

## **Benchmarking Peruvian Banks using Data Envelopment Analysis**

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### **Abstract**

Despite the growing literature on bank efficiency worldwide over the last decade, researchers have neglected the Peruvian banking sector. In this paper, the technique of data envelopment analysis (DEA) is used to investigate the efficiency of Peruvian banks for the period 2000 to 2009 to benchmark currently existing banks based on their super-efficiency scores over time. Further, an in-depth analysis of currently existing banks for the period 2008 to 2009 is conducted to check the robustness of DEA efficiency scores and the potential improvement of inputs and outputs for inefficient banks, indicating by how much and in what areas inefficient banks need to improve in order to be efficient. Our finding shows an increasing trend in technical efficiency during the period 2000 to 2009 which gives an indication of an affirmative effect of the reform process in the Peruvian banking sector. On average, the multinational banks are performing better than are domestic banks throughout the period except in 2007, during which a sharp decline in efficiency performance for both the groups was apparent, possibly a result of global financial turmoil. The application of jackknifing analysis with appropriate statistical tools shows the DEA efficiency scores are robust. Among the 14 currently existing banks, Banco Ripley and Banco Santander Peru were the best performers, whereas Banco Azteca was the worst performer, followed by Interbank and Banco de Comercio. Furthermore our findings suggest that inefficient banks require more rigorous policies with respect to the allocation of funds for additional loans as well as other earnings assets. In this way, presently inefficient banks may approach the efficiencies of the best practice banks.

*Keywords:* Peruvian banks, data envelopment analysis, efficiency, super-efficiency, jackknifing, sensitivity analysis.

*JEL Classification codes:* G21, C61

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The banking sector in Peru has undergone dramatic transformations since 1990 as a part of the processes of financial liberalization and international integration. Broadly speaking, the liberalization brought changes in terms of opening up entry points for new banks, consolidating banks through mergers and acquisition, and reducing government control on interest rate regulation. This series of reforms in the banking industry had the primary objective of improving the efficiencies of banks. Most countries in Latin America privatized aggressively, leading to a fall in the average state ownership of banks from 64% to 55% between 1970 and 1985 and a further drop from 55% to 40% between 1985 and 1995.

Ecuador, Chile, and Peru are countries that privatized the most, moving from levels of state ownership that were above (or near, in the case of Peru) 90%, to levels below 40% (below 30% and 20% in the cases of Peru and Chile respectively). Further, the decline in “barriers of entry” in the banking system allowed the entry of new commercial banks and other types of financial agents. According to the Latin American Shadow Financial Regulatory Committee, one of the most salient features of financial systems in Latin America is the growing role of multinational banks (MNBs) (Yi, 2008). At the end of 2001, foreign banks controlled more than 50% of the assets in the financial systems in many countries in Latin America; this was in contrast to the situation in 1995 when MNBs did not account for even a quarter of the assets in the financial system (Micco & Panizza, 2004).

Rojas (1999) noted multinational corporations (MNCs) became more important in the Peruvian economy after the liberalization process of the 1990s. According to the Superintendencia de Banca, Seguros y AFP (SBS), the regulator of the Peruvian banking sector, currently, almost 50% of all deposits in Peru are captured by foreign banks. Because of their global operations, MNBs have a greater scale advantage. As a result, the return on technological investment is large, while the marginal cost of technological investment is considerably smaller. Moreover, MNBs bring experience and best practices that have been shown to work in other operations around the world. In addition, the competitive advantage possessed by MNBs pressurizes domestic banks to become more productive. For Latin American countries, Crystal, Dages, and Goldberg (2001) argued foreign bank entry is associated with improved production of financial services and more banking competition, and it facilitates the early waves of privatization of government-owned domestic banks. Buch (2002), Hasan and Marton (2003), Drakos (2002), and Fries and Taci (2005) demonstrated that the entry of foreign banks creates an environment in which the entire banking system is forced to become more efficient, both directly and indirectly.

The consolidation of banks has been one of the important features of liberalization policies in Latin American countries. Between 1997 and 2005, most countries in the region experienced a profound decrease in the number of commercial banks, for example, by 15% in Argentina and 26% in Brazil, and approximately 10% in Latin America overall. The consolidation wave appears to have been evident in the early 2000s when the number of banks plummeted by about 33% between 2001 and 2005. In Peru, the number of banks decreased drastically from 25 in 1998 to 16 in 2000 and further reduced to 12 in 2005. The decrease is not only due to consolidation; to some extent, the entry of microfinance is also responsible for reducing the number of banks in Peru. Nevertheless, the consolidation of banking systems and the consequent reduction in the number of banks because of mergers and acquisitions and increased bank concentration led practitioners to claim that in the new environment, an improvement of banking efficiencies should be observed.

In the aftermath of liberalization, restructuring, and deregulation of financial markets worldwide, the focus of researchers shifted from manufacturing to the financial sector, with an emphasis on the evaluation of efficiency and productivity of financial institutions (Kumar & Charles, 2011). Numerous attempts have been made to study the efficiency and productivity of the banking sector in developed countries, with more focus on Europe and the USA (Berger & Humphrey, 1997; Berger, Demsetz, & Strahan, 1999; Isik & Hassan, 2002 a, b; Yildirim & Philippatos, 2003). In contrast, studies analyzing the efficiency of banks in Latin American countries are very limited and almost negligible in the case of Peru. In their extensive international literature survey, Berger and Humphrey (1997) noted the vast majority of the efficiency literature focuses on the banking markets of well-developed countries with particular emphasis on the U.S. markets.

In a recent survey paper, Fethi and Pasiouras (2010) provided an extensive survey on efficiency and productivity studies in the banking sector published in various research journals covering the period between 1998 and 2008. It was observed that 52.4% of the studies focused on banks in Asia, followed by 32.9% in Europe, 8.7% in the USA, 5.4% in Australia, and 0.67% in Africa. None of the studies in the list referred to banks in Latin American countries.

A few studies are focused on efficiency measurement using both parametric as well as nonparametric methods in selected Latin American countries. Taylor, Thompson, Thrall, and Dharmapala (1997) applied DEA

in the Mexican banking sector to estimate a production frontier for each year between 1989 and 1991 and classified 13 public banks according to their efficiency levels. León (1999) provided the DEA estimation for 1997 based on a cost frontier estimation for 23 Mexican banks. León observed larger banks and foreign banks as the most cost inefficient. Guerrero and Negrin (2005) investigated the Mexican banking system, estimating static and dynamic parametric models of banking efficiency. They used monthly data from commercial banks from 1997 to 2004 for the estimation of cost and profit functions using stochastic frontier analysis (SFA). Fuentes and Vergara (2007) used cost and profit functions to estimate efficiency at the bank level in Chile. Based on these measures, they explained cross-bank differences over time, which are related to bank size, ownership structure, and other relevant variables. Fuentes and Vergara found listed companies in Chile tended to show a higher level of efficiency than did those established as closed companies. Staub, da Silva e Souza, and Tabak (2010) used the technique of DEA to investigate cost, technical, and allocative efficiencies for Brazilian banks between 2000 and 2007. They observed low levels of economic (cost) efficiency in Brazilian banks compared to banks in Europe and the USA. Further, the state-owned banks were significantly more cost efficient than foreign, private domestic, and private with foreign participation banks.

Rivas, Ozuna, and Policastro (2006) investigated if the use of derivatives affects the efficiency of banks in Latin American countries such as Brazil, Chile, and Mexico. Rivas et al. found that (a) the level of efficiency of the banks is positively associated with bank size, and (b) regulatory and institutional constraints negatively affect the efficiency of Latin American banks. Carvallo and Kasman (2005) estimated a common stochastic cost frontier for a panel of 481 banks from 16 Latin American countries. The authors showed evidence of great variation among the countries, and they observed very small and very large banks are more inefficient than are other banks. Forster and Shaffer (2005) analyzed the relationship between bank efficiency and the absolute size of Latin American banks and revealed a statistically significant association among the variables. Chortareas, Girardone, and Garza-Garcia (2010) investigated the relationship between market structure, efficiency, and bank performance/profitability. Chortareas et al. used the technique of DEA to measure technical and scale efficiency for a sample of over 2,500 bank observations in nine Latin American countries including Peru between 1997 and 2005.

Although there is some literature on bank efficiency referring to Latin American countries (as cited above), systematic research on bank efficiency in Peru has hardly been conducted. Those studies published revealed that banks that operate efficiently have a better chance of sustaining their business in the future. Berger and Humphrey (1992) found, during the 1980s, that the high-cost banks experienced a higher rate of failure than did banks that are more efficient. On the other hand, in a study of banks during the 1920s, Wheelock and Wilson (1995) found that the less technically efficient a bank was, the greater its likelihood of failure. Moreover, efficiency indices could also be used to evaluate the impact of changes in regulation and market conditions on the performance of banks. Further, efficiency indices will also help a bank identify the areas of inefficiency and formulate suitable strategies to improve its relative position in the market. Efficiency indices can also provide a framework for the regulators to assess the health of individual banks and work out appropriate interventions to prevent systemic failures (Lacasta, 1988).

We seek to contribute to the banking efficiency literature in two ways. First, we examine the still little explored case of Peru, a developing economy with a banking system that has undergone major transformations. The period under analysis is a post-privatization period characterized by the consolidation of the banking sector through numerous mergers and acquisitions. Second, we benchmark Peruvian banks based on their performance over a period of 10 years. The ranking based on single period data can change dramatically as many one-time influences are realized, including tax benefits, negative net charge offs, and restructuring fees, so the ranking may not accurately portray banks with lasting strategy (Kumar & Charles, 2011). We have used the Fibonacci weighted geometric mean (FWGM) as an averaging method for super-efficiency scores. The FWGM computes weighted averages for a non-empty set of numbers that give more weight to the recent data points to make the result more responsive to new information and completely ignore the initial point, under the factual assumption that most banks perform well during their inception years.

The paper unfolds as follows: in the next section, an overview of the Peruvian banking system is provided. The section is followed by theoretical background wherein the detailed computational procedures for efficiency, super efficiency, and FWGM are described. The data concerning the selection of inputs and outputs and their sources are provided in the next section, followed by the results and discussion of the results. The final section concludes the study with discussion of the limitations and future scope.

## Peruvian Banking Sector: Reforms and Current Structure

In last two decades, the banking sectors of many Latin American countries have undergone rapid structural change. An important underlying determinant of such change has been the drive by countries to improve the efficiency and resilience of their financial systems through deregulation, the development of domestic capital markets, the privatization of state-owned financial entities, and the encouragement of foreign bank entry. Another determinant has been a market-driven process of consolidation, regional financial integration, and overall financial innovation. Because of this evolution, market forces have come to play a greater role in credit allocation, and the underlying structure of financial systems has undergone significant transformation.

During the middle of the 1990s, commercial banking in Peru migrated from a framework of specialized to universal banking. The provision of new banking legislation via the enactment of Law No. 26702, known as the General Law for the Banking and Insurance Systems, and the Charter Law for the Bank and Insurance Supervisor in December 1996 signaled an important change in the structure and supervision of the financial system. The main objectives of the General Law were to allow the system to adopt new intermediation mechanisms and promote competitiveness, with the aim of reducing the cost of money as well as introducing consolidated supervision and strengthening and consolidating the supervisory function of the SBS.

This incipient modernization of the financial sector, together with the privatization process as the part of overall economic policy, allowed for the entry of foreign banks. The entry of foreign banks contributed to the development of new technologies and gave rise to opportunities for the implementation of more efficient risk management procedures. Currently, six MNBs are operating in Peru: Banco Continental BBVA, Scotiabank Peru, Banco Financiero, Banco Interamericano de Finanzas, Citibank Peru, and HSBC Bank Peru. Together, these banks capture roughly 50% of all deposits in Peru.

In the middle of 1998, the Peruvian financial system faced a difficult situation when the consequences of the international financial crisis resulted in liquidity problems due to the reversion of credit lines from abroad. In order to confront the crisis, the SBS adopted a strategy aimed at ordering and optimizing the mechanisms for bank resolution. The strategy included managing the market exit process by identifying and transferring to the rest of the system valuable assets of distressed banks and empowering the Deposit Guarantee Fund (*Fondo de Seguro de Depósitos*) to inject capital and temporarily take control of banks under intervention. In addition, the government put in place a program to strengthen balance sheets via a temporary swap of loan portfolios for negotiable Treasury bonds for five years, which was complemented by a further plan. The packages involved 19 institutions and amounted to almost USD 450 million in total. The measures favored the process of consolidation within the financial system, giving rise to various mergers and acquisitions among firms. In April 1998, there were 25 banks operating in the sector of universal banking; in February 2007, that number was 11. Some banks exited the market quietly by selling their interests to larger banks, while some entered and some merged, forming new institutions. Banco Latino was sold to Interbank in 2001. Scotiabank bought Banco del Trabajo in 2009, which then became Financiera CrediScotia (a *financiera*<sup>1</sup>). Banco Santander Central Hispano was sold to Banco de Credito at the end of 2002. In addition, Bank Boston shut down in 2005, and its earning assets were sold to Banco de Credito. Banco Sudamericano and Banco Wiese merged in 2006, to become Scotiabank Peru. BNP Paribas Andes closed in 2006. Some banks entered the system in the 2000s. HSBC Bank opened in 2006. Banco Falabella and Banco Santander Peru opened in 2007. Banco Ripley and Banco Azteca opened in 2008. However, Banco Falabella and Banco Ripley already operated in the Peruvian financial system as *financieras*.

It is widely believed that bank consolidation results in a less competitive banking system. Despite this general belief, no clear evidence exists, from a theoretical point of view, that bank consolidation necessarily implies a less competitive banking environment because it depends mainly on the pattern of mergers<sup>2</sup>. As stated in Vives (2001), for example, a merger between firms serving overlapping or identical markets reduces competition and increases efficiency by eliminating duplication of activities. Alternatively, it is not clear whether competition and concentration go in opposite directions. Elimination of branching restrictions or a widespread use of ATMs that reduces geographical barriers can be shown to enhance, rather than hinder, banking competition, while inducing consolidation as a result of narrower margins<sup>3</sup>. A wide range of studies that have focused on analyzing USA and EU experiences concluded mergers seem to have been pro-competitive in general<sup>4</sup>, which in turn, may result in higher efficiency of banks.

Considering the implications derived from the above, in this paper, the performance of Peruvian banks in terms of their efficiency over the last 10 years during the liberalization period is examined. Further, the currently

existing banks are benchmarked based on their performance for the entire period of study using FWGM as an averaging method of super-efficiency scores. Within the framework of the present study, the results seem to be conclusive: the average technical efficiency shows an increasing trend on average. In addition, MNBs are performing better than domestic banks throughout the period except during 2007, where a sharp decline in the efficiency of both groups is apparent. Finally, a ranking based on FMGM in the present scenario is preferable compared to PTWM because of the entry of many banks within the study period.

## Methodology

Data envelopment analysis (DEA) is a modern approach for evaluating the productive performance of a set of peer entities called decision-making units (DMUs) with multiple outputs and inputs. DEA does not require any underlying assumption of a functional form relating to inputs and outputs. Given the set of inputs and outputs of different firms, it constructs its own functional form. DEA models can be distinguished according to whether they are input-oriented or output-oriented, for example, either minimizing inputs for a given level of output or maximizing output for a given level of input. In this study, we use an output-oriented CCR model to analyze the relative efficiency and super-efficiency of Peruvian banks during the post reform era.

It is assumed  $n$  DMUs exist. Each DMU <sub>$j$</sub>  ( $j=1,2,\dots,n$ ) consumes a vector of inputs,  $x_j = (x_{1j}, x_{2j}, \dots, x_{mj})^T$  to produce a vector of outputs,  $y_j = (y_{1j}, y_{2j}, \dots, y_{sj})^T$ . The superscript T represents transpose. The DMU to be evaluated is designated as DMU0 and its input-output vector is denoted as  $(x_0, y_0)$ .

Consider the following output-oriented CCR model in line with Charnes, Cooper, and Rhodes (1978), which involves a two-stage DEA process:

$$\begin{aligned}
 & \text{Max } \phi + \varepsilon \left( \sum_{r=1}^s s_r^+ + \sum_{i=1}^m s_i^- \right) \\
 & \text{s.t.} \\
 & \phi y_{r0} - \sum_{j=1}^n y_{rj} \lambda_j + s_r^+ = 0, \quad r = 1, 2, \dots, s, \\
 & \sum_{j=1}^n x_{ij} \lambda_j + s_i^- = x_{i0}, \quad i = 1, 2, \dots, m, \\
 & \lambda_j \geq 0, \quad s_r^+ \geq 0, \quad s_i^- \geq 0; \quad j = 1, 2, \dots, n; \\
 & r = 1, 2, \dots, s; \quad i = 1, 2, \dots, m,
 \end{aligned} \tag{1}$$

and  $\phi$  is otherwise unconstrained. Here  $\lambda_j$  represents the ‘structural’ variables,  $s_r^+$  and  $s_i^-$  represent ‘slacks’ and  $\varepsilon$  is a ‘non-Archimedean infinitesimal,’ which is defined to be smaller than any positive real number. System (1) assumes the best-practice frontier exhibits constant returns to scale (CRS); in other words, a best-practice DMU is both technically as well as scale efficient. If scale inefficiency is allowed in best practice DMUs, it can be assumed variables return to scale (VRS) and incorporate  $\sum_{j=1}^n \lambda_j = 1$  into the System (1). For a complete discussion on standard DEA models, refer to Cooper, Seiford, and Tone (2000).

*DEA efficiency definition:* DMU0 is DEA efficient if, and only if, the following two conditions are satisfied (a)  $\phi^* = 1$ , and (b)  $s_r^{+*} = s_i^{-*} = 0, \quad \forall i, r$ , where \* designates an optimum.

The System (1) divides DMUs into inefficient and efficient DMUs. However, because all efficient DMUs receive the same efficiency score of 1, it is not possible to distinguish among efficient DMUs. The super-efficiency models came into prominence as an aid to the sensitivity analysis of classical DEA models (Charnes Haag, Jaska, & Semple, 1992; Charnes, Rousseau, & Semple, 1996; Seiford & Zhu, 1998a, b; Zhu, 1996;). Andersen and Petersen (1993) proposed the use of super-efficiency DEA models in ranking the relative efficiency of each DMU. Since 1993, super-efficiency DEA models span a variety of applications. These include measuring technology and productivity changes (Färe, Grosskopf, & Lovell, 1994), identifying the extreme efficient DMU (Thrall, 1996), and two-person ratio efficiency games (Rousseau & Semple, 1995).

The ranking of efficient DMUs can be made using the super-efficiency score (Adler, Friedman, & Sinuany-Stern, 2002; Allen & Thanassoulis, 2004; Zhu, 2001), which is based on the idea put forth by Andersen and Petersen (1993).

$$\begin{aligned}
& \text{Max } \delta_0 + \varepsilon \left( \sum_{r=1}^s s_{0r}^+ + \sum_{i=1}^m s_{0i}^- \right) \\
& \text{s.t.} \\
& \delta_0 y_{r0} - \sum_{j=1, j \neq 0}^n y_{rj} \lambda_j + s_{0r}^+ = 0, \quad r = 1, 2, \dots, s, \\
& \sum_{j=1, j \neq 0}^n x_{ij} \lambda_j + s_{0i}^- = x_{i0}, \quad i = 1, 2, \dots, m, \\
& \delta_0 \geq 0, \lambda_j (j \neq 0) \geq 0, s_{0r}^+ \geq 0, s_{0i}^- \geq 0; \quad j = 1, \dots, n; \\
& r = 1, 2, \dots, s; \quad i = 1, 2, \dots, m.
\end{aligned} \tag{2}$$

The super-efficiency model given in System (2) is identical to the DEA models described above, but a DMU under evaluation is excluded from the reference set<sup>5</sup>. This allows a DMU to be located above the efficient frontier, in other words, to be super-efficient among the efficient DMUs. Therefore, the super-efficiency score for efficient DMUs can, in principle, take any value greater than or equal to 1. This procedure makes a ranking of efficient DMUs possible, in other words, the higher the value the higher the rank. It is to be noted that the scores for inefficient DMUs are unaltered, as in System (1). One can obtain the output-oriented super-efficiency model under VRS by incorporating  $\sum_{j \in E, j \neq 0} \lambda_j = 1$  into the System (2). However, a super-efficiency DEA model under different returns to scale other than constant return to scale could be subject to infeasible solutions for some extreme efficient DMUs<sup>6</sup>.

### Fibonacci Weighted Geometric Mean

The Fibonacci weighted geometric mean is a method of computing a kind of weighted average of a non-empty set of numbers that gives more weight to the recent data points to make it more responsive to the new information and completely ignore the initial point.

For the period 1 to T, consider a set of values (in this context, super efficiency values), say,  $e_t$ ,  $t = 1, 2, \dots, T$  and associated Fibonacci weights, say  $w = \{0, 0.146, 0.236, 0.382, 0.5, 0.618, 0.764, 0.854, 1, 1.146 \dots\}$ . The Fibonacci weighted geometric mean can be defined as

$$FWGM = \text{Exp} \left( \frac{\sum_{t=1}^T w_t \ln e_t}{\sum_{t=1}^T w_t} \right) \tag{3}$$

where,  $0 = w_1 < w_t < w_{t+1}, \forall t$ . Note that more emphasis is placed on the recent data points than are on the points in the immediate past. In this study, Equation 3 is applied to measure the mean super- efficiency scores of all banks during the study period, from 2000 until 2009, to find their positioning in the Peruvian banking sector. In order to ensure no bias across the banks, the initial period is assumed to be the inception period of a bank that existed in 2000.

### The Data

In the banking literature, considerable disagreement exists among researchers about what constitutes inputs and outputs of the banking industry (Casu, 2002; Sathye, 2003). Even today, no all-encompassing theory of banking firms and no agreement on the explicit definition and measurement of banks' inputs and outputs exist. Two different approaches appear in the literature with respect to the measurement of inputs and outputs of a bank, popularly known as the "production approach" and the "intermediation approach" (Humphrey, 1985).

The production approach views banks as using purchased inputs to produce deposits and various categories of bank assets. Both loans and deposits are treated as outputs, measured in terms of the number of accounts. The approach considers only operating costs and excludes the interest expenses paid on deposits because deposits are viewed as outputs. The intermediation approach, on the other hand, considers banks as financial

intermediaries and uses volume of deposits, loans, and other variables as inputs and outputs. The approach views the banks as using deposits together with purchased inputs to produce various categories of bank assets. Outputs are measured in monetary value, and total costs include all operating and interest expenses<sup>7</sup>.

Although the intermediation approach is most commonly used in empirical studies, neither approach is completely satisfactory, largely because deposits have both input and output characteristics not easily disaggregated empirically (Kumar & Gulati, 2008). Berger and Humphrey (1997) suggested the intermediation approach is best suited for analyzing bank level efficiency, whereas the production approach is well suited for measuring branch level efficiency. This is because, at the bank level, management will aim to reduce total costs and not only non-interest expenses, while at the branch level, a large number of customer service processing transactions take place and bank funding and investment decisions are mostly not under the control of branches.

Berger and Humphrey (1997) pointed out that, although no 'perfect approach' exists, the intermediation approach may be more appropriate for evaluating entire financial institutions because the approach is inclusive of interest expenses, which often account for approximately one and half to two-thirds of total costs. Moreover, the intermediation approach may be superior for evaluating the importance of frontier efficiency to the profitability of financial institutions because the minimization of the total costs, not just the production costs, is needed to maximize profits. Therefore, following Berger and Humphrey (1997), the intermediation approach has been used in the current study with a restricted choice of variables<sup>8</sup>, as opposed to the production approach for selecting inputs and outputs.

The more variables added, the greater becomes the chance some inefficient unit will dominate the added dimension and become efficient (Smith, 1997). Thus, to preserve the discriminatory power of DEA, the number of inputs and outputs should be kept at a reasonable level. The choice of inputs and outputs is guided by the choices made in previous studies as well as data availability. In the current study, two inputs, namely, total cost ( $x_1$ ) and total deposits ( $x_2$ ), have been used. The input total cost<sup>9</sup> is measured as the sum of total interest expenses and non-interest expenses including personal expenses. Non-interest expenses include service charges and commissions, expenses of general management affairs, salaries, and other expenses, including health insurance and securities portfolios. Some researchers (Kao & Liu, 2004; Ram Mohan & Ray, 2004; Sathye, 2003; Yeh, 1996) have treated interest expenses and non-interest expenses as two different inputs along with other inputs. However, following Casu and Molyneux (2003), Sealey and Lindley (1977), and Udhayakumar, Charles, and Kumar (2010), we have treated both together as a single input. This kind of treatment is mainly due to the well-known dimensionality problem associated with DEA, particularly with limited sample size: a high number of variables relative to the number of observations cause more units to be wrongly identified as efficient. When too many constraints are specified, the observations tend to become incomparable (Zhao, Casu, & Ferrari, 2008). The input, total deposits is taken as the sum of demand and savings deposits held by bank and non-bank depositors.

The above two inputs are used to produce two outputs: total loans ( $y_1$ ) and other earning assets (OEA) ( $y_2$ ). The output, total loans, is measured as the sum of all loan accounts intermediated by banks, and the output, OEA ( $y_2$ ), is measured as the sum of total securities (treasury bills, government bonds and other securities), deposits with banks, and equity investments.

To ensure the validity of the DEA model specification, an isotonicity test (Avkiran, 1999) was conducted; the test involves the calculation of all inter-correlations between inputs and outputs for identifying whether increasing amounts of inputs lead to greater outputs. The inter-correlation between inputs and outputs were observed to be positive (Pearson correlations  $> 0.90$ ;  $\alpha = 0.01$ ); the isotonicity test was passed, and the inclusion of inputs/outputs justified.

The basic data on inputs and outputs has been taken from Superintendencia de Banca, Seguros y AFP, published by the government institution that is in charge of regulating banks and insurance companies. The website is public and includes official information about the financial situation of all financial institutions in Peru. The sample consists of all the existing banks in Peru during the period spanning 2000 to 2009. As such, 22 banks are included, with the number of banks varying from 11 in the year 2006 to 16 in the year 2000. For only 8 banks in the sample was data available for the entire period of study. The Banco Latino merged with Interbank in 2001. As a result, the data for the above bank was available only for the year 2000.

A rule of thumb exists for deciding the minimum size of a sample in a DEA study. Golany and Roll (1989) and Homburg (2001) suggested the number of DMUs should be at least twice as high as the sum of the number of resources (inputs) and the number of activities (outputs). On the other hand, Nunamaker (1985) and Raab

and Lichty (2002) suggested the sample size should be at least three times larger than the sum of the number of inputs and outputs. There is no complete agreement on the requirement for sample size. However, a compromise could be made even if the sample size does not meet the above rules of thumb, provided the degree of homogeneity is comparatively high. In this study, with a total of two inputs and two outputs, a minimum sample size of 8 to 12 was required. A summary of the statistics of inputs and outputs for Peruvian banks for each year under study is available from the authors.

## Empirical Findings

First, System (1) is used to evaluate the efficiency score of each bank for the period 2000 to 2009. Second System(2) is applied to evaluate the super efficiency of all efficient banks to rank them based on their performance over the entire period of study by applying two different methods of averaging, namely, (a) the progressive time weighted mean approach (Kumar & Charles, 2011) and (b) the Fibonacci weighted geometric mean. Finally, the jackknifing method is used to check the robustness of the efficiency scores for the last two years, and the potential improvements for currently existing inefficient banks is analyzed for policy implications.

### *Efficiency analysis of Peruvian banks: 2000 - 2009*

Table 1 reports the super-efficiency scores for each individual bank between 2000 and 2009. A super-efficiency score of less than 1 indicates technical efficiency of the banks under CRS. The last three rows of the table show the average technical efficiency (ATE) of all the banks as well as the group of MNBs and domestic banks. The only banks shown to be efficient since their inception in the Peruvian banking sector are Banco Falabella and Banco Ripley. Most of the banks are efficient in at least one of the years since the year of their inception; exceptions are Banco del Trabajo, Banco Santander Central Hispano, Interbank, and Scotiabank Peru. The banks with the highest frequency for being on the frontier are Banco Continental BBVA, Citibank Peru, and Mibanco; these banks were efficient during 6 out of the 10 years of their existence in the sector. The average efficiency scores vary from 0.687 to 0.947 during the period of analysis. In a comparison across Latin American countries, Chortareas et al. (2010) observed the efficiency of Peruvian banks varied from 52.33 to 90.78 during the period 1997-2005 based on a country-specific DEA analysis. In spite of certain differences in the variables' inputs and outputs, the results are comparable for the common period of analysis.

As can be observed, MNBs performed better than domestic banks throughout the period except during 2007 when there was a downward shift in efficiency performance for both groups. This was the only year the domestic banks outperformed MNBs in terms of ATE. This result could be a consequence of the global financial turmoil that originated in August 2007 in the USA and affected many economies around the world. The Latin American (LA) financial markets experienced precipitous tumbles, despite the region enjoying strong economic growth from 2004 through to the beginning of the crisis. In August 2007, equity markets in the Latin American region fell 8% to 9% from their peaks as well and continued to see corrections (Yiu, Ho, & Jin, 2010). The region appeared to stabilize somewhat when Bear Sterns announced a rescue plan in March 2008.

Figure 1 shows the trend in average technical efficiency along with a 0.5 standard deviation spike, and the bar chart represents the percentage of efficient banks. As can be observed, the percentage of efficient banks varies from 15.38% in the year 2007 to 53.33% in the year 2002. The overall average efficiency trend increases, except for a slight decline in 2003 and a very sharp decline in 2007. Figure 2 shows the trends for average technical efficiency of two groups, the MNBs and domestic banks. The MNBs surpass domestic banks throughout the period except 2007. The evaluation of bank financial statements in three Latin American countries by Crystal et al. (2001) revealed significant behavioral differences. Foreign banks tended to maintain greater asset liquidity and relied less on deposit financing. In addition, foreign banks, particularly those with established in-country operations, typically showed stronger loan growth than did private domestic banks, even during periods of local economic difficulty. Although recently acquired banks had weaker loan growth, their focus on balance sheet repair could lay the foundation for future credit growth at a pace much closer to that set by established foreign banks. In another study, Crystal et al. (2002) found foreign banks follow tighter credit review policies and practices. The foreign banks provisioned more aggressively against bad loans and had higher loan recovery rates in some Latin American countries during the period 1995-2000.



Table 1  
Scores Based on Super Efficiency DEA model

DMU	Name of the Banks	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1	Banco Continental BBVA	0.7171	0.7253	1.1292	0.9319	1.3866	1.0851	1.1394	0.7745	1.2012	1.1456
2	Banco de Comercio	0.6231	0.7208	0.8959	0.7075	1.8988	0.6535	0.8014	0.5191	0.8324	0.8560
3	Banco de Credito	0.7049	0.7016	0.8830	0.7280	0.7737	1.0745	0.9990	0.5956	1.1778	1.0181
4	Banco del Trabajo	0.3408	0.5264	0.6212	0.6758	0.8538	0.9391	0.8231	0.5775	0.6682	x
5	Banco Financiero	0.7858	1.5574	0.9695	0.8271	0.8557	1.0297	1.0266	0.6590	1.0247	0.9742
6	Banco Interamericano de Finanzas	1.1346	1.0564	1.1705	0.9349	0.7400	1.1327	1.0023	0.6091	0.9619	0.8972
7	Banco Santander Central Hispano	0.9184	0.8945	0.7814	x	x	x	x	x	x	x
8	Banco Standard Chartered	0.9054	0.6354	1.5089	3.0500	1.0441	x	x	x	x	x
9	Banco Sudamericano	1.0055	0.9788	1.0043	0.9591	0.9314	0.8916	x	x	x	x
10	Banco Wiese	1.3433	0.8723	1.0908	0.6753	0.6993	0.7560	x	x	x	x
11	Bank Boston	1.0809	0.9899	1.0431	1.1736	1.2780	x	x	x	x	x
12	BNP Paribas	1.8261	0.8808	0.4637	1.0852	1.4650	1.7344	x	x	x	x
13	Citibank Peru	0.8969	1.0052	1.0849	1.0832	1.3006	1.1821	0.9791	0.6725	0.8965	1.4968
14	Interbank	0.7117	0.8164	0.7861	0.6826	0.6253	0.7311	0.7887	0.5003	0.8927	0.8723
15	Mibanco	0.8728	1.7747	1.6699	1.0978	1.0071	0.9705	1.2865	0.935	1.0162	0.9720
16	Scotiabank Peru	x	x	x	x	x	x	0.8109	0.5038	0.9231	0.9897
17	HSBC Bank Peru	x	x	x	x	x	x	3.2923	0.5800	0.9394	1.0881
18	Banco Falabella	x	x	x	x	x	x	x	1.0619	1.0275	1.1027
19	Banco Santander Peru	x	x	x	x	x	x	x	3.9496	0.9704	1.2083
20	Banco Ripley	x	x	x	x	x	x	x	x	1.2511	1.1192
21	Banco Azteca	x	x	x	x	x	x	x	x	0.4222	0.7026
22	Banco Latino	0.8828	x	x	x	x	x	x	x	x	x
	ATE (All Banks)	0.8350	0.8495	0.8934	0.8659	0.8914	0.9118	0.9275	0.6866	0.9005	0.9474
	ATE (MNBs)	0.8500	0.9313	0.9924	0.9235	0.8989	1.0000	0.9650	0.6332	0.9535	0.9769
	ATE (Domestic Banks)	0.8300	0.8197	0.8574	0.8428	0.8884	0.8677	0.8824	0.7325	0.8651	0.9254

Notes: (1) The super-efficiency score < 1 reported in the table is also the CCR efficiency score for inefficient DMU, whereas the super-efficiency score > 1 indicates a CCR efficiency score = 1. (2) Years shown in the table are financial years, for example, year 2000 indicates the financial year 1999-00. (3) The last three rows show the average technical efficiency (ATE) for all banks, multinational banks, and domestic banks respectively.

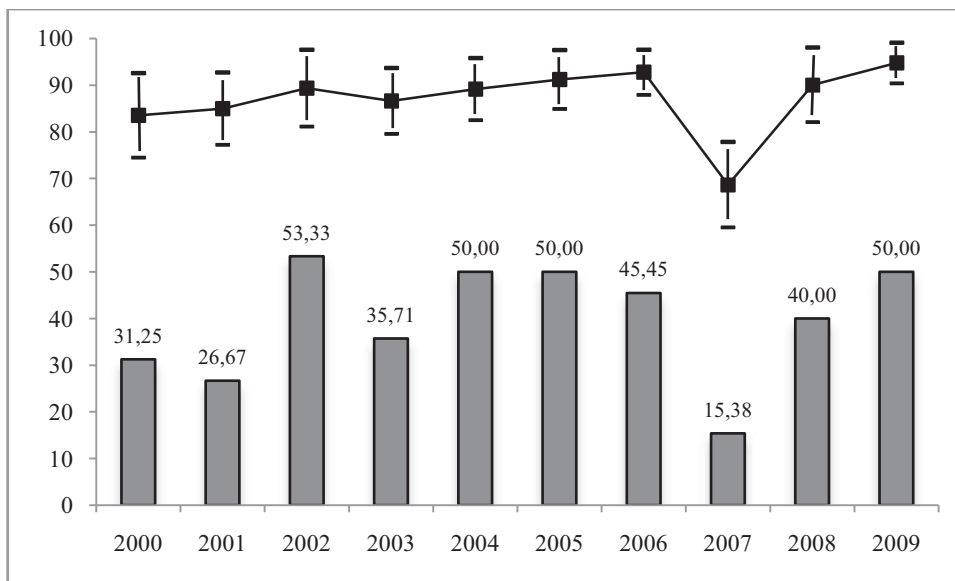


Figure 1. Trend of average technical efficiency with percentage of efficient banks.

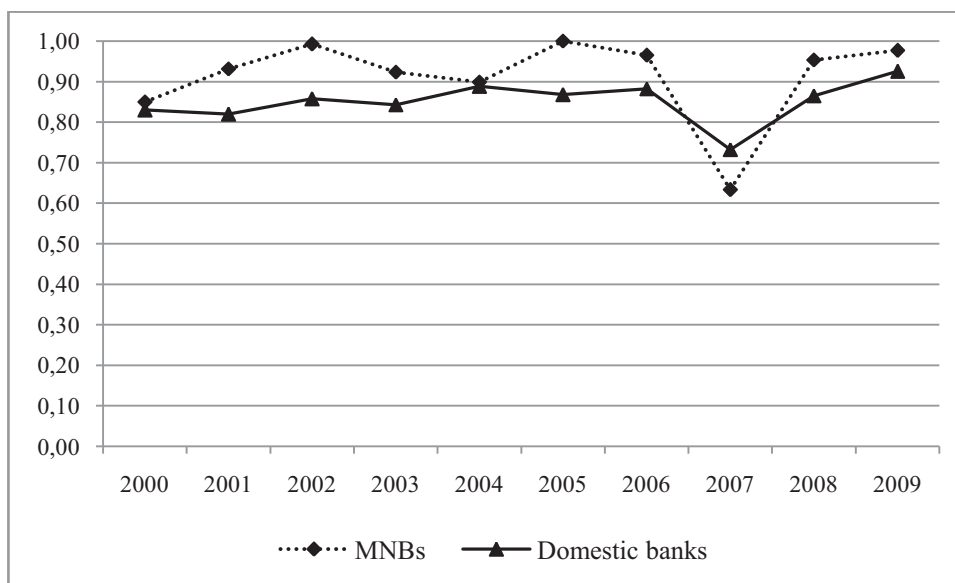


Figure 2. Trends of average technical efficiency of MNBs and domestic banks.

### Benchmarking the Currently Existing Peruvian Banks

Next, the super efficiency of all the efficient banks using the DEA model given in System (2) was calculated; the results are reported in Table 2. The current 14 existing banks are ranked based on their performance over the entire period for the study by applying (a) the progressive time weighted mean approach (PTWM) (Kumar & Charles, 2011) and (b) Fibonacci weighted geometric mean (FWGM) approach as proposed. Table 2 reports the status of the 14 currently existing banks' positions in the financial market within the sample studied. As can be observed, Banco Santander Peru and Banco Ripley are the best performers with ranks 1 and 2 based on the averaging method PTWM and rank 2 and 1 based on the proposed averaging method FWGM. Banco Azteca is the worst performer with its rank at 14, followed by Interbank with rank 13 and Banco de Comercio rank 12 using both averaging methods.

The large differences in the ranking of the two banks based on the above two methods can be observed; for example, Banco Falabella, which is ranked 3 by FWGM, is penalized and ranked 7 by the PTWM; HSBC Bank Peru, which is ranked 8 by FWGM, but ranked 3 by PTWM. The difference is because FWGM ignores information about the initial year’s performance because most of the banks use management tactics and strategies to attract customers by means of raising more loans and so forth during their inception years. For instance, HSBC Bank Peru and Banco Santander Peru in their respective inception years of 2006 and 2007 outperformed all other banks in terms of super efficiency (see Table 1). A few banks could not perform well in their inception years as well as over the entire study period, for example, Scotia Bank Peru and Banco Azteca.

Table 2  
Ranking of Peruvian Banks

DMU	Name of the Bank	PTWM	Rank	FWGM	Rank
1	Banco Continental BBVA	1.0757	06	1.0714	04
2	Banco de Comercio	0.8511	12	0.8030	12
3	Banco de Credito	0.9186	09	0.9079	09
5	Banco Financiero	0.9454	08	0.9289	07
6	Banco Interamericano de Finanzas	0.9184	10	0.8930	10
13	Citibank	1.0793	05	1.0515	06
14	Interbank	0.7496	13	0.7396	13
15	Mibanco	1.0915	04	1.0628	05
16	Scotiabank Peru	0.8547	11	0.8514	11
17	HSBC Bank Peru	1.1623	03	0.9220	08
18	Banco Falabella	1.0708	07	1.0733	03
19	Banco Santander Peru	1.5859	01	1.1112	02
20	Banco Ripley	1.1632	02	1.1192	01
21	Banco Azteca	0.6091	14	0.7026	14

Note. (i) PTWM and FWGM respectively indicates progressive time weighted mean and Fibonacci weighted geometric mean.

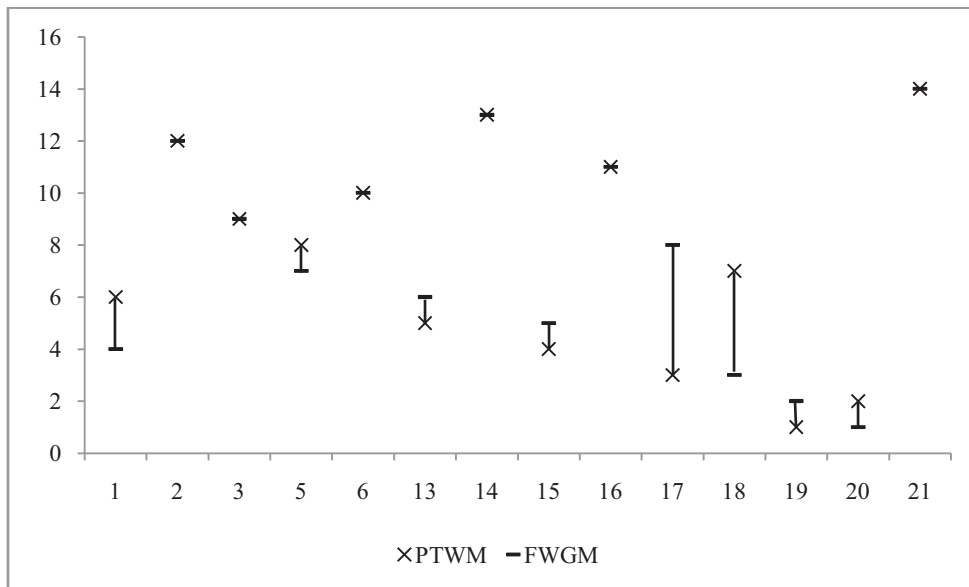


Figure 3. Differences in ranking of banks based on the PTWM and FWGM.

Figure 3 gives a quick view of differences in ranks based on the PTWM and FWGM. Out of 14 cases, six banks are ranked the same by both methods, and there is difference of 1 in the ranking of five cases. A huge difference in the rank can be observed in the case of HSBC Bank Peru, followed by Banco Falabella and Banco Continental BBVA, with differences in ranking by 5, 4, and 2 respectively.

### ***Robustness of Efficiency Scores and Classification of Currently Existing Inefficient Banks***

In-depth analysis was conducted to check the robustness of efficiency scores for the existing banks in Peru for the last two years and classify the inefficient banks into four groups. To test the robustness of the DEA results with respect to outliers, the jackknifing procedure was applied wherein a DEA analysis was conducted that dropped out each efficient bank one at a time from the analysis. Unlike Bonesronning and Rattso (1994), who dropped each bank one at a time, only the efficient banks that construct the frontier were dropped in this study, as suggested by Mostafa (2010). As such, nine additional DEA analyses were conducted using the model given in System (1). The similarity of efficiency rankings was tested with the model for all the banks included, dropping out each efficient bank one at a time using the Spearman  $r$  and Kendall  $\tau$  (b) rank correlation coefficient. As can be observed in Table 3, the correlation coefficients were all positive and significant at the 99% level of confidence in both years. An one sample  $t$ -test is conducted to test if the overall mean efficiency of banks differs significantly with the mean efficiency of banks after the removal of efficient banks one at a time from the analysis. The results do not reveal any significant differences between the said mean efficiency scores in either of the years, further confirming the robustness of the efficiency analysis.

Table 3  
*Jack-Knifing Analysis of Efficiency*

<i>Bank Removed from analysis</i>	<b>2008</b>					<b>2009</b>				
	<i>Mean TE</i>	<i>Correlation</i>		<i>NEB</i>	<i>New Bank in the Reference Set</i>	<i>Mean TE</i>	<i>Correlation</i>		<i>NEB</i>	<i>New Bank in the Reference Set</i>
		$\rho$	$\tau(b)$				$\rho$	$\tau(b)$		
Banco Continental BBVA	0.9308	0.848*	0.755*	7	Banco Interamericano de Finanzas	0.9544	0.873*	0.851*	7	Banco Interamericano de Finanzas
Banco de Credito	0.9213	0.960*	0.901*	6	Banco Santander Peru	0.9443	1.000*	1.000*	6	None
Banco Financiero	0.9126	1.000*	1.000*	5	None	-	-	-	-	-
Citibank Peru	-	-	-	-	-	0.9539	1.000*	1.000*	6	None
Mibanco	0.9107	1.000*	1.000*	5	None	-	-	-	-	-
HSBC Bank Peru	-	-	-	-	-	0.9491	0.936*	0.884*	7	Banco Financiero
Banco Falabella	0.9107	1.000*	1.000*	5	None	0.9475	0.911*	0.884*	7	Mibanco
Banco Santander Peru	-	-	-	-	-	0.9442	0.968*	0.951*	7	Scotiabank Peru
Banco Ripley	0.9205	1.000*	1.000*	5	None	0.9434	1.000*	1.000*	6	None
<b>One Sample t test</b>	<i>Test value = 0.9170, p-value = 0.830</i>					<i>Test value = 0.9474, P-Value = 0.697</i>				

Note. (i) \* indicates the correlation coefficient is statistically significant at a 99% level of confidence (ii) Test value in one sample t-test is the mean efficiency of all 14 banks in the sample (iii) NEB denotes the number of efficient banks.

Table 4 provides the classification of inefficient banks under four different categories during the last two years under study. The most inefficient banks are Banco Azteca and Banco de Comercio in both the years. This is consistent (although not necessary) with their ranking as 14 and 12 respectively, as shown in Table 2. The banks classified as marginally inefficient and whose performances are close to their peers are Banco Interamericano de Finanzas and Banco Santander Peru in 2008 and Banco Financiero and Scotiabank Peru in 2009. The banks

whose performances are below the median are Interbank in both the years and Citibank Peru in 2008. Finally, Scotiabank Peru and HSBC Bank Peru in 2008 and Banco Interamericano de Finanzas and Mibanco in 2009 are above median performers. Of note, the ranking of the banks may not necessarily be consistent with their current year of performance as indicated here because these banks are ranked (see Table 2) based on their performance over the period.

Table 4  
*Classification of Inefficient Banks*

Year	Category I (Most Inefficient)	Category II (Below Median)	Category III (Above Median)	Category IV (Marginally Inefficient)
2008	Banco Azteca, Banco de Comercio	Interbank, Citibank Peru	Scotiabank Peru, HSBC Bank Peru	Banco Interamericano de Finanzas, Banco Santander Peru
2009	Banco Azteca, Banco de Comercio	Interbank	Banco Interamericano de Finanzas, Mibanco	Banco Financiero, Scotiabank Peru

Note. The “most inefficient” category includes those banks which have TE scores below the first quartile. “Below median” banks are included in the category whose TE lies between the first and second quartile. The “above median” consists of the banks wherein TE scores lie between the second and third quartile. The banks with TE scores above the third quartile are included in the “marginally inefficient” category. For 2008,  $Q_1 = 0.8776$ ,  $Q_2 = 0.9098$ ,  $Q_3 = 0.9450$  and for 2009,  $Q_1 = 0.8642$ ,  $Q_2 = 0.8972$ ,  $Q_3 = 0.9731$ .

### **Potential Improvements of Inputs and Outputs for Inefficient Banks**

DEA establishes a best practice group of units for each inefficient unit and quantifies the amount of potential improvement. In simple terms, DEA indicates the level of resources savings and/or services improvements possible for each inefficient unit if it is to achieve the level of efficiency of the best practice units. It is computed by comparing the input and output of each bank with the inputs and outputs of its efficient set of reference banks. These efficient sets of reference banks are banks that operate under circumstances similar to that of the bank being compared, but have 100% efficiency. Table 5 reports the peer information for each inefficient bank for the last two years of the study period. As observed, Banco Continental BBVA is the reference DMU for most of the inefficient banks with a frequency of 6 out of 8 in 2008 and 5 out of 7 in 2009 Banco de Credito and Banco Ripley, each with a frequency of 4 out of 8 in 2008, and Banco Falabella and HSBC Bank Peru follow it, with the respective frequency of 5 and 3 out of 7 in 2009.

Table 5  
*Peers for Inefficient Banks*

DMU	Name of the Bank	2008	2009
2	Banco de Comercio	Banco Continental BBVA, Banco Financiero	Banco Continental BBVA, HSBC Bank Peru, Banco Falabella
5	Banco Financiero	–	Banco Continental BBVA, HSBC Bank Peru, Banco Falabella
6	Banco Interamericano de Finanzas	Banco Continental BBVA	Banco Continental BBVA
13	Citibank Peru	Banco Continental BBVA, Banco de Credito, Banco Ripley	–
14	Interbank	Banco Continental BBVA, Banco de Credito, Banco Ripley	Banco Continental BBVA, Banco de Credito, Banco Falabella
15	Mibanco	–	Banco Continental BBVA, HSBC Bank Peru, Banco Falabella
16	Scotiabank Peru	Banco Continental BBVA, Banco de Credito, Banco Ripley	Banco de Credito, Citibank Peru, Banco Santander Peru
17	HSBC Bank Peru	Banco Continental BBVA, Banco Financiero	–
19	Banco Santander Peru	Banco de Credito	–
21	Banco Azteca	Banco Falabella, Banco Ripley	Citibank Peru, Banco Falabella

The potential percentage improvements of different inputs and outputs for the current two years are reported in Table 6. The statistics indicate by how much and in what areas an inefficient DMU needs to improve in order to be efficient. This information can enable targets to be set that could help guide inefficient banks to improve their performances. As observed, given the level of deposits and costs, tremendous potential for improvement exists in the output OEA for Banco Azteca, followed by HSBC Bank Peru, Banco Interamericano de Finanzas, and Banco de Comercio in 2008. Similarly, the bank with a very high potential improvement level in total loans was observed to be Banco Azteca, followed by Banco Santander Peru, Banco de Comercio, Interbank, and Citibank Peru. However, remarkable improvement in the efficiency of the inefficient banks in the year 2009 exists, resulting in considerable reduction in their potential level of improvements for two outputs. Nevertheless, Banco Azteca has still more scope for improvement, as much as 42.34% in the total loans as well as in OEA. Given the current level of outputs, the total cost of the above bank should be controlled by more than 50%. The other banks needing to focus on increasing the quantity of loans and OEA are Banco de Comercio, Interbank, and Banco Interamericano de Finanzas.

Table 6  
*Potential Improvement of Inputs and Outputs (in %)*

DMU	Name of the Bank	2008				2009			
		<i>Deposit</i>	<i>Cost</i>	<i>Loans</i>	<i>OEA</i>	<i>Deposit</i>	<i>Cost</i>	<i>Loans</i>	<i>OEA</i>
1	Banco Continental BBVA	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	Banco de Comercio	0.00	0.00	20.13	207.05	0.00	0.00	16.82	16.82
3	Banco de Credito	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	Banco Financiero	0.00	0.00	0.00	0.00	0.00	0.00	2.64	2.65
6	Banco Interamericano de Finanzas	-12.96	0.00	3.96	329.61	-4.59	0.00	11.46	26.49
13	Citibank Peru	0.00	0.00	11.55	11.55	0.00	0.00	0.00	0.00
14	Interbank	0.00	0.00	12.03	12.03	0.00	0.00	14.64	14.64
15	Mibanco	0.00	0.00	0.00	0.00	0.00	0.00	2.88	2.88
16	Scotiabank Peru	0.00	0.00	8.33	8.33	0.00	0.00	1.04	1.04
17	HSBC Bank Peru	0.00	0.00	6.45	15163.80	0.00	0.00	0.00	0.00
18	Banco Falabella	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	Banco Santander Peru	-9.25	0.00	40.51	3.05	0.00	0.00	0.00	0.00
20	Banco Ripley	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	Banco Azteca	0.00	0.00	136.85	25097.84	0.00	-51.2	42.34	42.34

## Conclusion

In this study, the DEA technique was used to measure the efficiency of Peruvian banks and benchmark the currently existing banks during the post-reform period over the last 10 years based on the Fibonacci weighted geometric mean approach. On average, the technical efficiency shows improvement during the period 2000 to 2009. The results give a positive indication of the success of the reform process that resulted in an increase in the share of foreign banks and consolidation and privatization in the Peruvian banking sector. MNBs are performing better than domestic banks in terms of technical efficiency throughout the period except in the year 2007. In-depth analysis of existing banks for the final two years of the period under discussion shows the efficiency scores are robust. Among the 14 currently existing banks, Banco Ripley and Banco Santander Peru were the best performers, whereas Banco Azteca was the worst performer, followed by Interbank and Banco de Comercio. The findings further suggest that the currently existing inefficient banks should focus on policies to increase the number of loans as well other earning assets to improve efficiency performance on a par with best practice banks in Peru.

One of the limitations of the current study is that it is based on the intermediation approach and thus the production or value-added approach could be considered to give further insight on banks' efficiency. Another meaningful task to be fulfilled in future research could be to have a pre-liberalization as well as post-liberalization efficiency analysis, which may allow for comparison of results to see the effect of reforms in the banking sector, subject to the availability of data. Further, the current study could have applied the stochastic aspect of the DEA to capture stochastic noise for input and output data. On a positive note, the study is the first serious attempt to analyze the efficiency of the banking sector in Peru.

## Footnotes

- 1 A *financiera* is a type of financial institution that obtains resources from the public, and its specialty is to facilitate the placement of primary securities issues, operate with bearer securities, and render advice of a financial nature.
- 2 See Carletti, Hartmann, and Spagnolo (2005), Yanelle (1997), Scholtens (2000), and Canoy, Dijk, Lemmen, Mooij, and Weigand (2001) for a survey of the literature.
- 3 See Matutes and Vives (2000) and Cordella and Yeyati (2002) for an analytical discussion along these lines. The increase in concentration resulting from the elimination of branching restrictions in the USA is studied, for example, in Economides et al. (1995). See also Schargrodsky and Sturzenegger (2000) for a related study of the Argentinean banking sector.
- 4 For the USA case, see Avery, Bostic, and Samolyk (1998), Kroszner and Strahan (1998), Strahan and Weston (1996). For the EU case, see Vives (2001).
- 5 Reference set is a set where all DMUs under study are its member.
- 6 See Seiford and Zhu (1999) for a complete list of super-efficiency DEA models and the necessary and sufficient conditions for the infeasibility of various super-efficiency DEA models.
- 7 See Sealey and Lindley (1977) for a detailed discussion.
- 8 An increase in the number of outputs or inputs leads to an increase in efficiency scores. In small samples with many variables, almost all units may be on the frontier.
- 9 The production approach focuses on the bank's operating costs, that is, the cost of labor (employees) and physical capital (plant and equipment). The intermediary approach considers a financial firm's production process to be one of the financial intermediaries (the borrowing of funds and subsequent lending to these funds). In the intermediary approach, the focus is on the total costs, including both interest and operating expenses.

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