privately owned banks were provided with capital support, SDIF banks were liquidated and merged with or transferred to another bank. This new regulations scheme culminated into a low inflationary environment with low market interest rates and high rate of economic growth. Following this restructuring process, the Turkish banking system showed a rapid growth performance during the period 2002–2008.

In 2008, the subprime mortgage crisis hit the real economy of all countries around the world and led to a severe global recession. Due to its integration with the world economy and dependency on the external market, the Turkish economy was also severely affected by the 2008 global crisis. The financial position of Turkish banks, however, has not deteriorated to the same extent as was the case with banks in other emerging economies. This was mainly due to the comprehensive reforms adopted successfully after the 2001 crisis (Aysan and Ermisoglu, 2013b). Nevertheless, some negative effects of the global financial crisis were observed in the banking system in Turkey. Following the 2008 global crisis, concerns on the high default rates led to an increase in the cost of international funds for banks, which in turn caused a reduction in the credit supply. Meanwhile, the slowdown of the economic activity resulted in a fall in the demand for loans. Overall, the banking sector has faced with a substantial decrease in the credit growth, deterioration in asset quality and an increase in non-performing loans. The extraordinary measures taken abroad and in Turkey restored the confidence in the financial markets. Subsequently, the deterioration in the nonperforming loans stopped and the asset quality of the banking sector improved.

The 2008 global crisis evolved into a debt crisis in Europe with accumulation of external debts of governments to rescue troubled banks that had invested heavily in the US mortgage market. The crisis started in Greece where the sovereign debt burden became unsustainable and then spread to other member countries. Turkey was affected by the 2010 European debt crisis mainly through the trade channel as its major trade partners are EU countries. For the Turkish banking system, however, the effects of the crisis remained rather limited due to the lessons learned from the 2001 financial crisis and having relatively weaker financial ties to Europe compared to those of Eastern and Central Europe countries due to the low share of foreigners in the Turkish banking sector (Aysan and Ermisoglu, 2013a).

3. Methodology

This chapter describes the stochastic frontier approach we adopt to measure the cost efficiency of Turkish banks. As such, we utilize the commonly used cost function approach due to outputs in the banking sector being exogenous (demand determined) and not storable. Furthermore, as underlined by Kumbhakar and Lovell (2000), the cost function approach enables us to handle with the multiple outputs problem in measuring efficiency. The stochastic cost frontier function, introduced by Aigner et al. (1977) and Meeusen and van den Broeck (1977), can be expressed as:

$$C_{it} = C(y_{it}, w_{it}; \beta) exp(u_{it}) \exp(v_{it}) \quad (1)$$

where C_{it} is the total cost of the bank i $(i = 1, 2\ldots, N)$ in the period t $(t = 1, 2\ldots, T)$, y_{it} represents its output, w_{it} is a vector of input prices, β is a vector of parameters, u_{it} is the non-negative error term representing inefficiency and v_{it} is the i.i.d $N(0, \sigma_v^2)$ random errors being independently distributed of u_{it} and standing for measurement errors and exogenous random shocks received by the cost function. Under this methodology, a bank is considered as inefficient if its costs are higher than those of an efficient bank producing the same output under the same existing conditions.

The literature offers several different approaches to model the non-negative inefficiency component u_{it}. This study follows the true fixed effects model of Greene (2005). In its original form, the true fixed effects model treats time-invariant bank specific heterogeneity and time varying inefficiency separately by integrating bank specific dummy variables into the cost function. As a result, it manages to distinguish between unobserved heterogeneity and inefficiency. In this respect, it differs from the traditional estimators for stochastic frontier in a panel set-up which cannot estimate the firm's fixed effects separately from the time varying efficiency scores (Cornwell et al., 1990; Kumbhakar, 1990; Battese and Coelli, 1995). However, as underlined by Greene (2004), integrating the cost function with bank specific dummy variables, might lead to an overspecified cost function, which in turn may induce underestimation of inefficiencies. To circumvent such an underestimation problem, one can follow an alternative approach as proposed by Greene (2004) and have the heterogeneity reside in the inefficiency distribution. In this way, it is possible to account for unobserved bank specific heterogeneity at mean level in cost efficiencies. Following the suggestion of Greene (2004), we embed the heterogeneity in the inefficiency distribution and define the time-varying inefficiency effect u_{it} as:

$$\begin{aligned} u_{it} &= \left| N\left(\mu_{it}, \sigma_u^2\right) \right| \\ \mu_{it} &= \xi_i + \eta' z_{it} \end{aligned} \quad (2)$$

where z_{it} is the vector of explanatory variables that may influence bank inefficiency, η is the vector of parameters to be estimated and ξ_i is the bank specific intercept term placed to account for time-invariant bank specific heterogeneity and σ_u^2 is the variance of inefficiency. Obviously, with this specification u_{it} is assumed to follow a truncated-normal distribution with heterogeneous mean across banks.[2] Given the representations in (1) and (2), the cost efficiency for an individual bank can be defined as the ratio of the cost of the best practice firm having zero inefficiency and the cost of that bank. More specifically, the cost efficiency for the *i-th* bank at the *t-th* observation can be expressed as:

$$CE_{it} = \exp(-u_{it}) \quad (3)$$

which ensures that the cost efficiency is bounded between zero and one.

To continue with estimation, we need to specify an appropriate functional form for the cost frontier function in (1). Being in line with many studies in the literature, we employ a flexible translog cost function as:

$$\begin{aligned} \ln\left(\frac{C_{it}}{w_{2it}}\right) &= \beta_0 + \sum_j \beta_j \ln y_{jit} + \sum_k \alpha_k \ln\left(\frac{w_{kit}}{w_{2it}}\right) + \frac{1}{2}\sum_j \sum_l \delta_{jl} \ln y_{jit} \ln y_{lit} + \frac{1}{2}\sum_k \sum_p \phi_{kp} \ln\left(\frac{w_{kit}}{w_{2it}}\right) \\ &+ \frac{1}{2}\sum_j \sum_k \phi_{jk} \ln y_{jit} \ln\left(\frac{w_{kit}}{w_{2it}}\right) + \psi_1 \ln q_{it} + \frac{1}{2}\psi_2 \ln q_{it}^2 + \sum_j \psi_{3j} \ln y_{jit} \ln q_{it} \\ &+ \sum_k \psi_{4k} \ln\left(\frac{w_{kit}}{w_{2it}}\right) \ln q_{it} + \theta_1 t + \theta_2 t^2 + \sum_j \theta_{3j} \ln y_{jit} t + \sum_k \theta_{4k} \ln\left(\frac{w_{kit}}{w_{2it}}\right) t + \theta_5 \ln q_{it} t + u_{it} + v_{it} \end{aligned} \quad (4)$$

where $\ln C_{it}$ is the natural logarithm of the total cost of the ith bank in the period t, $\ln y_{jit}$ represents the natural logarithm of its jth output, $\ln w_{kit}$ is the natural logarithm of its kth input price, $\ln q_{it}$ denotes its equity being used to control observable heterogeneity among banks, t denotes time which is included to capture non-neutral technological changes. To be consistent with the economic theory, which requires the cost function to be monotonically increasing in input prices and outputs and to be concave in input prices, we imposed the regularity conditions, symmetry and linear homogeneity in input prices. The condition of symmetry requires:

$\delta_{jl} = \delta_{lj}\ \forall\ j,\ l\ \varphi_{kp} = \varphi_{pk}\ \forall\ k,\ p$ and $\phi_{jk} = \phi_{kj}\ \forall\ j,\ k$

The linear homogeneity restriction, on the other hand, is ensured by normalizing costs and input prices using one of the input price (w_{2it}).

Once the translog cost function (4) is specified, parameters of the cost function and the inefficiency model (2) are estimated through the one-step maximum likelihood estimation (MLE) method of Greene (2005), where the likelihood function is formed with the parameterizations $\lambda = \frac{\sigma_u}{\sigma_v}$ and $.\sigma = \sqrt{\sigma_u^2 + \sigma_v^2}$[3] This one step estimation approach allows for simultaneous estimation of the stochastic cost function and the inefficiency correlates. It accounts for the possible correlation between the variables affecting the cost function and the correlates of the inefficiency, which in turn eliminates any underestimation and bias problem. Following estimation of the parameters, bank-specific efficiency scores are computed using the Jondrow et al. (1982) formula.

4. Data

Our dataset is compiled from the balance sheets and income statements of 22 commercial (deposit) banks operating in Turkey

[2] Some of the studies impose the half-normal assumption on the inefficiencies. However, as proposed by Greene (1990), such an assumption might lead most banks to be clustered near full efficiency.

[3] See Greene (2005) for further details of the one-step MLE estimation procedure.

over the period 2003Q1-2015Q3.[4] Non-deposit banks, such as development and investment banks are excluded from our sample due to their functional differences from deposit banks. The banks included in our dataset are not homogenous with respect to their ownership status; that is of our 22 commercial banks 3 are state-owned, 12 are privately-owned domestic and 10 are foreign banks. State-owned, domestic private and foreign banks are defined as those with more than 50 percent of state, private domestic and foreign ownerships, respectively. The banks we analyse differ with regard to their scales as well. In fact, it is possible to divide the banks into three groups according to their market shares: small banks (banks having market share of less than 1 percent), medium-sized banks (banks having market share of between 1 and 8 percent) and large banks (banks having market share of more than 8 percent). Based on this classification, we have 7 large, 5 medium scaled and 10 small banks in our sample.

To construct the cost function (4), the total cost (C) is defined as the sum of interest and non-interest expenses, with the latter referring to the sum of provision of loan losses and other operating expenses. Regarding the outputs and input prices, we have two outputs, total loans (y_1) and total securities (y_2). The two input prices are the price of physical capital and labor (w_1), measured by the ratio of non-interest expenses to total assets, and price of loanable funds (w_2), defined as the ratio of total interest expenses to total deposits.[5] To circumvent any adverse effect of inflation in comparison of the results over the study period, all input and output prices are expressed in US dollars, being in line with Fukuyama and Matousek (2011) and Assaf et al. (2013).

Following the existing empirical literature, we specify our potential efficiency correlates (z_i) as intermediation ratio, deposit-to-liability ratio, loan loss provision ratio, capital ratio, liquidity ratio and finally natural logarithm of total assets.[6] Intermediation ratio defined as the ratio of loans to deposits is included to capture the differences of banks' ability to convert deposits into loans, as in Kasman and Yildirim (2006) and Manlagnit (2011). It is hypothesized that a bank with higher intermediation ratio would be more efficient, suggesting an inverse relationship between inefficiency and intermediation ratio. Similar to Manlagnit (2011) and Amidu and Wolfe (2013), we use deposit-to-liability ratio as a measure of banks' funding structure and expect the ratio to have a negative impact on inefficiency. Loan loss provision ratio measured by provisions for loan losses over total loans is employed to proxy for default risk or loan quality, as in Mester (1996), Altunbas et al. (2001), Demir et al. (2005), Rao (2005) and Manlagnit (2011). A positive correlation is expected between loan loss provisioning and inefficiency since an inefficient bank with high costs would have more problem loans. Capital ratio measured by equity over total assets is included to control for the regularity conditions. An inverse relationship is expected between inefficiency and capital ratio since a higher capital ratio might lead banks to be perceived as less risky and therefore they can borrow at lower interest rates and have lower costs (Fries and Taci, 2005; Kumbhakar and Wang, 2007; Manlagnit, 2011). Liquidity ratio defined as the ratio of liquid assets to total assets controls liquidity risk of banks. While lack of liquidity may force banks to borrow funds at excessive cost, holding liquid has an opportunity cost of higher returns (Rao, 2005; Koetter and Poghosyan, 2009; Ben-Khedhiri et al., 2011). Due to this conflict, we do not have priori expectations regarding the direction of the effect of liquidity ratio on inefficiency. Finally, we incorporate the logarithm of total assets as a proxy for bank size to control for the impact of scale bias on inefficiency, as in many studies including Hao et al. (2001), Demir et al. (2005) and Banker et al. (2011).

5. Empirical results

It is commonly acknowledged that the efficiency analysis is sensitive to the choice of the variables. In this respect, while omitting relevant variables could result in misleading conclusions, the use of unnecessary variables might clutter the analysis and create interpretation difficulties. Hence, choosing the most influential explanatory variables is of particular interest in efficiency analysis. Although we specify a set of potential efficiency correlates including intermediation ratio, deposit-to-liability ratio, loan loss provision ratio, capital ratio, liquidity ratio and finally natural logarithm of total assets, we have no exact information regarding which ones should be included in the model.

To this end, this chapter discusses two different approaches we adopted to specify cost efficiency scores of Turkish commercial banks. While the first section describes empirical findings derived from a search algorithm designed to detect the most appropriate model, the subsequent section presents the results obtained from the model averaging approach of Huang and Lai (2012). Persistency of cost efficiency scores of commercial banks is investigated in the final section.

5.1. Results from the search algorithm

To specify the cost frontier function with the most appropriate inefficiency correlates we adopt an exhaustive search algorithm aimed at minimizing the Akaike information criterion (AIC), which is a penalized likelihood criterion that trades off goodness of fit and parsimony. The algorithm starts with maximum likelihood estimation of the cost frontier function (4) by including all 6 inefficiency correlates and the corresponding AIC value is recorded. In the next step, the cost function is estimated by using all 5-subsets of inefficiency correlates and the model having minimum AIC is selected. This procedure continues with one correlate eliminated at each stage until only one is left. At the end, the algorithm selects 5 models out of 63 estimated cost functions and our preferred model is the one with the lowest value of AIC.

According to the algorithm, the cost frontier function with inefficiency correlates of intermediation ratio, capital ratio and the natural logarithm of total assets is chosen and the estimation results are reported in Table 2.[7] Being consistent with our priori expectations, intermediation ratio has a significant negative effect on the measured cost inefficiency, suggesting that banks with higher ability to convert deposits to loans enjoy higher levels of efficiency. In accordance with our expectations, the capital ratio also appears to be significantly and negatively correlated with the cost inefficiency. Well-capitalized banks are expected to be more efficient due to their high quality management and relatively less risky

[4] Balance sheet and income statement data is obtained from the database of The Banks Association of Turkey.

[5] Due to unavailability of the quarterly data for personnel expenses over the period 2003Q1-2005Q2, we are not able to use two separate input prices for physical capital and labor. Therefore, we augment these two prices and calculate a common price, as in Hasan and Marton (2003) and Kasman and Yildirim (2006).

[6] There are also studies including profit percent, loans to assets ratio, mortgage loans and wholesale funding as efficiency correlates in their analysis (e.g. Demir et al., 2005; Koetter and Poghosyan, 2009). We constraint our study to efficiency correlates that are most commonly used in the literature in order to circumvent the non-convergence problem in estimation due to having a small data set.

[7] Due to having a small data set, we first observed non-convergence problem in estimation of the model parameters. To overcome this problem, squared terms are dropped from the model, as in Koetter and Wedow (2010).

Table 2
Parameter estimates of the stochastic cost frontier.

Cost Frontier					
intercept	−2.415*** (0.675)	$\ln y_1 \ln y_2$	0.053*** (0.004)	$\ln y_2.t$	−0.002*** (0.000)
$\ln y_1$	−0.030 (0.043)	$\ln y_1 \ln\left(\frac{w_1}{w_2}\right)$	−0.089*** (0.010)	$\ln\left(\frac{w_1}{w_2}\right)\ln q$	0.121*** (0.022)
$\ln y_2$	−0.051 (0.067)	$\ln y_1.\ln q$	−0.027*** (0.005)	$\ln\left(\frac{w_1}{w_2}\right)t$	0.007*** (0.000)
$\ln\left(\frac{w_1}{w_2}\right)$	0.551*** (0.078)	$\ln y_1.t$	0.010*** (0.000)	lnq.t	−0.009*** (0.001)
lnq	1.609*** (0.099)	$\ln y_2.\ln\left(\frac{w_1}{w_2}\right)$	−0.037*** (0.013)		
t	−0.009** (0.004)	$\ln y_2.\ln q$	−0.042*** (0.005)		
Inefficiency correlates					
intercept	1.533*** (0.283)	ξ_{06}	0.263** (0.102)	ξ_{15}	0.394** (0.159)
Capital Ratio	−1.801** (0.798)	ξ_{07}	0.108 (0.085)	ξ_{16}	0.192** (0.093)
Intermediation Ratio	−0.709*** (0.194)	ξ_{08}	0.533** (0.209)	ξ_{17}	0.289** (0.129)
Logarithm of Total Assets	−0.038 (0.065)	ξ_{09}	0.069 (0.083)	ξ_{18}	−0.044 (0.074)
ξ_{01}	−0.086 (0.059)	ξ_{10}	0.155 (0.104)	ξ_{19}	0.144** (0.069)
ξ_{02}	0.434*** (0.125)	ξ_{11}	0.418** (0.167)	ξ_{20}	−0.032 (0.049)
ξ_{03}	0.315* (0.186)	ξ_{12}	0.102 (0.080)	ξ_{21}	0.042 (0.056)
ξ_{04}	0.462** (0.228)	ξ_{13}	0.206 (0.130)		
ξ_{05}	0.371** (0.158)	ξ_{14}	0.585* (0.305)		
Variance parameters of compound error					
λ	1.392*** (0.182)	σ	0.112*** (0.003)		
Log likelihood	1110.699	AIC	−2135.400	N	1120

Notes: Numbers in parentheses are standard errors and (***), (**) and (*) denote statistical significance at 1%, 5% and 10% significance levels, respectively.

position. Regarding the effect of bank size, measured by the logarithm of total assets of banks, it appears that the cost inefficiency does not differ significantly with respect to bank size.[8]

Having discussed the inefficiency correlates, we proceed further with the estimated efficiency scores. The first panel of Fig. 1 shows the weighted average of cost efficiency scores of commercial banks over the period 2003Q1-2015Q3. For convenience we also report them together with the corresponding standard errors in Table 3. The overall cost efficiency for the whole sample is found as approximately 87 percent, suggesting that an average commercial bank could improve its cost efficiency by approximately 13 percent to match its performance with the best practice bank producing same amount of goods and services with the same conditions. Turning to the efficiency scores over time, being in line with Ozkan-Gunay (2012), Figure clearly illustrates an upward trend in the cost efficiency scores during the post-crisis period 2003–2008, suggesting that the restructuring program fulfils its promise in terms of improving bank efficiency. Given that the Turkish banking system experienced a substantial improvement in terms of bank lending, asset quality and profitability during the post-crisis period as shown by Ozkan et al. (2014), this finding might not be surprising. Furthermore, the impact of the global financial crisis is also apparent from the deterioration of the efficiency scores after the third quarter of 2008. Over the following five quarters the cost efficiency declined by approximately 3 percentage points and finally reached its lowest level of 85 percent in the last quarter of 2009. Afterwards, the banking system started to recover and bounced back to its pre-crisis level of 88 percent in the last quarter of 2010. This reveals that the negative effect of the global crisis was felt but, unlike the findings of Assaf et al. (2013), a relatively quick recovery is observed at the end of 2010. The continued upward trend over the period 2011–2015 indicate further that the 2010 European debt crisis had no noticeable impact on the Turkish banking system in terms of average cost efficiency.

Before continuing with further discussions of efficiency scores, it is noteworthy to mention the incidental parameters problem of the true fixed effects model. Obviously, in a fixed effects model, the number of fixed-effect parameters, which are also called as incidental parameters, increases with the number of cross sections. In this situation, conventional asymptotic results that rely on infinite number cross sections, cannot be applied and the maximum likelihood estimators become inconsistent for a fixed number of periods. Greene (2005) examines this incidental parameters problem through a Monte-Carlo experiment and observes that the problem affects variances but not the slope coefficients. Moreover, there appears to be no substantial biases transmitted to inefficiency estimates. As a referee has pointed out, despite these findings of Greene, it would be nice to analyse robustness of our results to an increase in the number of cross sections (banks in our case). As such, we repeat our analysis by leaving small banks out and using large and medium-sized banks only. According to the results, the overall cost efficiency for the whole sample is found as approximately 92 percent, which is quite close to our initial average cost efficiency of 87 percent. Regarding the movement of efficiency scores over time, we observe a similar pattern to that shown in the first panel of Fig. 1, though the upward trend in the cost efficiency scores during the post-crisis period 2003–2008 turns to be less obvious.

Our next step is examining the efficiency scores across different ownership status. As mentioned before, of our 22 commercial banks 3 are state-owned, 9 are privately-owned domestic and 10 are foreign banks. The second panel of Fig. 1 illustrates efficiency scores for three different bank ownership types. It appears that private banks are the most efficient with the average cost efficiency of 91 percent, followed by foreign and state banks with average cost efficiencies of 89 and 78 percent, respectively. This result is in line with the literature for developing countries, where the most common finding is that on average foreign banks are more efficient than or roughly equally efficient to domestic private banks, with both groups being generally more efficient on average than state-

[8] We also conduct the generalized likelihood-ratio test of the null hypotheses that inefficiency effects are absent from the cost function, the inefficiency effects have a simple distribution (half-normal distribution), the inefficiency correlates we use have no significant effect on the cost inefficiencies and finally there is no heterogeneity in the cost inefficiencies. All four null hypotheses are strongly rejected, indicating that the specification of our model is perfectly adequate to measure the cost efficiency of Turkish banks. Test statistics are not reported here to conserve space but available upon request.

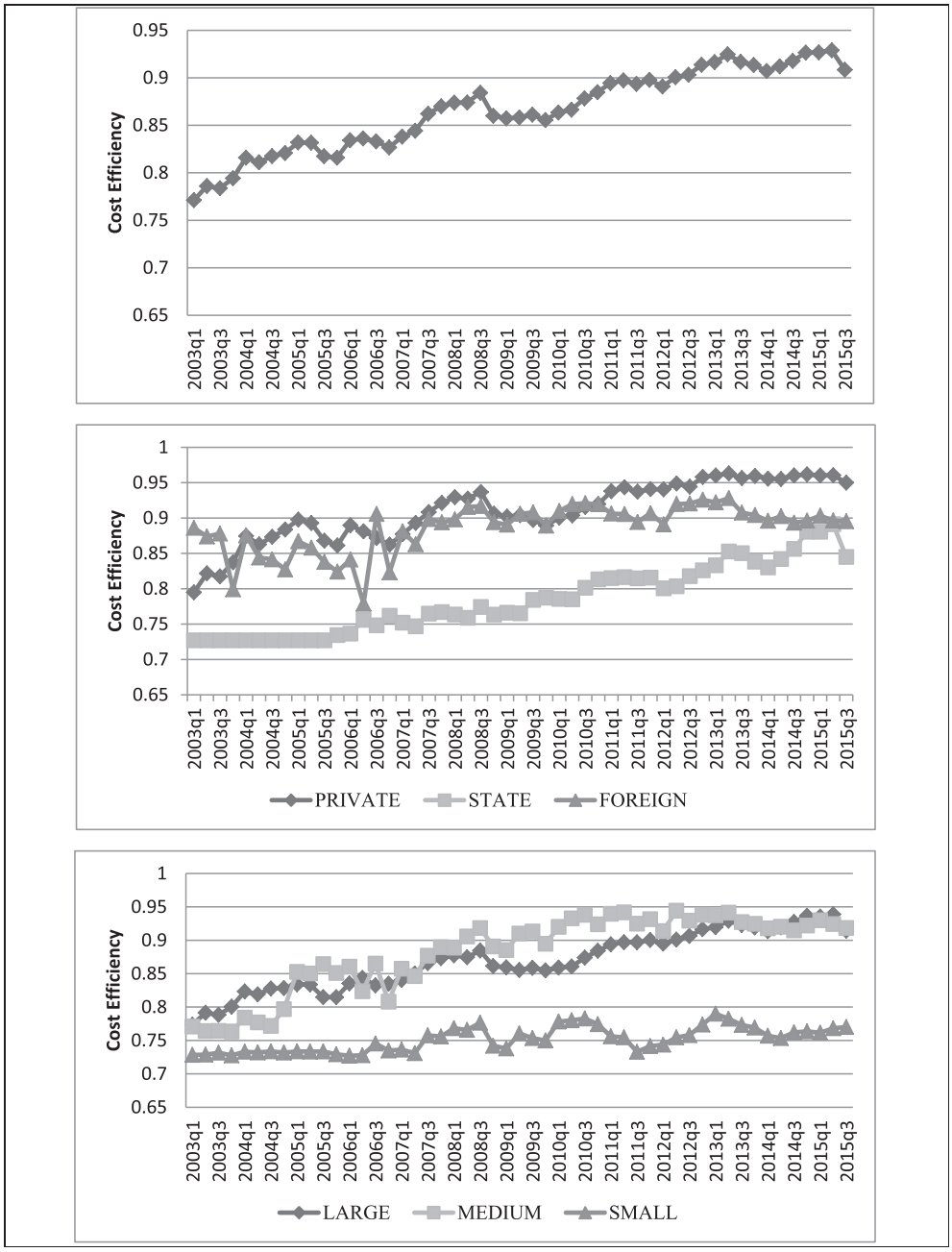

Fig. 1. Cost efficiency scores from the selected model.

owned banks (e.g. Delfino, 2003; Berger et al., 2005). As discussed by Isik and Hassan (2002) there are two main reasons behind the low cost efficiency of state-owned banks, differences in objectives and budget constraints. While foreign and private banks seek to boost their profits, state-owned banks in developing countries generally pursue objectives set by the government, such as developing specific industries or regions or export expansion. Secondly, the budget constraints of state-owned banks are less strict than those of foreign and private banks since they are frequently supplied by government subsidies or government guaranteed debts. This leads foreign and private banks to be more efficient by directing investment funds to efficient places.

Turning to the temporal movement of the efficiency scores for three different bank ownership types, the second panel of Fig. 1 clearly illustrates that with the exception of few abrupt changes, foreign and private banks have relatively similar upward trends until the third quarter of 2008. The exceptional behaviour of efficiency scores of foreign banks might result from mergers and acquisitions taken place during 2006. After the third quarter of 2008, the effect of the 2008 financial crisis became apparent for private and foreign banks with approximately 4 and 3 percentage points declines in efficiency scores, respectively. The recovery lasted for seven quarters for foreign banks, while private banks reached their pre-crisis level after eleven quarters. This finding might suggest that foreign banks, whose parent banks are mainly located in the EU and East Asian countries, were less severely affected by the global financial crisis than domestically owned private banks were. In accordance with the literature, this finding could be attributed to the fact that during episodes of financial turmoil domestic banks might face higher costs of external funding or might be cut off from

Table 3
Cost efficiency estimates from the selected model.

Time	Mean	Standard deviation	Time	Mean	Standard deviation	Time	Mean	Standard deviation
2003q1	0.771	0.061	2007q2	0.844	0.095	2011q3	0.893	0.085
2003q2	0.785	0.077	2007q3	0.862	0.095	2011q4	0.897	0.085
2003q3	0.783	0.067	2007q4	0.869	0.095	2012q1	0.890	0.085
2003q4	0.794	0.074	2008q1	0.873	0.098	2012q2	0.900	0.089
2004q1	0.815	0.095	2008q2	0.873	0.099	2012q3	0.903	0.087
2004q2	0.811	0.087	2008q3	0.884	0.097	2012q4	0.913	0.089
2004q3	0.817	0.093	2008q4	0.859	0.092	2013q1	0.916	0.088
2004q4	0.820	0.099	2009q1	0.857	0.092	2013q2	0.924	0.080
2005q1	0.831	0.098	2009q2	0.858	0.089	2013q3	0.916	0.075
2005q2	0.831	0.091	2009q3	0.861	0.083	2013q4	0.913	0.078
2005q3	0.817	0.087	2009q4	0.855	0.076	2014q1	0.907	0.081
2005q4	0.815	0.084	2010q1	0.863	0.080	2014q2	0.911	0.081
2006q1	0.834	0.097	2010q2	0.866	0.079	2014q3	0.917	0.076
2006q2	0.836	0.091	2010q3	0.878	0.082	2014q4	0.926	0.067
2006q3	0.833	0.087	2010q4	0.884	0.085	2015q1	0.926	0.063
2006q4	0.826	0.086	2011q1	0.894	0.088	2015q2	0.928	0.064
2007q1	0.838	0.091	2011q2	0.897	0.088	2015q3	0.908	0.066

Overall Mean (2003–2015): 0.865.

international financial markets (Efthyvoulou and Yildirim, 2014). Over the period 2011–2015, on the other hand, we observe an ongoing upward trend in the cost efficiencies of private banks coupled with slightly decreasing and relatively stable cost efficiencies of foreign banks. This differentiation could be related to the 2010 European debt crisis. Although the effects of the crisis remained rather limited for Turkish economy as noted by Aysan and Ermisoglu (2013a), they were more pronounced, on the average, for foreign banks due to the parent country of the biggest foreign bank being Greece where the debt crisis broke out. Moving on to the efficiency scores of state banks, we observe that a stable path followed over the period 2003–2005 was replaced with a gradual upward trend without being affected by the 2008 financial crisis.

Next, we proceed with examination of cost efficiencies for different bank scales. Despite being found insignificant, it is noteworthy to take a closer look at how bank size affects efficiency scores. The third panel of Fig. 1 illustrates weighted average of cost efficiencies for each group of commercial banks. According to the Figure, it seems that medium-sized banks have the highest average cost efficiency of 88 percent, and it is followed by large and small banks with the average cost efficiencies of 87 and 75 percent, respectively. In the empirical literature there is no consensus on the relationship between bank size and efficiency due to conflicting evidences. While some studies report an unclear or insignificant relationship between bank size and efficiency (e.g. Berger and Mester, 1997; Kasman and Yildirim, 2006) as in our case, some report a significantly positive relationship (e.g. Berger et al., 1993; Ataullah and Le, 2006) and some others reveal a significantly negative relationship (e.g. Isik and Hassan, 2002; Manlagnit, 2011).

In our case, although, average cost efficiencies of medium-sized and large banks are approximately same, their temporal movement seems to be different. More specifically, while they moved together by following a similar upward trend from 2003Q1 to 2008Q3, a diversification is observed over the period 2008Q3-2010Q4. With the global financial crisis, the upward trend of cost efficiencies of large banks was interrupted and they plummeted by approximately 3 percentage points. Medium-sized banks, however, appears to be almost unaffected by the crisis. The reason behind this could be explained by ownership types of these banks. Out of our 7 large banks, 3 are state-owned and 4 are private. Regarding the ownership types of medium-sized banks, 4 are foreign and only 1 out of 5 is private. Given the previous finding that foreign banks were less severely affected by the global financial crisis than domestically owned private banks were, it is not surprising to observe that the effect of the crisis remained rather limited for medium-sized banks with majority foreign ownership.

5.2. Results from the model averaging approach

As underlined by Huang and Lai (2012), although model selection is frequently employed in empirical studies as a tool to select the best model among the competing ones, different model selection criteria might result in different choices of models and more importantly the selected model may not be necessarily correct. To circumvent any possible problems, including the model uncertainty and omitted variable biases that may arise from relying on only the single (best) model, Huang and Lai (2012) suggest using a model-averaged estimator, which is a weighted average of estimators obtained from all competing models.

In this respect, to check whether the efficiency scores we derived from the best model selected through the previously discussed search algorithm are exposed to any bias problem or not, we repeat our analysis using the approach of Huang and Lai (2012). In this approach, the efficiency scores are calculated by taking the weighted average of efficiency scores obtained from all 63 estimated cost functions. It is important to specify appropriate weights. Following Huang and Lai (2012), we define the weight of the model j as

$$\pi_j^{AIC} = \frac{\exp\left(-\frac{1}{2}\Delta_j^{AIC}\right)}{\sum_{k=1}^{J}\exp\left(-\frac{1}{2}\Delta_k^{AIC}\right)}$$

where $\Delta_j^{AIC} = AIC_j - AIC_{\min}$ measures the AIC difference between model j and the best model among all J competing models. Once the weights are specified, it is straightforward to calculate the model-averaged cost efficiency scores. Fig. 2 illustrates these cost efficiencies. Compared to Fig. 1, it is clearly seen that the results obtained from the search algorithm are almost identical to those of the model averaging approach, confirming the robustness of our results.[9]

[9] We checked for the sensitivity of the model-averaged efficiency scores to alternative information criteria by calculating weights according to the Bayesian information criterion (BIC) of Schwarz, estimated efficiency scores remained almost unchanged.

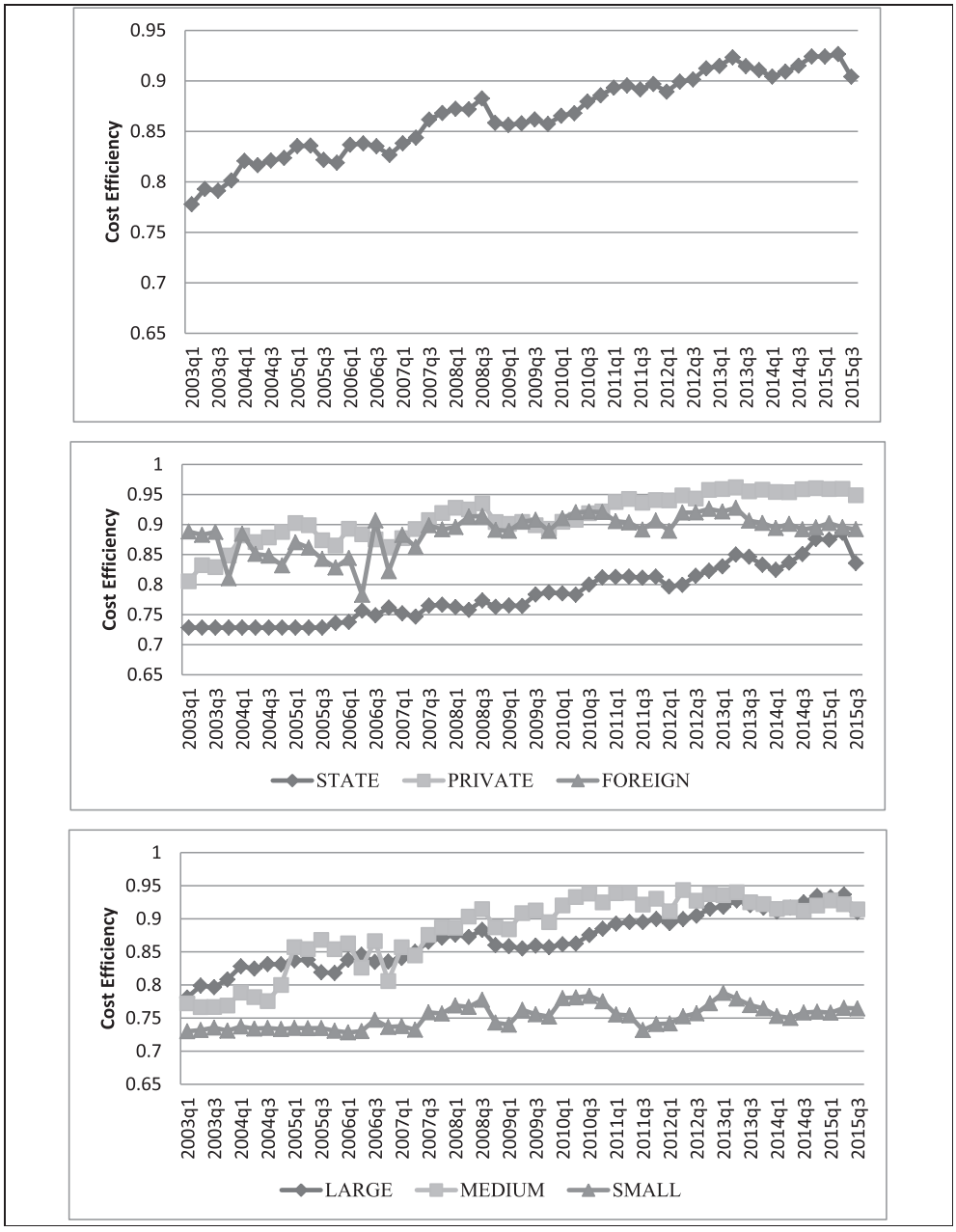

Fig. 2. Cost efficiency scores from the model averaging approach.

5.3. *Persistency analysis for cost inefficiency of Turkish banks*

As a final issue, we investigate the degree of persistency in cost inefficiencies of Turkish banks to address the question that whether an inefficient bank becomes efficient or remains inefficient over time. To this end, following Manlagnit (2011), we calculate the Spearman rank correlations for all commercial banks and sub-groups determined by ownership types and scale.[10] The Spearman rank correlations for all commercial banks appear to be statistically significant, suggesting persistency of cost inefficiency of commercial banks. In other words, this finding indicates that if a commercial bank is relatively cost inefficient, then, it is very likely to remain cost inefficient for quite a long period of time. Moreover, our results reveal that inefficiency is persistent for large banks, although it is not so persistent for medium-sized and small banks as the rank correlations are generally statistically insignificant and become negative over time. Regarding banks' ownership types, we observe that cost inefficiencies of private and state-owned banks are quite persistent. For foreign banks, however, correlations appear to be significant only in a few quarters, implying that cost inefficiency is relatively short-lived for foreign banks.

6. Conclusion

This study investigates the cost efficiency of Turkish commercial banks over the restructuring period of the Turkish banking system, which coincides with the 2008 financial global crisis and the 2010 European debt crisis. In this respect, we employ the true fixed

[10] Sparkman rank correlation matrices are not reported here to conserve space, however, interested readers may request the matrices from the authors.

effects model, where the unobserved bank heterogeneity is integrated in the inefficiency distribution at a mean level.

Adoption of a search algorithm, which is designed to detect the cost frontier function with the most appropriate inefficiency correlates, justifies that intermediation ratio, capital ratio and the natural logarithm of total assets are effective on measured cost inefficiency, with the direction of the effects being in accordance with our priori expectations. When examining the cost efficiency scores, it is seen that Turkish banks have experienced on the average a positive efficiency change during the period 2003–2008, suggesting that the restructuring program fulfils its promise in terms of improving bank efficiency. Moreover, although the negative effect of the 2008 global financial crisis was felt, a relatively quick recovery is observed at the end of 2010. We further observe that 2010 European debt crisis had no noticeable impact on the Turkish banking system in terms of average cost efficiency. Being in line with much of the existing literature, the analysis of the efficiency scores across different ownership types suggests that on average foreign banks are roughly equally efficient as domestic private banks, with both groups being more efficient than state-owned banks. Regarding the efficiency scores across different bank scales, it appears that small banks tend to have lower cost efficiency on average than medium-sized and large banks.

To check whether the estimated efficiency scores are exposed to any model selection bias or not, we repeat our analysis by adopting the model-averaging approach of Huang and Lai (2012). The results obtained from the search algorithm appear to be almost identical to those of the model averaging approach, confirming robustness of our results. Finally, we investigate the degree of persistency in cost inefficiencies of Turkish banks through the Spearman rank correlations. Overall, our results suggest persistency of cost inefficiency of commercial banks.

References

Aigner, D.J., Lovell, C.A., Schmidt, P., 1977. Formulation and estimation of stochastic frontier production function models. J. Econ. 6, 23–37.

Akın, G.G., Aysan, A.F., Yildiran, L., 2009. Transformation of the Turkish financial sector in the aftermath of the 2001 crisis. Turk. Glob. Econ. Neo-Liberal Restruct. Integr. Post-Crisis Era 73.

Altunbas, Y., Evans, L., Molyneux, P., 2001. Bank ownership and efficiency. J. Money, Credit Bank. 33 (4), 926–954.

Amidu, M., Wolfe, S., 2013. Does bank competition and diversification lead to greater stability? Evidence from emerging markets. Rev. Dev. Finance 3 (3), 152–166.

Assaf, A.G., Matousek, R., Tsionas, E.G., 2013. Turkish bank efficiency: Bayesian estimation with undesirable outputs. J. Bank. Finance 37 (2), 506–517.

Aysan, F.A., Ermisoglu, E., 2013a. Eurozone Debt Crisis and its Effects on Turkish Economy. MPRA Paper No. 50501.

Aysan, F.A., Ermisoglu, E., 2013b. Turkey's Capital Market and Banks: Recipe for Survival in Recessionary Times. MPRA Paper No. 50503.

Ataullah, A., Le, H., 2006. Economic reforms and bank efficiency in developing countries: the case of the Indian banking industry. Appl. Financ. Econ. 16 (9), 653–663.

Banker, R.D., Chang, H., Seok-Young, L., 2011. Differential impact of Korean banking system reforms on bank productivity. J. Bank. Finance 34 (7), 1450–1460.

Battese, G.E., Coelli, T.J., 1995. A model for technical efficiency effects in a stochastic frontier production for panel data. Empir. Econ. 20, 325–332.

Ben-Khedhiri, H., Casu, B., Naceur, S.B., 2011. What Drives the Performance of Selected MENA Banks? a Meta-frontier Analysis. IMF Working Papers, 11/34.

Berger, A.N., Hancock, D., Humphrey, D.B., 1993. Bank efficiency derived from the profit function. J. Bank. Finance 17 (2), 317–347.

Berger, A.N., Mester, L.J., 1997. Inside the black box: what explains differences in the efficiencies of financial institutions? J. Bank. Finance 21 (7), 895–947.

Berger, A.N., Clarke, G.R.G., Cull, R., Klapper, L., Udell, G.F., 2005. Corporate governance and bank performance: a joint analysis of the static, selection, and dynamic effects of domestic, foreign, and state ownership. J. Bank. Finance 29 (8), 2179–2222.

Cornwell, C., Schmidt, P., Sickles, R., 1990. Production frontiers with cross-sectional and time series variation in efficiency levels. J. Econ. 46, 185–200.

Delfino, M.E., 2003. In: Bank Ownership, Privatization and Efficiency: Empirical Evidence from Argentina. University of Warwick. Working paper.

Demir, N., Mahmud, S.F., Babuscu, S., 2005. The technical inefficiency effects of Turkish banks after financial liberalization. Dev. Econ. 43 (3), 396–411.

Denizer, C., Dinc, M., Tarimcilar, M., 2007. Financial liberalization and banking efficiency: evidence from Turkey. J. Prod. Anal 27, 177–195.

Du, J., Girma, S., 2011. Cost economies, efficiency and productivity growth in the Chinese banking industry: evidence from a quarterly panel dataset. Empir. Econ. 41, 199–226.

Efthyvoulou, G., Yildirim, C., 2014. Market power in CEE banking sectors and the impact of the global financial crisis. J. Bank. Finance 40, 11–27.

El-Gamal, M., Inanoglu, H., 2005. Inefficiency and heterogeneity in Turkish banking: 1990-2000. J. Appl. Econ. 20, 641–664.

Erkoc, T.E., 2012. Estimation methodology of economic efficiency: stochastic frontier analysis vs data envelopment analysis. Int. J. Acad. Res. Econ. Manag. 1 (1).

Ertugrul, A., Zaim, O., 1999. Economic crises and efficiency in Turkish banking industry. METU Stud. Dev. 26, 99–116.

Fries, S., Taci, A., 2005. Cost efficiency of banks in transition: evidence from 289 banks in 15 post-communist countries. J. Bank. Finance 29 (1), 55–81.

Fukuyama, H., Matousek, R., 2011. Efficiency of Turkish banking: two stage network system. Variable returns to scale model. J. Int. Financ Mark. Inst Money 21 (1), 75–91.

Greene, W., 1990. A gamma-distributed stochastic frontier model. J. Econ. 46, 141–163.

Greene, W., 2004. Distinguishing between heterogeneity and inefficiency: stochastic frontier analysis of the World Health Organization's panel data on national health care systems. Health Econ. 13, 959–980.

Greene, W., 2005. Fixed and random effects in stochastic frontier models. J. Prod. Anal 23, 7–23.

Hao, J., Hunter, W.C., Kang, W.K., 2001. Deregulation and efficiency: the case of private Korean banks. J. Econ. Bus. 53 (2), 237–254.

Hasan, I., Marton, K., 2003. Development and efficiency of the banking sector in a transitional economy: Hungarian experience. J. Bank. Finance 27 (12), 2249–2271.

Huang, C.J., Lai, H., 2012. Estimation of stochastic frontier models based on multi-model inference. J. Prod. Anal 38 (3), 273–284.

Isik, I., Hassan, M.K., 2002. Technical, scale and allocative efficiencies of Turkish banking industry. J. Bank. Finance 26, 719–766.

Jondrow, J., Lovell, C.A.K., Materov, I.S., Schmidt, P., 1982. On the estimation of technical inefficiency in the stochastic production function model. J. Econ. 19 (2–3), 233–238.

Kasman, A., 2002. Cost efficiency, scale economies and technological progress in Turkish banking. Cent. Bank. Rev. 1, 1–20.

Kasman, A., Yildirim, C., 2006. Cost and profit efficiencies in transition banking: the case of new EU members. Appl. Econ. 38 (9), 1079–1090.

Koetter, M., Poghosyan, T., 2009. The identification of technology regimes in banking: implications for the market power-fragility nexus. J. Bank. Finance 33 (8), 1413–1422.

Koetter, M., Wedow, M., 2010. Finance and growth in a bank based economy: is it quantity or quality that matters? J. Int. Money Finance 29 (8), 1529–1545.

Kumbhakar, S., 1990. Production frontiers, panel data and time-varying technical inefficiency. J. Econ. 46, 201–212.

Kumbhakar, S., Lovell, C.A.K., 2000. Stochastic Production Frontiers. Cambridge University Press, Cambridge.

Kumbhakar, S.C., Wang, D., 2007. Economic reforms, efficiency and productivity in Chinese banking. J. Regul. Econ. 32, 105–129.

Kumbhakar, S., Peresetsky, A., 2013. Cost efficiency of Kazakhstan and Russian banks: results from competing panel data models. Macroecon. Finance Emerg. Mark. Econ. 6 (1), 88–113.

Manlagnit, M.C.V., 2011. Cost efficiency, determinants, and risk preferences in banking: a case of stochastic frontier analysis in the Philippines. J. Asian Econ. 22, 23–35.

Meeusen, W., van den Broeck, J., 1977. Efficiency estimation from Cobb-Douglas production functions with composed error. Int. Econ. Rev. 18, 435–444.

Mester, L.J., 1996. A study of bank efficiency taking to account risk-preferences. J. Bank. Finance 20, 1025–1045.

Ozkan-Gunay, E.N., 2012. Risk incorporation and efficiency in emerging market banks during the global crisis: evidence from Turkey, 2002-2009. Emerg. Mark. Finance Trade 48 (5), 91–102.

Ozkan, S., Balsari, C.K., Varan, S., 2014. Effect of banking regulation on performance: evidence from Turkey. Emerg. Mark. Finance Trade 50 (4), 196–211.

Poghosyan, T., Kumbhakar, S.C., 2010. Heterogeneity of technological regimes and banking efficiency in former socialist economies. J. Prod. Anal 33, 19–31.

Rao, A., 2005. Cost frontier efficiency and risk-return analysis in an emerging market. Int. Rev. Financ Anal 14 (3), 283–303.

Williams, J., 2012. Efficiency and market power in Latin American banking. J. Financ Stab. 8 (4), 263–276.

Yildirim, C., 2002. Evolution of banking efficiency within an unstable macroeconomic environment: the case of Turkish commercial banks. Appl. Econ. 34, 2289–2301.

Zaim, O., 1995. The effect of financial liberalization on the efficiency of Turkish commercial banks. Appl. Financ. Econ. 5, 257–264.