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Determinants of Bank Efficiency: The Case of Brazil

Patricia Tecles* Benjamin M. Tabak †

Abstract

This paper analyzes the efficiency of the Brazilian banking sector over the post-privatization period of 2000-2007. We employ a Bayesian stochastic frontier approach, which provides exact efficiency estimates and confidence intervals and thus, allows an accurate comparison across institutions and bank groups. The results suggest that large banks are the most cost and profit efficient, supporting the concentration process observed in recent years. Foreign banks have achieved a good performance through either the establishment of new affiliates and the acquisition of local banks. The remaining public banks have had improvements in cost efficiency, but are relatively profit inefficient. Finally, we observe a positive impact of capitalization on efficiency.

Stochastic Frontier; Bayesian methods; Banking system; emerging markets.

JEL Classification: G15; G21; G28.

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1 Introduction

The evaluation of efficiency in the banking sector has gained large attention to help improve the allocation of investments. Research studies have also been concerned with the impact of the financial sector on other sectors and thus, on economic growth. The efficiency measure is a tool for management and policy decisions on how to improve bank performance, providing information on country- and bank-specific features related to efficiency gains. This measure compares the ability of banks to transform inputs into financial products and services, relative to the costs they incurred or to their earned profits.

We seek to contribute to the banking efficiency literature in three manners. First, we examine the still little explored case of Brazil, a developing economy with a banking system that has undergone major transformations. Inefficiency levels in emerging countries have been found particularly high, causing losses to financial development and stability (Some of the studies conducted in this context are Denizer et al. (2007), Ariff and Can (2008) and Sathye (2003)). Research in a large variety of countries, with different political and economic environments, may help regulators and managers achieve a more efficient banking system. In order to provide an efficiency measure that is comparable with the results from different economies, environmental factors are taken into account in the model. As argued by Kenjegalieva et al. (2009), this procedure disentangles the country effect. Furthermore, Drake et al. (2006) suggested that it also prevents the bias from the uneven impact of these factors on different sector and size groups.

The period under analysis is a post-privatization period, characterized by the consolidation of the banking sector through numerous mergers and acquisitions. After financial deregulation, technological changes and opening up of the market to foreign entry, banks have looked for scope and scale gains, leading to an increasing concentration process. Our findings indicate that large banks were better able to adapt to the new market structure, with the highest efficiency levels.

Second, we evaluate the role of foreign entry, which has taken place through the establishment of new affiliates and the acquisition of local banks. We acknowledge the importance of analyzing both cost and profit efficiencies, specially when studying different sector and ownership institutions. While the competition in the banking activity makes cost efficiency pursuit crucial for success in the market, measures of profit efficiency indicate the best practices that should be applied by firms. Although the international literature has focused on the cost side of inefficiencies, empirical evidence shows that there are significant levels of profit inefficiency in banking activity. According to Maudos et al. (2002), the profit maximization objective is a more comprehensive source of information for managers since it does not only require that goods and services be produced at a minimum cost, but it also demands the maximization of revenues. As reported by Berger and Mester (1997), cost and profit levels of inefficiency are not necessarily correlated to each other. In that way, managerial skills are better analyzed through both cost and profit efficiencies.

Many studies that find foreign banks inefficient analyze only the cost side. In fact, in this study, foreign banks had the best results on the profit side. The public banks that remained after privatization showed improved cost efficiency. However, they are relatively profit inefficient, which may be due to a different orientation.

Finally, we evaluate banking efficiency using a Bayesian stochastic frontier approach (SFA), introduced by van den Broeck et al. (1994), and whose implementation is described by Griffin and Steel (2007). The SFA was independently developed by Aigner et al. (1977) and Meeusen and van den Broeck (1977) and is broadly found in efficiency studies, accounting for measurement error and inefficiency in a composed error term. However, the classical procedures to estimate efficiency levels do not provide standard errors or confidence intervals without strong assumptions, such as limiting normal distributions to parameters. The Bayesian approach has several advantages over classical methods of inference. Through Bayesian methods, we derive exact [1] distributions of parameters or functions of interest, without using asymptotic approximations. In that way, parameter uncertainty is fully taken into account, since each parameter is assigned to a probability distribution. Posterior densities for the efficiencies are easily obtained, thus it is possible to accurately compare efficiencies among banks.

The Bayesian inference in frontier models requires first defining priors to parameters. The priors reflect the information content of the parameters in the model before we analyse the data and can be used to impose restrictions based on economic theory, such as monotonicity and concavity. The sampling distribution or likelihood estimate is then combined with the prior to pro-

[1] It is usual to make inferences asymptotically, using normal approximations of the model, which might be satisfactory in some cases. One advantage of the Bayesian approach is that it allows obtaining the posterior exact distribution of parameters.

duce a density estimate. The posterior distribution is presented in a manner that can be readily interpreted using the Gibbs sampling technique. Dou and Hodgson (1996) studied the robustness of Bayesian analysis and Gibbs sampling in spectral analysis in physics and demonstrated that Bayesian inference and Gibbs sampling can give very accurate results. In order to compare the results to other common specifications we test alternative models and also estimate efficiencies through Data Envelopment Analysis (DEA).

Besides inference on efficiency levels, bank characteristics are included in the model to analyze the influence of size, ownership, market share, equity and non-performing loans on individual performance. A wide sample allows us to analyze the frontiers from banks with different specializations. We also look for time trends to evaluate if cost and profit efficiencies have increased over time with technological change.

The remainder of the paper is organized as follows. Section 2 comments on the banking efficiency literature, especially on studies dedicated to Bayesian methods. Section 3 briefly describes the recent banking structure in Brazil. Section 4 presents the methodology used to estimate efficiencies and Section 5 reports the obtained results. Section 6 concludes.

2 Literature Review

Banking efficiency has been the subject of many studies in the past decades (Berger and Humphrey (1997), Amel et al. (2004), Brissimisa et al. (2009)). Most studies have found that there are inefficiencies in the banking sector for a variety of countries employing different methods such as the Data Envelopment Analysis (DEA) and the SFA (see Bhattacharyya et al. (1997) and Saha and Ravisankar (2000) for the DEA, Fries and Taci (2005) and Bonin et al. (2005) for the SFA and Sturm and Williams (2004) for a comparison between both).

The interest in estimating bank efficiency is related to questions about which characteristics can be observed in outperforming institutions, such as size, ownership and market share. The studies seek to identify improvements after privatization, foreign entry, mergers and changes in countries' macroeconomic and regulatory conditions.

Studies conducted in developed countries normally find efficiency levels above those yielded by emerging market works. For instance, the reported average cost efficiency for the United States is 86% (Berger and Mester (1997)), 85% for the European Union (Hollo and Nagy (2006)) and about 93% for Japan (Altunbas et al. (2000)). Regarding emerging countries, literature reports estimates of 79% for China (Ariff and Can (2008)), between 91 and 97% for India (Das et al. (2004)) and 72% for Turkey (Isik and Hassan (2002)). Profit efficiencies are commonly found to be lower in all countries. A 50% estimate is reported for the US (Berger and Mester (1997)), 69% for the EU (Hollo and Nagy (2006)), between 40 and 65% for India (Das et al. (2004)) and 50.5% for China (Ariff and Can (2008)). However, the different economic and political environments make efficiency levels difficult to be directly comparable across countries.

Table 1 summarizes the results of empirical works conducted in the Brazilian banking system. Their reported mean efficiencies largely differ due to different choices made on methods, variable specification and data sample. The studies by Périco et al. (2008) and Silva and Neto (2002), for example, which found mean efficiencies of 0.84 and 0.86, respectively, focused on samples of large banks only. Therefore, the comparison among the results needs to be treated with caution.

The recent literature has suggested estimating the SFA by employing Bayesian methods. It is considered an accurate tool for inference on efficiencies, with easy incorporation of priors and economic restrictions. Van den Broeck et al. [1994] presented the methodology by defining several inefficiency distribution models that could be treated separately or mixed. Fernandez et al. (2000) and Fernandez et al. (2005) contrast it with classical approaches, which construct only point estimates for firm-specific efficiency. They follow the Bayesian approach to estimate frontiers with multiple outputs. For O'Donnell and Coelli (2005), it is also convenient for imposing concavity and convexity constraints. Griffin and Steel (2004) highlight the capacity of the model to impose economic regularity conditions, and the formal treatment of parameter and model uncertainty.

Zhang (2000) compares the performance of Bayesian and maximum likelihood estimation methods in terms of the mean square error criterion. The result indicates the superiority of the former in estimating stochastic frontier models. Kim and Schmidt (2000), on the other hand, do not report significant differences between efficiency estimates of Bayesian and classical procedures with comparable assumptions.

The Bayesian stochastic frontier approach has recently been used in empirical works on banking efficiency. With a panel data from US commercial banks, Kumbhakar and Tsionas (2005) estimate technical and allocative inefficiencies in a translog-cost system. The former was found to be around 96% and the latter, 90%. Dealing with different samples from the US, Marsh et al. (2003) report an average efficiency of 70% and Sfiridis and Daniels (2006), 87%. Okeahalam (2006) analyzes bank branches in South Africa, providing an insight into the overall banking system efficiency. He also gives preference to the Bayesian cost frontier approach with the use of the Gibbs sampling technique, finding a posterior mean of 83%.

Place Table 1 About Here

3 The Brazilian Banking System

The banking system in Brazil provides a special case to study efficiency, with several transformations in its structure in the last decades. The new regulation of the financial system in 1988 permitted institutions to provide different financial services, universalizing their activities. The inflation observed since the 1960s was at that time sharply rising, but favorable to the banking sector. Financial institutions succeeded in implementing innovations and took advantage of inflation revenues, such as arbitrage on interest rates. The opening up of the system produced, at first, a rise in the number of banks in operation. However, in July 1994, the Brazilian government launched a monetary reform that stabilized prices and reverted this process. While eliminating easy earnings from inflation transfers, the transition to a low inflation environment led to increased credit operations, exposing banks to rising risks and consequently to non-performing loans. The Central Bank had to intervene in public and private banks with insolvency problems through liquidation, recapitalization and restructuring programs [2]. The system also witnessed a large number of mergers and acquisitions, through foreign entry and domestic consolidation.

At the end of 1988, there were 104 operating banks, out of which 49 were private banks, 26 had foreign control (19 were direct subsidiaries of foreign banks) and 29 were public banks. Of these banks, 64 banks survived until 2000, when the total number of banks reached 192. During this period, the

[2]The Program of Incentives for the Restructuring and Strengthening of the National Financial System (PROER) and the Program of Incentives for the Reduction of State´s Participation in Banking Activities (PROES) are described in detail in Baer and Nazmi (2000).

percentage of foreign control in terms of assets increased from 9.62 to 33.11%, due to the acquisition of domestic private and public banks. The economic stabilization plan of 1994 was also committed to reducing the participation of the public sector in the financial system. Of the 29 federal and state public banks, eight were privatized and five were closed.

Despite the consolidation trend, the banking sector remains fragmented, with several smaller banks operating among large retail groups. Table 2 reports the number of banks in our sample for each year in the 2000-2007 period. Table 3 below shows the descriptive statistics for the Brazilian banking system, comprehending 156 banks. Among 1,517 observations, 175 are from large banks, 210 from medium-sized banks, 630 from small banks and 502 from microbanks.

Place Tables 2 and 3 About Here

After the reform, when banks had shown their fragility to operate in regular circumstances of price, competition forced management improvements. Figure 1 illustrates the banking profit and non-performing loans (NPL) paths since 2000. According to data from the Central Bank of Brazil, operational expenses showed a decreasing trend from December, 2003, while revenues from banking services have increased. The negative profit registered in the first semester of 2001 occurred due to adjustments on equity related to privatizations. The fall in the NPL rates contributed to a more consistent expansion of credit. However, as the Brazilian banking system was still relatively inefficient in the years after price stabilization (Baer and Nazmi (2000) measured it in terms of the ratio of administrative and personnel expenses over revenues and of clients serviced per branch), it is interesting to measure how efficiency has evolved in the more recent period and analyze whether the efforts for strengthening the national financial system have allowed banks to become more efficient, with greater ability to compete in the market.

We have chosen the sample period from 2000 to 2007 due to data limitation. Prior to 2000 there is no information on non-performing loans and the quality of the data is questionable since there were major changes in the Brazilian plan of accounts[3].

Place Figure 1 About Here

[3]The data sample used, taken from the Brazilian plan of accounts, is audited by the Central Bank and, therefore, is the best data available for analysis.

4 Methodology

The concepts explored in our paper are those of cost and profit efficiencies, which have, according to Berger and Mester (1997), the best economic foundation, as they depend on economic optimization in reaction to market prices and competition. Cost inefficiency measures the amount of reduction in costs that would take place if no inefficiency were observed, while profit inefficiency measures how far a bank is from the maximum possible profit, given the level of input prices and output quantities[4]. The alternative profit efficiency here employed takes into account the differences in output quality and price, as it considers the higher revenue earned from better quality outputs.

Inefficiency levels from the cost perspective represent the distance from the cost frontier, that is, the cost of a best-practice firm. To estimate the cost frontier and inefficiencies in the Brazilian banking system, we employ Bayesian stochastic frontier analysis, as it provides exact inference on firm-specific estimates and controls for measurement error.

The frontiers will be estimated separately for the four groups of banks defined according to their size. McAllister and McManus (1993) showed that fitting a single function over an entire sample that varied widely in terms of size and output mix led to biased results. They argued that small banks typically produce output mixes that are different from those of large banks. This appears to be the case in Brazil, where small banks operate in niche markets, with specialized financial services. Therefore, in order to accurately estimate the banking technology, the banks are grouped by size, according to the classifications of the Central Bank of Brazil, which bases size on the cumulative total assets of the financial system: banks that add up to 75% of the total banking assets are classified as large banks, 75%-90% as medium-sized banks, 90%-99% as small banks and all the remaining ones as microbanks. There are 175 observations from large banks, 210 from medium-sized ones, 630 from small ones and 502 from microbanks.

The cost frontier is a function of input prices P and output quantities Q. The model regresses the logarithm of cost, $\ln C_{i,t}$, of a firm i at time t, on

[4]The standard approach to estimate the profit function requires data on input quantities and output prices, which were not available. However, the alternative approach is suitable for our case. As Berger and Mester (1997) argued, in an imperfect competitive environment, it is reasonable to assume that banks choose output prices. Other important studies have employed it before (see Bonin et al. (2005) and Berger et al. (2009)).

the cost frontier

$$\ln C_{i,t} = f(Q_{i,t}, P_{i,t}) + u_{i,t} + v_{i,t}, \tag{1}$$

$$v_{i,t} \sim N(0, \sigma^2), \tag{2}$$

where $u_{i,t}$ is the measure of inefficiency, a positive error term, since higher inefficiency increases cost. Inefficiencies are allowed to vary with each firm and over time. The $v_{i,t}$ is the noise component, which is outside the control of management, assumed to follow a normal distribution. Since $\ln C_{i,t}$ is the logarithm of cost, the time-varying efficiency $r_{i,t}$ of firm i is $\mathrm{e}(-u_{i,t})$:

$$r_{i,t} = \frac{\text{cost of an efficient firm}}{\text{cost of firm } i} = \frac{\mathrm{e}(f(Q_{i,t}, P_{i,t}))}{\mathrm{e}(f(Q_{i,t}, P_{i,t}) + u_{i,t})} = \mathrm{e}(-u_{i,t}), \tag{3}$$

taking on a value between 0 and 1.

There is not a consensus on the proper definition of inputs and outputs to be used in the frontier specification. This paper follows the intermediation approach proposed by Sealey and Lindley (1977), and widely employed in the literature (Hasan and Marton (2003), Berger et al. (2009), Ray (2007), among others). It assumes that the bank collects funds, using labor and physical capital, to transform them into loans and other earning assets. Besides this specification, we will test another model, in which deposits are also viewed as outputs, providing liquidity, safekeeping and payment services to depositors.

This approach is better suited to compare the performance of different banks since it captures the decisions taken to minimize costs considering both operating and interest expenses, as argued by Berger and Humphrey (1997). When efficiency is measured for the entire institution, which is our purpose, and not separately by branches, it is important to also consider the management funding and investment abilities. Furthermore, the analysis of profit efficiency requires minimization of total costs, not only of production costs. In the Brazilian system, interest expenses commonly account for more than two thirds of the total expenses.

Alternative measures, such as the number of deposit and loan accounts serviced, and the number of employees are constrained by data availability. However, our description of inputs and outputs is compatible with the objective of cost minimization (or profit maximization): to produce loans, investments and deposit services incurring in the least interest, salaries and office expenses possible.

Therefore, we have three inputs: labor, physical capital and purchased funds. The price of labor, P_1, is calculated as the ratio of personnel expenses to total assets, the price of purchased funds, P_2, as the interest paid on borrowed funds divided by total funds, whereas the price of physical capital, P_3, is calculated as the ratio of operating (i.e. non-interest reduced by personnel) expenses to total assets. Total costs are the sum of interest and non-interest costs.

We use investments, Q_1, total deposits, Q_2, and total loans, Q_3 as outputs. Output variables and costs are normalized by total loans and the prices of funds and labor are normalized by the price of capital. Therefore, the specification assumes homogeneity with respect to prices and reduces heteroskedasticity [5]. Also, exchange (ER) and unemployment (UR) rates are included to capture environmental effects. The exchange rate is defined as the half-yearly change rate of the dollar exchange rate (sell price). The unemployment rate is defined as the half-yearly change rate of the unemployment rate. Both data were obtained from Banco Central do Brasil. To specify the cost function, a translog functional form is adopted, which has the advantage of flexibility in specification. The frontier for $\ln(C/P_3 * Q_3)$ is defined as

$$\begin{aligned} f(Q_{i,t}, P_{i,t}) &= \beta_0 + \sum_{j=1}^{2} \beta_j \ln(Q_j/Q_3)_{it} \\ &+ \sum_{j=1}^{2} \delta_j \ln(P_j/P_3)_{it} + \frac{1}{2}\sum_{j=1}^{2}\sum_{k=1}^{2} \beta_{jk} \ln(Q_j/Q_3)_{it} \ln(Q_k/Q_3)_{it} \\ &+ \frac{1}{2}\sum_{j=1}^{2}\sum_{k=1}^{2} \delta_{jk} \ln(P_j/P_3)_{it} \ln(P_k/P_3)_{it} \\ &+ \sum_{j=1}^{2}\sum_{k=1}^{2} \omega_{jk} \ln(Q_j/Q_3)_{it} \ln(P_k/P_3)_{it} + \alpha_1 ER_t + \alpha_2 UR_t. \end{aligned} \tag{4}$$

Following the standard symmetry restrictions, the parameters β_{12} and β_{21} are equalized. The same applies to δ_{12} and δ_{21}. In order to investigate the effects of technological change on banks performance, a frontier that contains time trends instead of the exchange and unemployment rates will be also

[5] See Hasan and Marton (2003) and Berger et al. (2009) for other examples employing this procedure.

estimated[6].

We also study profit efficiency. Total profit was measured by net profit earned by the bank. Following the literature, we add a constant amount to profit for all banks, which equals the lowest profit obtained in each semester plus one, to avoid having negative net profits for any bank observation so that we may take logarithms of all profit function variables. To estimate profit efficiency, the same outputs and prices are considered. The profit frontier is specified similarly to expression 4, but the inefficiencies appear with a negative sign in the regression

$$\ln Z_{i,t} = f(Q_{i,t}, P_{i,t}) - u_{i,t} + v_{i,t}, \tag{5}$$

where $\ln Z_{i,t}$ is the logarithm of profit.

In Bayesian models, the parameters are attributed prior distributions, containing previous knowledge on them, before the data analysis starts. The priors on parameters adopted here are based on Griffin and Steel (2007).

The first model assigns a gamma distribution with mean $2/\ \lambda$ to the inefficiencies $u_{i,t}$:

$$u_{i,t} \sim \mathrm{Ga}(2, \lambda), \tag{6}$$

The inefficiencies are assumed to depend upon covariates, as in Koop et al. (1997). They are: market share of loans (MS), non-performing loans (NPL), equity over assets ratio and ownership dummies[7]. The λ parameter is then specified as:

$$\begin{aligned} \lambda &= \mathrm{e}(\gamma_1 MS + \gamma_2 NPL + \gamma_3 Equity \\ &+ \gamma_4 Public + \gamma_5 Private + \gamma_6 Foreign). \end{aligned} \tag{7}$$

Foreign banks are defined as those with foreign control greater than 50% of total ownership. There are 202 observations from public banks, 851 from private ones and 464 from foreign ones. The NPL and equity variables are included to control for loan quality and risk preferences.

The parameter γ is distributed as follows:

$$\mathrm{e}\gamma_n \sim \mathrm{e}(-\ln r^*), \tag{8}$$

[6] Further research could focus on disentangling the effects from time trend and environment when dealing with data from one country.

[7] We follow Griffin and Steel (2007) and include the dummies of all the three ownership types, i.e. public, private and foreign, as there is not an intercept in the regression. The model is specified this way so an equal efficiency prior is assumed for all banks.

where r^* is set at 0.65, following Marzec and Osiewalski (2001). Evaluating expression 7 by the means of the covariates results in a prior mean efficiency of 0.7. Parameters β, δ, ω and α are assigned normal distributions with large variance, while a gamma distribution is assumed for the scale σ^2:

$$\sigma^{-2} \sim \text{Ga}(0.001, 0.001). \tag{9}$$

In order to test the sensitivity of the prior assumption for r^* on individual efficiencies, we also estimate the model above with a prior mean efficiency of 0.85. The findings did not vary significantly. The robustness of the results is checked by alternatively defining an exponential distribution to inefficiencies, depending on covariates:

$$u_{i,t} \sim \text{e}(\lambda), \tag{10}$$

where λ is defined in the same way as in gamma distribution.

5 Empirical Results

The data used in the estimations cover 156 banks for the period between 2000 and 2007, with 1,517 half-yearly observations. Some banks started operating after the initial period and some participated in merger processes. To proceed with the Bayesian inference, the model was run using the WinBUGS software, which implements Markov Chain Monte Carlo (MCMC) techniques, more specifically, the Gibbs sampling. The first 10,000 of a total of 250,000 iterations were discarded and the chain was thinned every five draws.

The means and 95% confidence intervals of the parameters of the cost model with gamma inefficiency distribution are described in Table 4. The large differences in the cost functions of each size group strengthen the need to estimate separate frontiers. The coefficients α_1 and α_2 show that the environmental factors do not have the same effects across banks with different size, but instead have a major impact over large banks. For these banks, a positive variation in the exchange and unemployment rates reflects in increased costs, so that, by not including such variables, their efficiency may be underestimated.

In respect to the covariates describing inefficiencies we find for most banks a positive effect of market share and a negative coefficient for the the non-performing loans variable, although not significant. The sign of the equity coefficient indicates lower cost efficiency for banks with larger capitalization.

The relationship between ownership and efficiency will be discussed in more detail in the analysis of the evolution of efficiencies over time. As the variance of the symmetric error term σ^2 is significant, we assure that the error term is random.

Place Table 4 About Here

Table 5 reports the results for the profit model. Again, fitting the entire sample of banks to a single frontier does not seem appropriate, since the parameters vary widely among the groups. Regarding the inefficiency covariates, equity influences profit efficiency levels with a positive effect. This result is consistent with the moral hazard theory (Isik and Hassan (2003)), assuming that when shareholders have more capital at risk in the institution, there are more incentives to force an efficient management.

Place Table 5 About Here

The exact posterior distributions of parameters are derived, containing the information assumed in the prior and observed in data. The posterior distribution of the efficiencies is of particular interest, by allowing to make inference on the efficiency of different bank groups. Figures 2 and 3 show the kernel densities of mean efficiencies from large, medium-sized and small banks and microbanks for the cost and profit functions, respectively, when the gamma distribution is assumed. There is no economically implausible value, as they show zero probability of efficiencies lower than zero and larger than one.

Large banks were found to be the most efficient in both models, which supports the concentration of the banking system observed in recent years. Banks have participated in a large number of mergers and acquisitions, not only for scale gains, but also to achieve specific niche markets, competing for profitable client portfolios. The large banks, both domestic and foreign, have outperformed their counterparts. This evidence, however, does not imply in scale gains for all banks. As noted previously, smaller banks operate with different output mixes and specialized services. Therefore, it is not certain that these banks will benefit from an expansion.

Place Figures 2 and 3 About Here

In order to examine how the mean efficiency level has varied over time, figures 4 and 5 show the average cost and profit efficiencies for each of the 15 periods analyzed. The former varies from 0.63 in December, 2002 to 0.69 in June, 2002. The total mean is found to be 0.66, meaning that costs could be reduced by 34%, relative to the best-practice bank. Profit efficiency ranges from 0.71, observed in December, 2006 to 0.79, observed in December, 2001, with a mean of 0.75.

The low result for the second semester of 2002 is explained by the period of instability, caused by expectations about the presidential elections. A high degree of uncertainty, reflected in high exchange rate volatility, attracted capital flows to more favorable assets, as federal bonds. Moreover, the international scenario was also unstable, leading investments from emerging countries to less risky economies.

The figures also compare efficiency levels among public, private and foreign banks, which have mean cost efficiency estimations of 0.73, 0.71 and 0.53, respectively. Regarding profit efficiency, foreign banks have shown the best profit strategies on average, with a mean efficiency of 0.79. Private and public banks follow with 0.73 and 0.70 mean efficiencies, respectively.

In terms of cost efficiency, foreign banks show much lower results than domestic banks, while public banks have the lowest efficiency on the profit side. This finding emphasizes the importance of estimating both cost and profit functions for efficiency evaluation, as they provide different perspectives on how efficiently banks are managing their costs and revenues. Berger et al. (2009) reported a similar result for the state-owned banks in China. They were found to be very profit inefficient, but only slightly more cost inefficient than their counterparts. These banks might be saving costs from low monitoring of loans, which results in more non-performing loans and lower revenues. They might also take advantage of government subsidies on the cost side, such as lower office rents and rates on state deposits. In the Brazilian case, one explanation for the lower profit efficiency of public banks is that they may be used to finance social projects and therefore may have a different orientation, if compared to the private profit maximizing banks. On the other hand, our estimates for foreign banks suggest they are cost inefficient and profit efficient relative to other banks. Foreign banks might incur in higher expenses with technology development of financial services, which increases their costs but provides additional revenues.

Place Figures 4 and 5 About Here

As Fachada (2008) noticed, the recent departure of foreign banks from the country has been attributed to the highly distressed domestic institutions they took over. His work estimated the relationship between the profitability of foreign banks and the mode of entry in the market, and it was not significant. We further investigate the choice of foreign banks entry and also could not find evidence for the argument. Foreign banks that entered the Brazilian market by acquiring domestic institutions did not present significant different average efficiencies than banks that started establishing a new affiliate (greenfield banks). Therefore, foreign entry, either through acquisition of domestic banks or the opening of new institutions, has been beneficial in terms of banking efficiency.

5.1 Alternative specifications

The first test that we submit the model concerns changes in the prior mean efficiency. Inference on efficiencies do not largely differ. When assuming a 0.85 value, posterior mean increases from 0.660 to 0.665 for the cost model, and from 0.746 to 0.749 for the profit model.

Alternative specifications of the model were also used in order to check the robustness of the results. Table 6 summarizes the mean efficiencies of the main model, analyzed in the previous section, and the following models. First, we attribute an exponential distribution to inefficiency terms to compare the results with the gamma distribution. Qualitative results are independent of the specification. The mean efficiency for the cost model is 0.74 and for the profit model, 0.81, which are higher than results from the gamma distribution. Following Griffin and Steel (2007), we examine the deviance information criterion (DIC) values reported by WinBUGS as a criterion to model comparison. Lower values of the criterion indicate better fitting models. Table 7 reports the DIC values for the cost and profit models. The gamma inefficiency distribution seems to fit better both cost and profit functions, except for the profit frontier of small and microbanks [8].

Place Tables 6 and 7 About Here

A model with an alternative specification of the outputs was also estimated (the "intermediation" model), following the intermediation approach,

[8]Empirical results of the parameters from the alternative models have been omitted to save space, but are available upon request.

which does not include deposits as one of the outputs. The most noticeable difference is the decrease in the cost efficiency of public banks. Deposits seem to be an important portion of the output from these banks; when not accounted for, efficiency is severely affected. The cost function is affected probably due to the large volume of governmental accounts under their responsibility.Furthermore, the large public servant payroll which have accounts in public banks also plays a role. An additional explanation is the large judicial deposits which are present mainly in public banks.

The last model proposed includes a linear and a quadratic time trend to account for technological change over time. The trend coefficients of the cost model are not significant for medium-sized banks, small banks and microbanks but are significant and negative for the large banks. It suggests that large banks are managing to reduce their cost over time through development of superior equipment and processes. The coefficients of the profit model are significant and imply a profit decreasing path, counterbalanced by a positive squared trend.

5.2 DEA model

The nonparametric Data Envelopment Analysis is a widely employed approach in the banking efficiency literature as in Ray and Das (2010) and Banker and Natarajan (2008). We also estimate the cost efficiencies through DEA, using the same data sample, in order to conduct a comparison to the SFA results. We follow Banker and Natarajan (2004) and estimate technical cost efficiencies using aggregate cost variables. We employ this specification due to the lack of good quality disaggregated data. Denote by $Y = (y_1, \cdots, y_n)$ the production matrix of n banks. Let $C = (c_1, \ldots, c_n)$ denote the vector of total costs, where c_j denotes the total cost of production of bank j and let $V = (v_1, \cdots, v_n)$ denotes the input cost matrix. Here v_{ij}, is the expenditure of bank j in input i (the ith component of vector v_j).

We compute the cost efficiency of bank j as

$$r_j = \text{argmin}\left\{r; Y\theta \geq y_j, C\theta \leq rc_j, \theta 1 = 1, \theta \geq 0\right\}.$$

Figure 6 presents the evolution of cost efficiency by ownership. The ranking of the different types of banks is similar to the SFA results. However, the mean efficiencies of each size-type group differ considerably. They are 0.63, 0.50, 0.61 and 0.71 for the large, medium-sized, small and micro banks, respectively.

The DEA approach has the advantage of not requiring a prior assumption on the production or cost functions. However, it is more appropriate when estimating efficiencies with output and input quantities data. In our case we seek to estimate cost and profit efficiencies having input prices data. The DEA also does not distinguish the inefficiency term from the noise component. Despite the advantages from each approach, we emphasize the similarity between the results and that, by employing the Bayesian inference, we can achieve accurate confidence intervals for the efficiency levels.

Place Figure 6 About Here

6 Conclusions

This study estimated cost and profit efficiency for the Brazilian banking system through the stochastic frontier approach, applying Bayesian methods. The purpose was to evaluate how efficiency levels have evolved in the past few years and how they are associated with characteristics of the banking institutions, namely, size, ownership, market share, non-performing loans and equity.

Inefficiency levels were modeled by exponential and gamma distributions. Average cost efficiency is found to be 0.66 while average profit is estimated to be 0.75. These values are consistent with the literature on emerging economies, although cost efficiency is lower than the international average of 0.75, reported by Berger and Humphrey (1997), which includes developed countries. The cost efficiency measure did not show great variance over time, except for the unstable period of 2002, during the Brazilian presidential elections. A significant fall in cost efficiency can be observed in this period.

The profit model results report an outperformance of large banks. This may explain the recent wave of mergers and acquisitions, realized not only for scale gains, but also to achieve specific markets, competing for profitable client portfolios.

The efficiency evaluation in Brazil has important implications for financial regulation and management. After several interventions in problematic banks in the 1990s, under the PROER, and the new improved regulation conditions, foreign and large banks showed the highest improvement in efficiency, a reflection of their effort to reduce costs through technological development. The cost efficiency of public banks followed a rising path, which may impact on profit gains in the long term. For policymakers, the results stress the benefits from foreign entry and the need to foster competition in the banking sector, as it still presents considerable inefficiency levels. The potential gains from further reforms involve not only banking efficiency, but also a better allocation of credit and, consequently, economic growth [9].

Concerning bank managers, the analysis reports features of the most efficient institutions. Results suggest that banks with higher equity level are associated with increased profit efficiency. According to (Isik and Hassan (2003)), outperforming banks tend to present higher capitalization, measured by equity over assets. This is in conformity with the moral hazard theory, which argues that when a larger ratio of equity capital is at risk, managers have more incentives to monitor bank efficiency. That way, there are opportunities for efficiency gains in most of the banking institutions analyzed.

Bayesian methods have proved useful in efficiency analysis. They provide assessment of confidence intervals, allow incorporating prior information and making inferences on the actual efficiencies of each firm. While we estimate separate frontiers for different bank size groups, Greene (2005) develops an alternative approach to deal with heterogeneity in the banking system that might provide an interesting comparison to the present results. Future research could also focus on different aspects of emerging banking systems such as international comparisons.

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Table 1: Summary of the literature on banking efficiency in Brazil

Author (year)	Model	Inputs	Outputs	Environmental variables	Mean efficiency
Becker et al. (2003)	DEA	Number of branches, operating expenses and IT investments	Financial intermediation, service and international operation revenues	Ownership	0.646
Chabalgoity et al. (2007)	DEA	Funds, physical capital and operating expenses	Loans, service revenues and investments	Ownership	0.703
Périco et al. (2008)	DEA	Equity, total assets and deposits	Net profits		0.841
Tabak et al. (2005)	DEA	Employees, fixed assets and funds	Intrinsic Value Added	Size, ownership and specialization	0.450
Silva and Neto (2002)	SFA	Labor, physical capital and deposits	Investments and loans	Assets, equity, NPL and ownership	0.860
Ruiz et al. (2008)	SFA	Capital and deposits	Liquid assets, deposits and investments	Ownership, loan provision, market share, equity and exchange expenses	0.830
Souza et al. (2006)	DEA	Labor, capital and funds	Loans, deposits and investments	NPL, ownership, size and specialization	foreign: 0.534 domestic: 0.610
Souza et al. (2008)	FDH*	Labor, physical capital and funds	Total assets	NPL, ownership, size and specialization	
Staub et al. (2010)	DEA	Labor, capital and funds	Loans, deposits and investments	NPL, ownership, size, specialization and equity ratio	0.401 to 0.495

*Free disposal hull

Table 2: Number of banks

	Total	Large	Medium	Small	Micro	Public	Private	Foreign
2000	115	18	17	41	39	17	65	33
2001	111	15	15	48	33	16	62	33
2002	104	12	15	45	32	13	58	33
2003	101	12	16	43	30	13	55	33
2004	94	8	13	44	29	12	54	28
2005	93	10	13	39	31	13	54	26
2006	95	9	12	37	37	12	55	28
2007	94	9	10	39	36	12	52	30

This table presents the evolution in the number of banks in the sample during the 2000-2007 period, by size and ownership. Source: Banco Central do Brasil.

Table 3: Descriptive statistics

Variable	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
Cost	0.578	5.320	22.721	597.322	22456917
Profit	166.209	1984.971	24.876	677.410	28905454
Deposits	1.644	5.295	17.036	356.598	7976436
Investments	0.267	2.800	20.017	432.970	11786898
Price of labor	0.682	8.778	18.341	371.414	8664246
Price of funds	0.006	0.013	8.209	96.487	569471
Market share	0.011	0.032	4.647	27.207	42499
NPL	0.019	0.035	6.000	57.446	196476
Equity/Assets	0.220	0.181	2.142	8.073	2787

This table presents the descriptive statistics of outputs and input prices for efficiency estimation. Outputs are normalized by the amount of loans and input prices are normalized by the price of capital. Costs and profits are normalized by both measures. Within a total of 1517 observations, 202 refer to public banks, 851 to private banks and 464 to foreign banks. There are 175 observations from large banks, 210 from medium-sized banks, 630 from small banks and 502 from microbanks.

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Table 4: Statistics of the cost model with gamma inefficiency distribution

Parameter	Large	Medium	Small	Micro	Whole sample
β_0	1.630*	1.586*	0.825*	1.335*	1.658*
	[0.977 , 2.162]	[1.080 , 2.034]	[0.477 , 1.163]	[0.911 , 1.792]	[1.445 , 1.869]
β_1	0.647*	0.514*	0.061	0.207*	0.211*
	[0.446 , 0.846]	[0.306 , 0.696]	[-0.012 , 0.134]	[0.125 , 0.297]	[0.163 , 0.259]
β_2	0.089	0.390*	0.810*	0.336*	0.476*
	[-0.309 , 0.511]	[0.061 , 0.756]	[0.680 , 0.939]	[0.142 , 0.532]	[0.384 , 0.566]
δ_1	-0.187	0.112	0.562*	0.115	0.271*
	[-0.539 , 0.157]	[-0.156 , 0.394]	[0.441 , 0.682]	[-0.055 , 0.273]	[0.186 , 0.355]
δ_2	0.496*	0.446*	0.161*	0.456*	0.483*
	[0.176 , 0.791]	[0.310 , 0.569]	[0.051 , 0.269]	[0.299 , 0.631]	[0.415 , 0.552]
β_{11}	0.162*	0.157*	0.063*	0.077*	0.090*
	[0.123 , 0.200]	[0.127 , 0.183]	[0.053 , 0.074]	[0.063 , 0.090]	[0.083 , 0.098]
β_{12}	-0.399*	-0.215*	-0.021	-0.201*	-0.166*
	[-0.513 , -0.281]	[-0.318 , -0.107]	[-0.069 , 0.027]	[-0.250 , -0.151]	[-0.196 , -0.135]
β_{22}	0.312*	0.094	0.037	0.231*	0.156*
	[0.147 , 0.485]	[-0.028 , 0.209]	[-0.015 , 0.088]	[0.181 , 0.279]	[0.114 , 0.194]
δ_{11}	0.230*	0.089	0.010	0.139*	0.100*
	[0.056 , 0.396]	[-0.051 , 0.224]	[-0.030 , 0.050]	[0.106 , 0.168]	[0.070 , 0.128]
δ_{12}	-0.305*	-0.099	0.021	-0.203*	-0.093*
	[-0.479 , -0.119]	[-0.205 , 0.018]	[-0.016 , 0.058]	[-0.244 , -0.163]	[-0.122 , -0.063]
δ_{22}	0.102*	0.089*	0.032*	0.096*	0.089*
	[0.012 , 0.185]	[0.057 , 0.117]	[0.013 , 0.050]	[0.066 , 0.130]	[0.076 , 0.101]
ω_{11}	-0.147*	-0.078*	-0.013	-0.100*	-0.082*
	[-0.203 , -0.088]	[-0.129 , -0.023]	[-0.034 , 0.008]	[-0.119 , -0.080]	[-0.096 , -0.067]
ω_{12}	0.067*	-0.019	-0.054*	0.014	-0.013*
	[0.022 , 0.107]	[-0.049 , 0.009]	[-0.068 , -0.040]	[-0.002 , 0.029]	[-0.022 , -0.003]
ω_{21}	0.299*	0.062	0.007	0.181*	0.113*
	[0.145 , 0.464]	[-0.046 , 0.164]	[-0.035 , 0.048]	[0.157 , 0.202]	[0.080 , 0.143]
ω_{22}	-0.145*	-0.001	0.025*	-0.097*	-0.043*
	[-0.259 , -0.030]	[-0.046 , 0.048]	[0.002 , 0.047]	[-0.123 , -0.071]	[-0.060 , -0.025]
α_1	0.301*	-0.038	-0.071	-0.004	-0.005
	[0.098 , 0.511]	[-0.289 , 0.226]	[-0.269 , 0.132]	[-0.257 , 0.242]	[-0.019 , 0.009]
α_2	0.187*	0.123	0.139	-0.035	0.000
	[0.012 , 0.382]	[-0.167 , 0.417]	[-0.082 , 0.362]	[-0.321 , 0.247]	[-0.001 , 0.002]
γ_1	0.678	0.046	0.211	-0.082	0.557
	[-0.923 , 1.929]	[-2.718 , 1.818]	[-2.413 , 1.848]	[-3.112 , 1.801]	[-1.052 , 1.889]
γ_2	0.364	-0.706	-0.358	-0.751	-1.568*
	[-1.994 , 1.936]	[-3.003 , 1.095]	[-2.146 , 1.139]	[-2.288 , 0.619]	[-2.815 , -0.368]
γ_3	-1.197	-1.993*	-2.265*	-1.036*	-1.570*
	[-3.619 , 0.857]	[-3.529 , -0.533]	[-2.825 , -1.688]	[-1.367 , -0.710]	[-1.876 , -1.266]
γ_4	2.815*	1.902*	2.080*	0.961*	0.969*
	[2.467 , 3.157]	[1.559 , 2.257]	[1.829 , 2.340]	[0.599 , 1.305]	[0.300 , 1.672]
γ_5	2.622*	2.534*	2.404*	1.623*	1.310*
	[2.259 , 2.995]	[2.243 , 2.830]	[2.203 , 2.619]	[1.479 , 1.769]	[0.652 , 2.001]
γ_6	1.436*	1.433*	1.596*	1.098*	0.513
	[1.103 , 1.785]	[1.164 , 1.696]	[1.429 , 1.766]	[0.851 , 1.347]	[-0.150 , 1.217]
σ^2	0.001*	0.002*	0.012*	0.003*	0.026*
	[0.000 , 0.003]	[0.000 , 0.005]	[0.007 , 0.020]	[0.000 , 0.008]	[0.019 , 0.033]

This table presents the posterior mean and 95% confidence region for parameters of the cost model and of the inefficiency covariates from the model with gamma distribution. They were computed based on 250,000 iterations generated from the Gibbs sampling algorithm. * statistically significant.

Table 5: Statistics of the profit model with gamma inefficiency distribution

Parameter	Large	Medium	Small	Micro	Whole sample
β_0	1.623*	5.637*	7.733*	10.400*	11.370*
	[1.058 , 2.238]	[4.787 , 6.505]	[7.002 , 8.471]	[9.487 , 11.320]	[10.790 , 11.950]
β_1	-0.254*	0.358*	0.309*	-0.140	-0.022
	[-0.463 , -0.045]	[0.162 , 0.549]	[0.186 , 0.430]	[-0.331 , 0.054]	[-0.134 , 0.091]
β_2	1.354*	1.507*	0.992*	0.538*	0.530*
	[0.880 , 1.823]	[1.112 , 1.911]	[0.747 , 1.238]	[0.216 , 0.867]	[0.311 , 0.743]
δ_1	0.829*	1.046*	1.275*	0.483*	0.779*
	[0.439 , 1.217]	[0.670 , 1.431]	[1.034 , 1.514]	[0.202 , 0.764]	[0.588 , 0.971]
δ_2	-0.013	0.394*	0.469*	1.239*	1.564*
	[-0.290 , 0.266]	[0.160 , 0.632]	[0.240 , 0.699]	[0.903 , 1.579]	[1.369 , 1.759]
β_{11}	-0.026	0.076*	0.062*	-0.055*	-0.003
	[-0.068 , 0.017]	[0.047 , 0.106]	[0.043 , 0.081]	[-0.092 , -0.017]	[-0.024 , 0.017]
β_{12}	0.237*	0.010	-0.080*	0.089	0.099*
	[0.102 , 0.372]	[-0.088 , 0.103]	[-0.149 , -0.015]	[-0.001 , 0.180]	[0.042 , 0.155]
β_{22}	0.121	0.110	0.208*	0.445*	0.340*
	[-0.096 , 0.343]	[-0.017 , 0.243]	[0.125 , 0.291]	[0.359 , 0.532]	[0.282 , 0.399]
δ_{11}	0.136	0.033	0.227*	0.177*	0.188*
	[-0.036 , 0.322]	[-0.099 , 0.172]	[0.166 , 0.288]	[0.129 , 0.224]	[0.155 , 0.221]
δ_{12}	0.004	0.170*	0.006	-0.299*	-0.117*
	[-0.218 , 0.209]	[0.034 , 0.301]	[-0.072 , 0.084]	[-0.383 , -0.214]	[-0.164 , -0.070]
δ_{22}	0.030	0.001	0.027	0.197*	0.207*
	[-0.061 , 0.123]	[-0.044 , 0.045]	[-0.013 , 0.068]	[0.133 , 0.264]	[0.171 , 0.243]
ω_{11}	0.036	0.009	-0.023	0.038	0.024
	[-0.023 , 0.096]	[-0.041 , 0.058]	[-0.054 , 0.007]	[-0.006 , 0.080]	[-0.001 , 0.049]
ω_{12}	-0.054*	-0.007	0.012	0.010	-0.016
	[-0.092 , -0.015]	[-0.041 , 0.027]	[-0.011 , 0.035]	[-0.032 , 0.051]	[-0.035 , 0.003]
ω_{21}	0.126	0.061	0.217*	0.251*	0.246*
	[-0.072 , 0.334]	[-0.050 , 0.175]	[0.154 , 0.282]	[0.196 , 0.306]	[0.208 , 0.283]
ω_{22}	0.030	0.128*	-0.016	-0.210*	-0.144*
	[-0.117 , 0.172]	[0.067 , 0.187]	[-0.060 , 0.029]	[-0.262 , -0.158]	[-0.174 , -0.114]
α_1	-0.146	0.105	0.196	0.704	-0.092*
	[-0.427 , 0.140]	[-0.328 , 0.549]	[-0.322 , 0.698]	[-0.215 , 1.628]	[-0.144 , -0.040]
α_2	-0.174	-0.514*	0.212	0.357	0.008*
	[-0.437 , 0.092]	[-0.996 , -0.036]	[-0.379 , 0.807]	[-0.649 , 1.359]	[0.002 , 0.014]
γ_1	0.593	-0.608	-0.422	-0.157	-0.107
	[-1.120 , 1.923]	[-4.389 , 1.620]	[-4.031 , 1.671]	[-3.317 , 1.747]	[-1.843 , 1.404]
γ_2	0.178	0.470	-0.707	-0.160	-0.820
	[-2.456 , 1.872]	[-1.553 , 1.912]	[-3.510 , 1.403]	[-2.967 , 1.663]	[-2.889 , 1.021]
γ_3	1.327	1.720*	1.622*	2.419*	0.868*
	[-0.037 , 2.397]	[0.705 , 2.583]	[0.185 , 2.532]	[1.766 , 2.997]	[0.118 , 1.609]
γ_4	2.276*	1.239*	1.574*	0.354	1.178*
	[1.856 , 2.701]	[0.892 , 1.615]	[1.139 , 2.102]	[-0.263 , 1.110]	[0.501 , 1.828]
γ_5	2.469*	1.901*	1.894*	0.850*	1.451*
	[2.056 , 2.893]	[1.519 , 2.337]	[1.501 , 2.366]	[0.500 , 1.255]	[0.790 , 2.096]
γ_6	2.752*	1.744*	1.940*	0.570*	1.588*
	[2.369 , 3.148]	[1.410 , 2.126]	[1.540 , 2.400]	[0.070 , 1.186]	[0.913 , 2.237]
σ^2	0.012*	0.036*	0.286*	0.679*	0.667*
	[0.008 , 0.016]	[0.021 , 0.055]	[0.249 , 0.325]	[0.583 , 0.783]	[0.607 , 0.729]

This table presents the posterior mean and 95% confidence region for parameters of the profit model and of the inefficiency covariates from the model with gamma distribution. They were computed based on 250,000 iterations generated from the Gibbs sampling algorithm. * statistically significant.

Table 6: Efficiencies from the main and alternative models

		Cost				Profit			
Model	Ownership	Large	Medium	Small	Micro	Large	Medium	Small	Micro
Main	Public	0.901	0.702	0.721	0.426	0.848	0.649	0.729	0.492
	Private	0.867	0.823	0.770	0.621	0.880	0.799	0.801	0.675
	Foreign	0.619	0.579	0.587	0.352	0.907	0.773	0.809	0.736
	Total	0.783	0.694	0.703	0.557	0.882	0.755	0.793	0.681
Exponential	Public	0.931	0.725	0.817	0.515	0.907	0.736	0.774	0.660
	Private	0.911	0.878	0.858	0.708	0.927	0.880	0.832	0.802
	Foreign	0.658	0.633	0.679	0.424	0.939	0.848	0.855	0.698
	Total	0.822	0.742	0.794	0.640	0.926	0.835	0.831	0.774
Intermediation	Public	0.576	0.522	0.416	0.397	0.875	0.669	0.819	0.440
	Private	0.847	0.772	0.740	0.548	0.842	0.812	0.789	0.599
	Foreign	0.604	0.608	0.675	0.389	0.899	0.785	0.681	0.698
	Total	0.687	0.648	0.671	0.509	0.871	0.769	0.758	0.614
Time trends	Public	0.910	0.704	0.733	0.437	0.859	0.628	0.725	0.529
	Private	0.875	0.823	0.779	0.623	0.897	0.832	0.801	0.683
	Foreign	0.623	0.585	0.597	0.350	0.903	0.753	0.799	0.753
	Total	0.790	0.697	0.713	0.558	0.889	0.754	0.789	0.693

This table presents the mean efficiencies from the main model and from the models with the following modifications in specification: exponential inefficiency distribution, intermediation approach (does not include deposits as an output) and linear and quadratic time trends included in the frontier.

Table 7: DIC values

Model	Distribution	Large	Medium	Small	Micro
cost	exponential	-457.469	-540.673	-215.761	-490.694
	gamma	-542.879	-543.792	-548.312	-1216.09
profit	exponential	-203.737	31.162	1055.66	1309.53
	gamma	-205.932	8.278	1081.26	1314.04

This table presents the DIC values as a model comparison criterion.

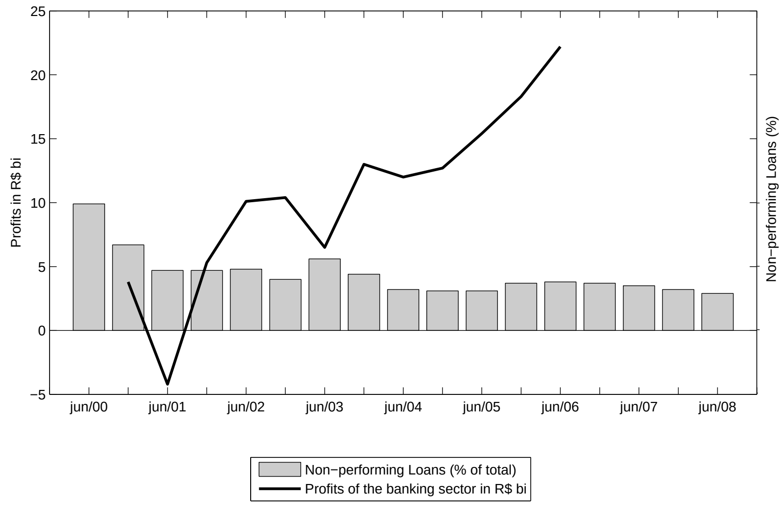

Figure 1: This figure shows the evolution of average NPL and profits of the Brazilian banking sector for the period from 2000 to 2008. Source: Banco Central do Brasil.

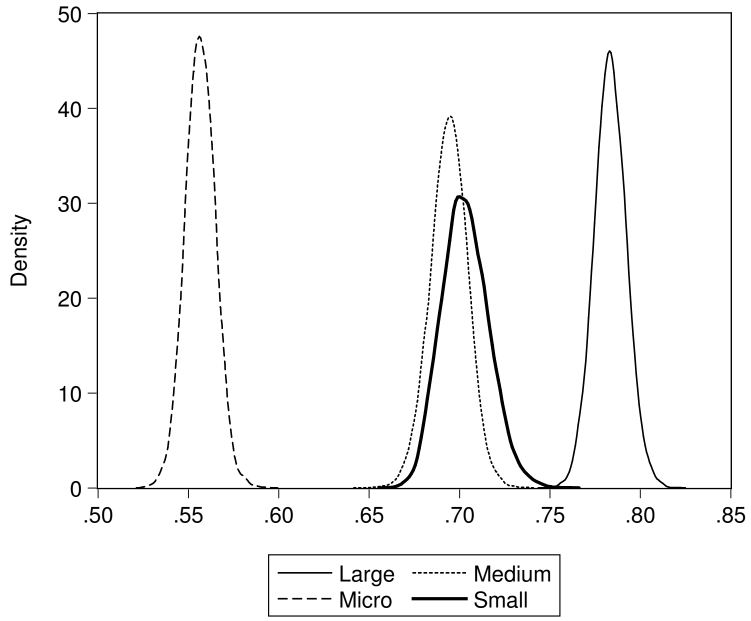

Figure 2: This figure shows the kernel densities of cost efficiency for large, medium-sized and small banks and microbanks. Model with gamma inefficiency distribution.

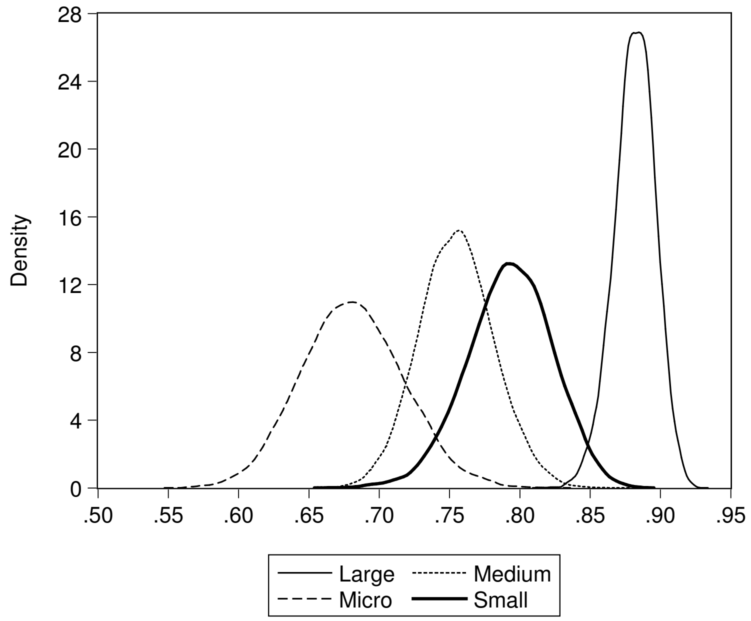

Figure 3: This figure shows the kernel densities of profit efficiency for large, medium-sized and small banks and microbanks. Model with gamma inefficiency distribution.

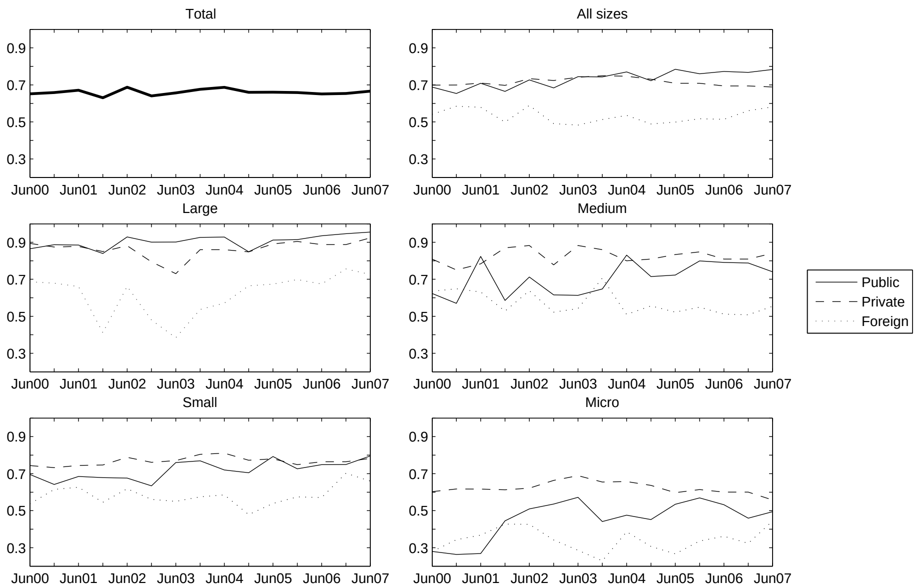

Figure 4: Evolution of cost efficiencies over time by ownership type. Model with gamma inefficiency distribution.

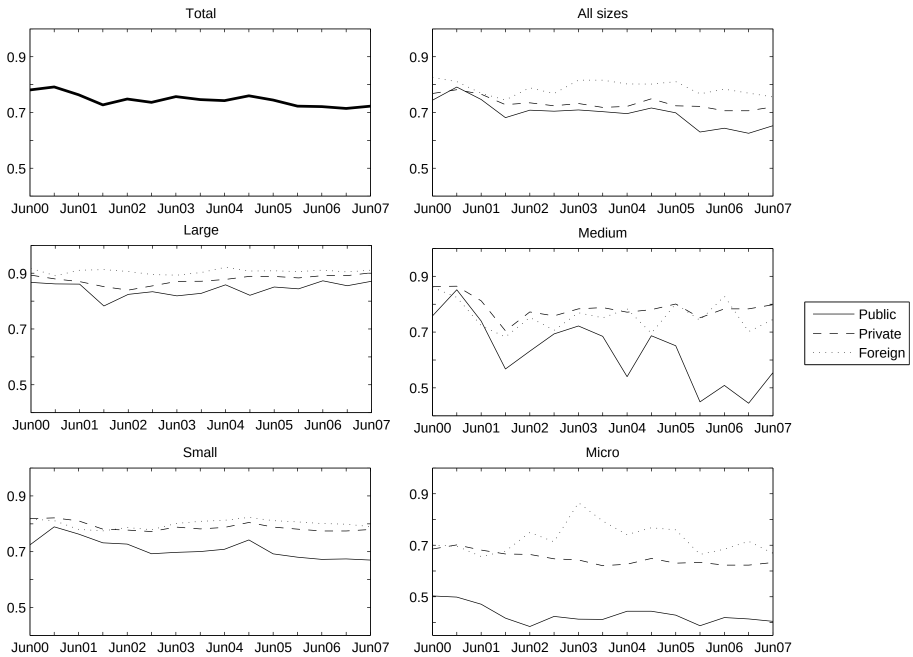

Figure 5: Evolution of profit efficiencies over time by ownership type. Model with gamma inefficiency distribution.

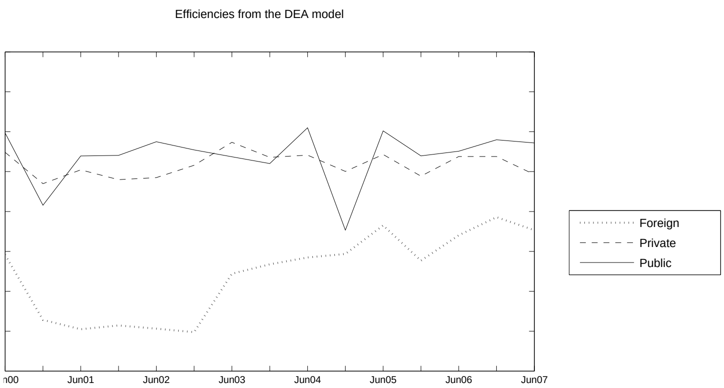

Figure 6: Evolution of cost efficiencies over time by ownership type, estimated by Data Envelopment Analysis.

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