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Evolution of Bank Efficiency in Brazil: A DEA Approach

Roberta B. Staub* Geraldo Souza †
Benjamin M. Tabak ‡

Abstract

This paper investigates cost, technical and allocative efficiency for Brazilian banks in the recent period (2000-2007). The empirical results imply that non-performing loans is an important indicator of efficiency level, as well as market share. Evidence is in favor of the home field advantage hypothesis since foreign banks are less cost efficient than their domestic counterparts. Furthermore, the agency theory hypothesis is not accepted as state-owned banks are more cost efficient than private banks. This could be due to: 1. the number of state-owned banks was reduced in the last years and only more efficient banks are left in the Brazilian banking system, and 2.state-owned banks hold very large public servants payroll accounts and therefore have an important advantage. Further research could exploit profit efficiency as private banks may have higher profit efficiency.
Keywords: DEA, Bank Efficiency, Emerging Markets, Bank Consolidation, Ownership.

JEL: G21, G34.

*Banco Central do Brasil
†Universidade de Brasilia and Embrapa
‡Banco Central do Brasil and Universidade Catolica de Brasilia. E-mail: benjamin.tabak@bcb.gov.br; benjamin@ucb.br.

1 Introduction

In the past decade the Brazilian banking industry underwent major transformations, with the entry of foreign banks, substantial mergers and acquisitions (M&A) activity and the privatization of state-owned banks[1]. This paper studies the bank efficiency for the Brazilian banking system for the recent period and seeks to address whether there are differences in efficiency due to ownership structure, assessing the relative efficiency of foreign, public and private domestic banks, among other aspects.

The debate on the role of public and foreign banks in Brazil has been intensified in recent years, as the share of public banks is still high (more than one third of banking assets), while the participation of foreign banks have been increasing. Financial markets in Brazil were opened up in the early 1990´s to foreign participation in order to enhance competition and efficiency. Fachada (2008), using accounting framework and panel data estimation, showed for the second half of the 1990's that greater foreign banking presence contributed to reduce overhead costs of domestic banks, but not their profitability.

In 2006 Bank of America sold all Bank Boston's Brazilian assets to Bank Itau (third largest bank by assets after the deal), in exchange for Itau shares. Therefore, Bank of America has changed its participation form in the banking system. It had a small portion in the market and now it has a significant investment in one of the leaders in Brazilian banking system. This suggests that foreign banks may have difficulties in increasing its participation in the Brazilian banking system and may be relatively inefficient. This is an important question that will be addressed in this paper.

The Brazilian experience is interesting due to its importance in Latin America (largest banking system) and also due to the weight of state-owned and foreign banks. Besides, the corporate bond market is not well developed, which reinforces the relevance of the banking system.

In emerging markets, banks play a major role in financial development[2]. This is especially true since stock and corporate bond markets are usually underdeveloped. Moreover, the development of the banking system and the increase of its efficiency are related to higher economic growth. Therefore, understanding the determinants of bank efficiency is helpful for the design of

[1]Mainly in the recent period, large banks have been buying small specialized banks, that operate on a more local basis and niche markets.

[2]See Levine et al. (2000).

better management strategies and public policies.

We contribute to the banking literature by examining the cost, allocative and technical efficiency of Brazilian banking system in the recent period (2000-2007). The research questions addressed in this paper are: Are foreign banks more efficient than domestic banks ? Has bank efficiency increased over the years ? What are the main sources of inefficiency ? Do banks that engage in different activities perform differently in terms of cost efficiency ? Are large banks more efficient ? Are private banks more efficient than public banks ? These findings may provide some important insights to both policy makers and bank managers.

The remainder of the paper is structured as follows. Next section discusses the literature review for banking efficiencies studies. In section 3 we expose the definitions of inputs, outputs and covariates, while section 4 introduces the methodology. Section 5 put forward some data issues, the sample used in the paper and the definition of outputs and inputs, while section 6 presents empirical results. Finally, section 7 provides some final considerations.

2 Literature Review

There is a vast literature on bank efficiency discussing different aspects such as the role of ownership, bank size and differences in the regulatory framework and its impacts on banking efficiency.

Kwan (2006) uses the stochastic frontier approach to study the cost efficiency of banks in Hong Kong. The results show a quite large, but declining, inefficiency and a positive correlation between bank size and inefficiency, probably due to different portfolio compositions. Ariff and Can (2007) estimate cost and profit efficiency of Chinese banks by the non-parametric DEA approach and the second-stage Tobit regression. They find that private and medium-sized banks are the most efficient. Drake et al. (2006) use similar methodology for the Honk Kong banking system and find a strong positive size-efficiency relationship. Park and Weber (2006) study bank inefficiency and productivity change of the Korean banking sector with the financial liberalization and the Asian financial crisis. By using the directional technology distance function, they find that technical progress has offset the declines in industry efficiency and that the reforms generated productivity growth. When estimating standard stochastic frontiers, Bos and Kool (2006) use exogenous input prices. They analyze the impact of local market conditions on

cost and profit efficiency with data from banks in Netherlands and find that decentralization benefits cost and profit efficiencies. Maudos and Guevara (2007) analyze the consequences of market power for the efficient management of banks with data from the EU-15 countries. They find a positive relationship between them, but the welfare gains with increased competition are higher than the loss in cost efficiency.

In the Brazilian case the recent wave of M&A has shown a number of large banks buying small and very small banks that are highly specialized, which suggests that these large banks may be trying to increase their efficiency in these niche markets (*niche markets hypothesis*). Unfortunately, we do not have a list of all M&A activity in the Brazilian banking system, and therefore to test whether the niche markets hypothesis is plausible we have to evaluate the relative efficiency of banks of different sizes[3].

Regarding the effect of foreign ownership on bank efficiency, Lensink et al. (2007) use stochastic frontier analysis in 105 countries. They find a negative effect that becomes less pronounced with better home and host countries regulatory environment and smaller institutional differences between them. With similar approach, Sensarma (2006) also finds lower efficiency levels for foreign banks in India during the deregulation period. With different results, Havrylchyk (2006) and Sturm and Williams (2004) employ the DEA on the Polish and Australian banking sectors, respectively, finding that foreign banks are more efficient. Mamatzakis et al. (2007) also find lower levels of inefficiency for foreign ownership banks among the ten new European Union member states. In their previous work (Staikouras et al., 2007), similar findings were achieved when analyzing six South Eastern European countries, but significant inefficiency differences were observed among them. Sengupta (2007) investigates how information asymmetries affects foreign entry and lending behavior in credit markets by modeling competition between entrant and incumbent banks. He supports that a better legal environment may help overcome informational disadvantages.

It is not clear whether foreign, public or domestic banks would be more efficient and the results depend on a variety of factors. Garcia-Cestosa and Surroca (2007) show that different bank types may differ in their goals. For example, public banks may favor contributing to regional development instead of focusing only on profit making. Sathye (2003) shows that in the

[3]For a discussion on M&A activity and bank efficiency see Amel et al. (2004), Koetter et al. (2007), Rezitis (2007), and Bos and Schmidel (2007).

case of India public banks are more efficient than private domestic banks. Overall, the results in the literature provide mixed evidence.

The evaluation of the impact of banking system reforms has also been subject of extensive research[4]. Beck et al. (2005) analyze the reform of state banks in Brazil, evaluating how the choice among privatization, federalization and restructuring was made and assessing the impact of it on bank performance. They find positive effects of privatization, but not for the restructuring process. Baer and Nazmi (2000) examine the crises that emerged with the end of inflation in Brazil and the implications of the newly emerging bank structure. They conclude that its banking system still remains inefficient and that competition and private sector involvement could increase efficiency.

A branch of the literature has also studied the effects of financial liberalization on bank efficiency. Leightner and Lovell (1998) find that small foreign banks had the largest improvement in performance and that the rapid growth experience in Thailand also carried risk, which should be monitored. Kraft and Tirtiroglu (1998) analyze the Croatian banking system and conclude that government must create a competitive framework, as the new private banks have not proved to be at least as efficient as the old ones. Mertens and Urga (2001) study the efficiency of commercial banks in Ukraine. They find that small banks are more efficient concerning cost, but less efficient in terms of profit and that large banks present significant scale diseconomies. Isik and Hassan (2002) estimate cost and profit efficiencies of Turkish banks and find that they decreased over time, due to diseconomies of scale. Also, private and foreign banks were found to be more efficient. Hasan and Marton (2003) find similar results concerning the Hungarian experience. These studies have found that foreign banks in developed countries exhibited lower efficiency in comparison with domestic banks.

Berger et al. (2000) develop two main hypothesis to explain differences in the performance between foreign and domestic banks, the *home field advantage hypothesis* and *the global advantage hypothesis*. According to the first, domestic institutions are generally more efficient than institutions from foreign nations due to organizational diseconomies to operating or monitoring an institution from a distance and also to differences in regulatory and su-

[4]See Yildirim and Philippatos (2007), Boubakri et al. (2005), Clarke et al. (2005a, 2005b), Fries and Taci (2005), Patti and Hardly (2005), Iannotta et al. (2007), Williams and Nguyen (2005), and Bonin et al. (2005) .

pervisory environment. Under the *global advantage hypothesis* some foreign institutions are able to overcome these disadvantages and operate more efficiently. They spread their superior managerial skills or best-practice policies and are able to lower their costs.

We analyze how ownership structure and size influences our efficiency estimates. In 1996 the Brazilian government launched the PROES (Program of Incentives to the Reduction of the State-level Public Sector in the Bank Activity) to reduce the participation of state-owned banks in the banking activity[5]. In 2001 the PROEF (Program for the Strengthening of the Federal Financial Institutions) was launched and troubled assets from state-owned banks were transferred and some of these banks received capital injections[6].

Public banks are expected to be less efficient than private banks due to agency problems. However, in Brazil there are two important considerations regarding state-owned banks. First, these banks hold very large public servants payroll accounts and therefore have an important advantage. Second, most of the bad debts from state-owned banks were written off under the PROES and PROEF. Therefore, it is not clear on whether state-owned banks would be more or less efficient than their private counterparts. Nonetheless, this is a testable hypothesis, which we denominate the *agency theory hypothesis*.

3 Definitions of inputs, outputs and covariates

We employ the intermediation approach to measure bank efficiency. Therefore, banks can be seen as primarily intermediating funds between savers and investors. In this case, funds and interest expenses they generate can be seen as a main input variable. We also employ capital (operational expenses net of personnel expenses) and labor (personnel expenses) as inputs. Therefore, banks are assumed to have three inputs: labor, capital and purchased funds.

Interest expenses may depend on the economic cycle and therefore are not totally controlled by banks. Nonetheless, banks compete in the funds market

[5] An important consideration is that these banks had severe debt problems and therefore the federal government offered financial packages to bail them out and either liquidate or privatize them.

[6] See Baer and Nazmi (2000) and Nakane and Weintraub (2005).

and decide to some extent how much they will pay for its use. Besides, within the DEA approach we compare the relative use of funds across banks.

We include deposits as outputs since it is assumed that they are proportionate to the output of depositors services provided following Berger and Humphrey (1991). Furthermore, loans and investments are important outputs to be considered in the Brazilian case. Loans and investments account for about two thirds of banking assets and are important services provided by banks.

In the DEA approach one compares the generation of outputs of each individual bank relative to its peers. Higher interest expenses imply in a relative larger utilization of purchased funds. Therefore, an efficient bank is able to use fewer inputs such as interest expenses and capital and labor expenses and produce more outputs such as deposits, loans and investments.

Technical efficiency is associated to the efficient use of inputs within the bank's technology. Therefore, if technical efficiency explains a larger part of the overall efficiency we can infer that this may be due to under-utilization or waste of inputs. In the case of utilization of funds it suggests that more efficient banks are able to produce more output with lower interest expenses. On the other hand, allocative efficiency is related to how the mix of inputs affects the production process. If a bank has a small allocative efficiency then one can argue that by changing the mix of its inputs usage (funds, capital and labor) it could increase its output.

The banking literature has provided evidence that bank size may be important in explaining bank efficiency. Therefore, we test whether the variable size can help explaining efficiency scores. To include size as an explanatory variable in the panel data efficiency specification we employ the classification provided by the Central Bank of Brazil. All banks that add up to 75% of total banking assets are classified as large (9 banks). Medium sized banks are the banks that add up from 75%-90% of total assets (10 banks). Banks that add from 90-99% of bank assets are classified as small (39 banks). The remainders of banks are classified as micro (36 banks).

Size is an important variable as it may reflect important advantages that specific banks have in the banking sector. Small or micro banks, for example, may have costs advantages to operate in niche markets. Furthermore, the recent wave of M&A acquisitions in which large banks buy micro banks could be an attempt to increase large banks efficiency. This is also true for the market share variable.

We employ non-performing loans and equity over assets ratio as covari-

ates. Non-performing loans is an important covariate in order to control for credit risk. The equity over assets ratio can help testing the moral hazard hypothesis that suggests that banks with higher capital should be more cautious and therefore would have higher efficiency rankings. The other covariate of interest is ownership. Ownership is important due to cultural differences that reflect in the management and to spillovers that foreign banks may receive from their headquarters abroad. Furthermore, foreign banks may have borrowing facilities in international markets, which may imply in lower borrowing costs.

The bank classifications are presented below. Using a panel data model we test whether bank classification is a significant variable in the explanation of bank efficiency. Empirical results suggest that bank classifications are important in the determination of bank efficiency. According to its activity, banks are classified as: Complex, Credit, Treasury and Business, Retail and others [7].

Ownership is defined as: Foreign, Private Domestic, Foreign Participation and State-owned banks [8]. Dummy variables were included for the categorical variables and also to capture the time effects.

4 Methodology

Basically two approaches are available in the literature to assess bank efficiency. The stochastic efficiency frontier analysis and the deterministic frontier analysis. In the context of deterministic frontiers Data Envelopment Analysis (DEA) is by far the most used technique.

With multiple outputs, for the stochastic frontier, typically one specifies a parametric log cost function $C(\ln p, \ln y, \theta)$ dependent on log factor input

[7] The Central Bank of Brazil classifies banks as complex when they enter in different activities such as credit operations, business and treasury. Banks are classified as credit and treasury and business when they perform predominantly these operations, respectively. Banks are classified as retail when they have a large network of branches and a large number of customers.

[8] Domestic banks with foreign participation include banks in which foreign investors hold a participation equal to or greater than 10% and lower than 50% in total equity, whereas foreign banks include banks in which investors hold more than 50% of total equity. State-owned banks are defined as those in which the Brazilian government holds more than 50% of total equity.

prices $\ln p$ and log output levels $\ln y$ and postulates the model

$$\ln C_{it} = C(\ln p_{it}, \ln y_{it}, \theta) + v_{it} + u_{it} i = 1, \ldots, N \;\; t = 1, \ldots, T$$

for cost data C_{it} for a panel of N banks and T time periods. In this formulation the stochastic components v_{it} and u_{it} represent random errors and inefficiency errors respectively. Typical parametric log cost families are provided by the Translog form (Coelli et al, 2005), the CES (Gallant, 1982), and the Fourier Flexible Form (Gallant, 1982). The latter endows the analysis with nonparamentric properties. The random errors v_{it} are assumed to be uncorrelated across time and panel, and normally distributed with mean zero and variance $\sigma^2 > 0$. A flexible family of distributions to model the u_{it} (Khumbhakar and Lovell, 2000) is provided by truncation of the normal. In this context one postulates $u_{it} = z'_{it}\delta + w_{it}$ where z_{it} is a vector of bank specific inefficiency variables (covariates), δ is a vector of unknown coefficients of the firm specific inefficiency variables and w_{it} is the truncation at $-z'_{it}\delta$ of the normal with mean zero and variance σ_u^2.

We see three problems with this approach in the present instance. The first relates to the specification of the response function. Models more general than the Cobb-Douglas, as the Translog, pose statistical complications to estimate scale efficiencies. The alternative Fourier Flexible Form is essentially nonparametric but it is not straight forward to impose curvature restrictions on the cost function neither to find an appropriate order for the Fourier series involved in the process. Secondly is difficult to justify the assumption of independence through time. Thirdly, in the context of multiple outputs, it is necessary to obtain data on factor input prices. In our application we have only poor proxies of these quantities.

Data Envelopment Analysis on the other hand is a technique easy to deal with multiple outputs and allows the assessment of cost, technical and scale efficiencies without direct knowledge of factor input prices. This is the main reason for its use here. Banker and Natarajan (2004) shows how these measurements can be computed only using total expenditures data. Data Envelopment Analysis, in the context of the study of the influence of contextual variables, has the drawback of relying on two stage statistical procedures, where efficiencies computed in the first stage are modeled via a regression model in the second stage. The procedure poses technical problems since efficiency measurements will be correlated. If the contextual variables are exogenous to the production process, Simmar and Wilson (2007), Souza and

Staub (2007) and Banker and Natarajan (2008) show that the two stage analysis is viable and, under certain error conditions, may even capture non-parametric stochastic efficiency results. See Banker and Natarajan (2008). Motivated by these recent results in DEA we consider here an extension to panel data.

In this article we deal with three panel data models. Estimation for all three is available in Stata. The first is dynamic in the DEA response and follows Arelano and Bond (1991) and Blundel and Bond (1998). The second is autoregressive in the error structure and follows Parks (1967) and Baltagi and Wu (1999). The third is non dynamic and assumes a Tobit response to deal with truncation in the DEA response.

The general form of non dynamic panel data models used here models a response y as a function of covariates x_k as

$$y_{it} = \sum_{k=1}^{K} x_{itk} + u_{it}$$

where u_{it} include random errors and stochastic or fixed specific panel effects. For example an autoregressive first order specification without random effects assumes $u_{it} = \rho u_{it-1} + \epsilon_{it}$ where ϵ_{it} is the white noise in t and uncorrelated in i. We assume a common correlation coefficient across panel. This is a particular case of Parks (1967).

The formulation of Baltagi and Wu (1999) allows for bank and random effects, i.e, $u_{it} = \nu_i + \eta_t + \zeta_{it}$ where the ν_i and η_t are random panel and time effects and $\zeta_{it} = \rho\zeta_{it-1} + \epsilon_{it}$ is the first order autoregressive process. In this model $|\rho| < 1$ and ϵ_{it} is independent and identically distributed (iid) with mean 0 and variance σ^2_ϵ. If η_t are assumed to be realizations of an iid process with mean 0 and variance σ^2, then it is a random-effects model. Estimation is carried out via generalized least squares. Parks (1967) allows for correlation between panels and distinct autoregressive parameters but the panel should be balanced.

The Tobit representation assumes a similar structure as the Baltagi and Wu model with $\rho = 0$ and stochastic panel effects. The response is $y^0_{i,t}$ and $u_{it} = \nu_i + \epsilon_{i,t}$. The random effects, ν_i are assumed iid $N(0, \sigma^2)$ and $\epsilon_{i,t}$ are iid $N(0, \sigma^2_\epsilon)$ independent of the ν_i.

The responses $y^0_{i,t}$ represent the censored values of $y_{i,t}$. For an efficiency measurement in (0,1), $y_{i,t} = y^0_{i,t}$. If $y_{i,t} = 1$ then $y_{i,t} \leq y^0_{i,t}$. Estimation is via maximum likelihood.

The dynamic panel of Arelano and Bond (1991) and Blundel and Bond (1998) assumes

$$y_{it} = \sum_{j=1}^{p} \alpha_j y_{i,t-j} + \sum_{k=1}^{K} x_{itk} + u_{it}$$

where $u_{it} = \nu_i + \epsilon_{it}$, the ν_i being stochastic panel specific effects uncorrelated with ϵ_{it}. The statistical analysis for this model uses GMM and is robust to the presence of second order autocorrelation and heteroskedasticity in the random components ϵ_{it}.

Consider a production process with n production units (banks). Each unit uses variable quantities of p inputs to produce varying quantities of s different outputs y. Denote by $Y = (y_1, \cdots, y_n)$ the $s \times n$ production matrix of the n banks and by $X = (x_1, \cdots, x_n)$ the $p \times n$ input matrix. Notice that the element $y_r \geq 0$ is the $s \times 1$ output vector of bank r and x_r is the $p \times 1$ vector of inputs used by bank r to produce y_r (the condition $l \geq 0$ means that at least one component of l is strictly positive). The matrices $Y = (y_{ir})$ and $X = (x_{ir})$ must satisfy: $\sum_i l_{ir} > 0$ and $\sum_r l_{ir} > 0$ where l is x or y. In our application $p = 3$ and $s = 3$ and it will be required $x_r, y_r > 0$ (which means that all components of the input and output vectors are strictly positive).

Following Banker and Natarajan (2004) we deal with the notions of economic, technical and allocative cost efficiencies using aggregate cost variables. In this context let $C = (c_1, \ldots, c_n)$ denote the vector of total costs, where c_r denotes the total cost of production of bank r and let $V = (v_1, \cdots, v_n)$ denotes the input cost matrix. Here v_{ir}, is the expenditure of bank r in input i (the ith component of vector v_r). If a vector of input prices $g = (g_1, \cdots, g_p)$ is known one must have $v_{ir} = g_i x_{ir}$ and $c_r = \sum_{i=1}^{p} v_{ir}$.

We compute the economic (cost) efficiency of bank r as

$$\theta_r^e = \operatorname{argmin} \{\theta; Y\lambda \geq y_r, C\lambda \leq \theta c_r, \lambda 1 = 1, \lambda \geq 0\}.$$

Technical efficiency is computed as

$$\theta_r^{tec} = \operatorname{argmin} \{\theta; Y\lambda \geq y_r, V\lambda \leq \theta v_r, \lambda 1 = 1, \lambda \geq 0\}.$$

Finally, allocative efficiency is computed as the ratio

$$\theta_r^a = \frac{\theta_r^e}{\theta_r^{tec}}.$$

The efficiency measurements are computed for each bank, for each of T years generating a panel of observations $(\theta_{it}^e, \theta_{it}^{tec}, \theta_{it}^a)$ with $t = 1, \cdots, T$ and

$i = 1, \cdots, n$. We use statistical models to assess the significance of covariates (factors) on these measurements assuming independence between factors and errors. The models we use, except for the Tobit, fall in the category of dynamic panel data analysis and take into account serial correlation in the bank population. Cross-correlations between banks within times induced by DEA calculations or otherwise seem to be negligible and following Souza and Staub (2007) and Banker and Natarajan (2008) they were not modeled.

It is worth mentioning that banks that are more efficient in a specific year tend to continue efficient in the next year. This persistence effect can be modeled more properly with dynamic models.

5 Data

5.1 Overview of the Brazilian Banking System

Table 1 presents the participation of banks by ownership in main aggregates for the banking system. It is worth noticing that state-owned banks still have a large share in the banking market and therefore studies that assess relative inefficiencies of these banks are important. Furthermore, foreign banks also have a large share of the market in the period under analysis.

Place Table 1 About Here

The number of banks has been decreased over the years. A large number of small and micro banks may be an obstacle to reaching a more adequate cost structure within the banking system. Many M&A have taken place in recent years, specially with large banks acquiring small and micro banks.

Table 2 presents the evolution of the Brazilian banking system by ownership structure. The number of banks has decreased from 184 in 2000 to 140 banks in 2007. Foreign banks are defined as those in which foreign investors hold more than 50% of total equity, while banks with foreign participation are those in which foreign investors hold at least 10% but less than 50% of total equity[9].

Place Table 2 About Here

[9]The sampling period beginning in 2000 was chosen due to data constraints. The plan of accounts had some modifications and some of the variables are not available for the period before 2000 such as non-performing loans.

It is worth noticing the decrease in the number of banks with foreign participation. The number of banks have decreased due to M&A activity. Specifically, these banks were acquired by large banks within the time period under analysis.

5.2 Sampling Procedure and Data Definitions

Our data comprises Brazilian banks for the period 2000-2007. The balance sheet and income statement data are taken from the COSIF, the plan of accounts that all Brazilian financial institutions have to report to the Central Bank on a monthly basis. The sample data includes an unbalanced panel data of 127 banks, which accounts for more than 95% of banking assets in the time period under consideration.

The definition of outputs and inputs in banking studies is controversial[10]. Under the intermediation approach banks function as financial intermediaries converting and transferring financial assets between surplus units and deficit units. Each output is measured in value and not in number of transactions or accounts. There is not a unique recommendation on what should be considered the proper set of inputs and outputs[11]. Following the intermediation approach we employ three outputs, which are investments, total loans net of provision loans, and deposits and three inputs, interest expenses, operational expenses net of personnel expenses (proxy for capital expenses), and personnel expenses (labor).

In the analysis only banks that have deposits and perform credit operations and therefore perform traditional universal banking operations were included. Thus, we have excluded highly specialized banks such as automotive banks (e.g. Volkswagen)[12].

The covariates of interest for our analysis - factors likely to affect inefficiency are nonperforming loans (NPL), market share in the loans market (MS), equity, bank activity, bank size and bank ownership. The first three are continuous variates. All other covariates are categorical. According to its activity, banks are classified as: Complex, Credit, Treasury and Business,

[10]See Colwell and Davis (1992) and Berger and Humphrey (1997) for an in-depth discussion on the matter.

[11]Some studies use off-balance sheet as an output. Unfortunately, due to data constraints we are not able to consider them in the analysis.

[12]This sampling approach should help avoid spurious DEA measurements resulting from unique bank specializations.

Retail and others. The variable *size* assumes the following categories: Large, Medium, Small and Micro banks. Ownership can be: Foreign, Private Domestic, Foreign Participation and State-owned banks. Dummy variables were included for the categorical variables and also to capture the time effects.

Table 3 presents the average inputs (I1 = operational expenses net of personnel expenses, I2 = personnel expenses and I3= interest expenses) and outputs (O1=Total loans net of provision loans, O2 = Investments and O3 = deposits) for the period under analysis.

Place Table 3 About Here

6 Empirical Results

The evolution of cost, technical and allocative efficiencies for the entire sample is presented in Table 4. The average allocative and technical efficiencies (inefficiencies) are about 66.9% (51.40%) and 63.3% (57.98%), respectively, which are quite low compared to other countries (Berger and Humphrey (2000)).

Place Table 4 About Here

Allocative efficiency is always greater than technical efficiency for the period from June 2000 to December 2002. However, in the latter period, beginning in June 2003, allocative efficiency falls and is below technical efficiency in the end of 2006 and 2007. In the period from 2000 to 2002 the main source of cost inefficiency seems to be due to technical inefficiency rather than allocative inefficiency.

The higher technical inefficiency implies that the managers of Brazilian banks were able to choose the proper input mix given the prices, but were not able to utilize all factor inputs. Therefore, the cost inefficiency may be explained, at least partially, by under-utilization of inputs. In our specification banks employ purchased funds, capital and labor as inputs and produce investments, deposits and loans. Therefore, under-utilization of inputs for a specific bank could be related to large interest expenses or capital and personnel expenses and a low production if compared to its peers.

On the first semester of 2002 a reserves transfer system was put in operation as part of the new Brazilian payment system, which was set to reduce

interbank settlement risk and therefore, mitigate systemic risk. This implementation required investments on technology by Brazilian banks, which may be one of the reasons technical inefficiency is higher than allocative inefficiency within the 2000-2002 period[13].

The lowest average cost efficiency is located in December 2002, a year in which the leftist party won the elections, which generated strong depreciations of domestic currency (Real *vis-a-vis* the US dollar) and turbulence in financial markets. Although such fears were dissipated in the early 2003, with a formal commitment of the new elected president to the previous economic policy, cost efficiency fluctuates in the 40%-50% range in the time period.

In the period 2002-2007 allocative inefficiency increases, which may be due to fluctuations and instability in factor prices[14].

Table 5 presents average cost, technical and allocative efficiencies for banks according to size, activity and ownership. Regarding to size the highest efficiency of micro banks suggests that the *niche markets hypothesis* is a plausible assumption, which may help explain the recent M&A wave.

Place Table 5 About Here

When we turn the analysis to banks with different ownership structure it is striking the relative inefficiency of foreign banks. Furthermore, public banks are the most efficient. This supports the *agency hypothesis*.

6.1 Panel Data Results

The dynamic panel model specification is

$$y_{i,t} = \alpha_0 + \alpha_1 y_{i,t-1} + \alpha_2 NPL_{i,t-1} + \alpha_3 MS_{i,t} + \alpha_4 MS_{i,t-1}$$

$$+\alpha_5 Equity_{i,t-1} + \alpha_6 Activity_{i,t} + \alpha_7 Size_{i,t} + \alpha_8 Ownership_{i,t} + \alpha_9 t + u_{i,t}$$

for $i = 1, ..., n$ and $t = 1, ..., T$. As before i represents a bank and t is time. The variable y is an efficiency measurement. $NPL_{i,t-1}$ is the ratio of non-performing loans over total loans of bank i at period $t-1$, $MS_{i,t}$ is the market share of bank i in the loans market, $Equity_{i,t-1}$ is the log of

[13]These technology investments are generally built on very large scale and therefore may imply in some idle capacity, which should pressure technical efficiency down.

[14]See Minella et al. (2003) that discuss the difficulties of implementing an inflation targeting framework for stabilizing expectations under high exchange rate volatility.

bank's i equity, *Activity* is a vector of dummy variables to capture the effects of specialization, *Size* is a vector of dummy variables to capture size effects, *Ownership* is a vector of dummy variables that capture ownership effects, α_k are unknown parameters and the u_{it} are the error componets. Except for the presence of the lagged component of the response variable the dependence on the exogenous variables is the same for the other two non dynamic models specified in Section 4. For the Baltagi and Wu model, time is random.

Table 6 shows the overall fits of the three panel data models considered in the analysis. For cost and technical efficiencies the dynamic specification is best. For the allocative efficiency the Baltagi and Wu non dynamic model is superior. The statistical fits of the best models are shown in Table 7. The dynamic models pass the Sargan and autocorrelation specifications tests. The Hausman specification test cannot be computed for the Baltagi Wu model since the difference of covariance matrices between the estimators of the random and fixed models is not positive definite. For economic efficiency, the only categorical effect detected is ownership. The significance is due to the superiority of state banks. For allocative efficiency, activity, size and ownership are significant effects. Again the ownership effect is due to the superiority of state banks and the activity effect is due to complex institutions. These results fairly agree with the unadjusted descriptive statistics. For technical efficiency none of the categorical variables are statistically significant. These results are shown in Tables 8 and 9.

We see evidence in favor of the *home field advantage hypothesis* as foreign banks are less cost efficient than their domestic counterparts. The *agency theory hypothesis* is not accepted since state-owned banks are more efficient than private banks.

Non-performing loans (NPL) show a negative effect for all efficiency models. It is marginally significant for cost efficiency and highly significant for allocative efficiency. Market share is significant in all instances and equities only for allocative efficiency. The persistence effect is highly significant and positive for all models.

7 Conclusions

This study estimates cost, technical and allocative efficiencies for the Brazilian banking system in the recent period (2000-2007) using cost data and Data Envelopment Analysis. Empirical results suggest that Brazilian bank-

ing inefficiency is high if compared to other countries.

We employ three different panel data specifications to analyze the determinants of bank efficiency scores. From these models we can infer that non-performing loans is an important indicator of efficiency level, as well as market share. Evidence is in favor of the *home field advantage hypothesis* since foreign banks are less cost efficient than their domestic counterparts. Furthermore, the *agency theory hypothesis* is not accepted as state-owned banks are more cost efficient than private banks. This could be due to: 1. the number of state-owned banks was reduced in the last years and only more efficient banks are left in the Brazilian banking system, and 2.state-owned banks hold very large public servants payroll accounts and therefore have an important advantage. Further research could exploit profit efficiency as private banks may have higher profit efficiency.

Banks with foreign participation and the foreign banks are the least economic efficient compared to other ownership types, which suggests that *global advantage hypothesis* is not prevailing in Brazil. It is worth mentioning that most of the banks with foreign participation were bought by large banks (both private domestic and foreign) in the period under analysis, which suggests that higher efficiency may be the target within M&A activity.

There doesn't seem to be substantial differences in banks pursuing different activities. Size is not an important factor for economic efficiency although descriptive statistics suggests that small banks are more efficient within the time period under analysis. This would imply the *niche markets hypothesis*. However the statistical findings are not significant.

The results presented in this paper are important for the development of financial regulation and for bank managers. Further research could focus on the direct effects of the M&A on bank efficiency. They may be very useful for improving bank organizational performance. The high technical inefficiency suggests that there is still a large way to improve bank efficiency in Brazil. These results are also important for financial regulators. Non-performing loans are an important macro-prudential indicator and have been shown to be an important determinant of bank efficiency. Therefore, the evaluation of bank efficiency by itself could be an important evaluation tool for bank supervision. Furthermore, average bank efficiency varies over time and therefore it seems to be responding either to macroeconomic shocks or to changes in financial regulation. Assessing these responses is an important issue for further research.

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Table 1: Banking Participation in Main Aggregates as of December, 2000 and 2006 (in %).

	Equity	Total Assets	Deposits	Credit Operations
2000				
State-Owned	16.68	41.03	49.58	42.53
Private	83.32	58.97	50.42	57.47
Foreign	36.44	24.41	16.53	20.76
Private Domestic	33.64	27.11	28.18	28.89
Foreign Participation	13.23	7.44	5.71	7.82
Total	100	100	100	100
2006				
State-Owned	24.82	36.1	45.55	31.07
Private	75.18	63.9	54.45	68.93
Foreign	23.81	21.68	20.5	22.04
Private Domestic	44.88	36.48	28.95	40.01
Foreign Participation	6.49	5.74	5	6.87
Total	100	100	100	100

This Table shows banking participation in the main aggregates as of December, 2000 and 2006. Domestic banks with foreign participation include banks with foreign participation equal to or greater than 10% and lower than 50%.

Table 2: Evolution of the Banking System by Ownership.

	Private Domestic	Foreign	Foreign participation	Private	Public	total
Jun-00	93	56	10	159	25	184
Dec-00	89	53	9	151	23	174
Jun-01	90	53	9	152	23	175
Dec-01	86	55	8	149	20	169
Jun-02	82	53	7	142	19	161
Dec-02	78	57	4	139	19	158
Jun-03	74	55	5	134	18	152
Dec-03	75	56	3	134	18	152
Jun-04	73	53	2	128	16	144
Dec-04	72	54	2	128	16	144
Jun-05	72	53	2	127	16	143
Dec-05	71	54	2	127	16	143
Jun-06	69	52	2	123	15	138
Dec-06	70	53	1	124	15	139
Jun-07	70	54	1	125	15	140

This Table shows the number of state-owned and private (foreign and domestic) banks for the period 2000-2007. Domestic banks with foreign participation include banks in which foreign investors hold a participation equal to or greater than 10% and lower than 50% in total equity, whereas foreign banks include banks in which investors hold more than 50% of total equity.

Table 3: Average Inputs and Outputs for 2000-2007.

	O1	O2	O3	I1	I2	I3
Jun-00	2,163	125	2,494	767	105	270
Dec-00	2,483	137	2,667	925	125	324
Jun-01	2,543	144	2,929	1,583	123	438
Dec-01	2,590	158	3,257	1,794	141	406
Jun-02	2,905	175	3,720	2,030	131	605
Dec-02	3,117	153	4,316	4,285	160	777
Jun-03	3,105	149	4,306	2,962	143	511
Dec-03	3,451	187	4,732	2,096	176	492
Jun-04	3,930	212	5,314	2,282	175	454
Dec-04	4,256	225	5,708	2,275	193	443
Jun-05	4,707	249	6,137	2,535	193	510
Dec-05	5,087	270	6,589	2,681	210	579
Jun-06	5,644	318	7,072	3,345	215	589
Dec-06	6,292	343	7,502	2,458	234	554
Jun-07	7,247	375	8,123	2,928	242	594

This Table shows the average outputs and inputs for June 2000 to June 2007. Outputs: O1=Total loans net of provision loans, O2 = Investments, and O3 = deposits. Inputs: I1 = operational expenses net of personnel expenses, I2 = personnel expenses, and I3= interest rates expenses.

Table 4: Evolution of Cost (CE), Technical (TE) and Allocative Efficiencies (AE).

		CE		TE		AE	
Variable	N	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Jun-00	115	0.482	0.250	0.681	0.253	0.684	0.215
Dec-00	116	0.444	0.249	0.559	0.260	0.767	0.171
Jun-01	111	0.452	0.278	0.591	0.274	0.709	0.216
Dec-01	108	0.445	0.276	0.573	0.284	0.722	0.225
Jun-02	104	0.438	0.288	0.576	0.293	0.697	0.228
Dec-02	101	0.401	0.297	0.580	0.308	0.618	0.286
Jun-03	101	0.427	0.295	0.656	0.269	0.588	0.304
Dec-03	98	0.462	0.275	0.652	0.262	0.666	0.251
Jun-04	94	0.433	0.260	0.674	0.280	0.626	0.241
Dec-04	94	0.430	0.247	0.621	0.244	0.676	0.260
Jun-05	93	0.486	0.284	0.701	0.255	0.676	0.336
Dec-05	97	0.445	0.270	0.632	0.256	0.667	0.261
Jun-06	95	0.466	0.282	0.681	0.251	0.643	0.256
Dec-06	97	0.495	0.267	0.696	0.252	0.681	0.225
Jun-07	94	0.402	0.256	0.658	0.253	0.574	0.248
Total	1518	0.447	0.272	0.633	0.270	0.669	0.253

This Table shows the evolution of cost, technical and allocative efficiencies for the Brazilian banking sector for the period 2000-2007.

Table 5: Average Cost (CE), Technical (TE) and Allocative Efficiencies (AE) for the 2000-2007 period.

	CE	TE	AE
Large	0.38	0.65	0.58
Medium	0.29	0.47	0.52
Small	0.42	0.65	0.62
Micro	0.42	0.72	0.54
Complex	0.41	0.66	0.61
Credit	0.44	0.69	0.62
Treasury and Business	0.25	0.51	0.43
Retail	0.44	0.71	0.60
Foreign	0.28	0.55	0.45
Private Domestic	0.41	0.70	0.58
Foreign Participation	0.38	0.56	0.66
Public	0.66	0.77	0.85

This Table shows average cost, technical and allocative efficiencies for the Brazilian banking sector for the period 2000-2007 for banks classified according to size, activity and ownership, respectively.

Table 6: Mean residual sum of squares (MSS) and mean absolute residuals (MAE) for Baltagi and Wu, Tobit and Dynamic models.

Measure	Model	Cost	Technical	Allocative
MSS	Baltagi and Wu	0.043	0.050	0.035
	Tobit	0.043	0.049	0.036
	Dynamic	0.028	0.044	0.052
MAE	Baltagi and Wu	0.163	0.186	0.149
	Tobit	0.164	0.181	0.151
	Dynamic	0.130	0.175	0.181

Table 7: Best Models for Cost, Technical and Allocative efficiencies. Values in parenthesis are standard errors. Levels Others, Foreign Participation and Small were omitted from the analysis. **,* stand for statistical significance at 1% and 5%, respectively.

Parameter	Cost	Technical	Allocative
Constant	0.817	1.666	2.222**
	(0.661)	(0.893)	(0.247)
DEA_{t-1}	0.410**	0.250**	-
	(0.079)	(0.057)	-
NPL_{t-1}	-0.209	-0.251	-0.328**
	(0.112)	(0.170)	(0.127)
MS_t	0.064**	0.069**	0.047**
	(0.020)	(0.020)	(0.009)
MS_{t-1}	-0.044**	-0.040	-0.008
	(0.014)	(0.026)	(0.010)
$Equity_{t-1}$	-0.025	-0.064	-0.079**
	(0.028)	(0.038)	(0.010)
Time	0.000	0.008**	-
	(0.003)	(0.003)	-
Complex	-0.008	0.281	0.194*
	(0.148)	(0.157)	(0.078)
Credit	0.044	0.100	0.114
	(0.099)	(0.114)	(0.065)
Treasury and Business	0.023	0.074	0.078
	(0.087)	(0.103)	(0.064)
Retail	0.013	0.148	0.076
	(0.097)	(0.113)	(0.065)
Large	-0.065	0.026	0.036
	(0.043)	(0.062)	(0.037)
Micro	0.016	0.054	0.026
	(0.050)	(0.039)	(0.022)
Medium	-0.028	0.003	0.041*
	(0.030)	(0.040)	(0.020)
Foreign	-0.087	-0.007	-0.034
	(0.095)	(0.113)	(0.054)
Domestic Private	0.054	-0.032	0.142*
	(0.119)	(0.174)	(0.056)
State-owned	0.297*	0.217	0.354**
	(0.135)	(0.170)	(0.062)

Table 8: Chi-square tests for categorical effects, first and second order autocorrelation tests (Q1 and Q2, respectively), and Sargan's specification test.**,* stand for statistical significance at 1% and 5%,respectively.

Type	Cost	Technical	Allocative
χ^2-test Activity	2.12	5.12	9.91*
χ^2-test Ownership	15.27**	5.77	119.71**
χ^2-test Size	2.36	2.33	6.27
Q1	-6.62**	-7.75**	-
Q2	1.47	1.50	-
Sargan	111.45	110.52	-

Table 9: Chi-square tests for the hypothesis A=B. **,* stand for statistical significance at 1% and 5%, respectively.

Effect			Chi-square		
	A	B	Cost	Technical	Allocativ
Activity	Complex	Credit	0.21	2.85	2.81
		Treasury and Business	0.06	3.27	5.31*
		Retail	0.03	1.67	6.85**
	Credit	Treasury and Business	0.35	0.34	3.28
		Retail	1.93	1.8	4.26*
	Treasury and Business	Retail	0.07	2.43	0.01
Control	Foreign	Domestic Private	2.42	0.03	49.45**
		State owned	14.48**	3.59	105.77**
	Domestic Private	State owned	6.18*	4.02**	33.7**
Size	Large	Micro	1.38	0.15	0.05
		Medium	1.51	0.24	0.02
	Micro	Medium	0.54	0.93	0.25

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