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THE EVOLUTION OF EFFICIENCY IN COSTA RICAN BANKING SYSTEM 2005-2015: EVIDENCE FROM DATA ENVELOPMENT ANALYSIS

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ABSTRACT

In this study the technical and scale efficiency of Costa Rican banking system is estimated for the 2005-2015 period, through the Data Envelopment Analysis (DEA). The estimations are within the approach of variable returns to scale with slacks developed by Banker, Charnes, and Cooper (1984) and the constant returns to scale approach developed by Charnes, Cooper, and Rhodes (1978). Efficiency scores were estimated annually for each bank to get the average for state banks, private banks, and the whole system. The inputs and outputs considered in the DEA model were defined through the intermediation approach. Through the application of DEA was concluded that a) for the whole system there are no clear efficiency improvements during the period analyzed, b) the most efficient banks were Banco BCT and Banco General, c) private banks were on average more efficient than state banks and d) the goods of net use were, on average, the input with bigger slack.

KEYWORDS: EFFICIENCY FRONTIER, TECHNICAL EFFICIENCY, BANKING, LINEAR PROGRAMMING, RESOURCE MANAGEMENT.

RESUMEN

En esta investigación se estima el nivel de eficiencia técnica y de escala para el sistema bancario costarricense para el periodo 2005-2015 mediante la metodología de Análisis Envolvente de Datos (AED). Las estimaciones se realizan desde la perspectiva de rendimientos variables de escala con variables de holgura desarrollada por Banker, Charnes, y Cooper (1984) y rendimientos constantes de escala desarrollada por Charnes, Cooper, y Rhodes (1978). Los niveles de eficiencia se estiman anualmente de forma individual para cada entidad bancaria para obtener promedios para el sistema total, segmento privado y estatal. Los insumos y productos considerados el modelo fueron definidos de acuerdo al enfoque de intermediación. Mediante la aplicación de los modelos AED se concluye que a) no hay evidencia de mejoras en el nivel de eficiencia técnica y de escala del sistema bancario durante el periodo analizado, b) los bancos más eficientes fueron el Banco BCT y el Banco General, c) los bancos privados son en promedio más eficientes que los estatales y d) los bienes de uso neto son el insumo con mayor nivel de holgura.

PALABRAS CLAVE: FRONTERA DE EFICIENCIA, EFICIENCIA TÉCNICA, BANCA, PROGRAMACIÓN LINEAL, GESTIÓN DE RECURSOS.

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I. INTRODUCTION

In this study is estimated the technical and scale efficiency of Costa Rican banking system for the 2005-2015 period, through the Data Envelopment Analysis (DEA). The estimations are within the approach of variable returns to scale with slacks developed by Banker, Charnes, and Cooper (1984) and the constant returns to scale approach developed by Charnes, Cooper, and Rhodes (1978). Efficiency scores were estimated annually for each bank to get the simple average for state banks, private banks, and the whole system. The inputs and outputs considered in the DEA model were defined through the intermediation approach.

The study of efficiency for the Costa Rican banking has been developed mostly with the intermediation margin approach and some financial ratios, omitting efficiency perspectives such as the technical and scale. For instance, Camacho and Mesalles (1994), estimated the efficiency levels through several margin measures for the 1987-1992 period. Loría (2013), followed the same approach for the 1988-2013 period, determining margins by currency. Finally, Villamichel (2015) follows the same method than previous authors for the period 1995-2015, nevertheless, added the analysis of the administrative expense to assets ratio.

The application of DEA to Costa Rican banking is entirely new; although, the study follows the methodological framework applied by several authors to non-financial research. Some of them are, Xirinachs (2012) who estimated bayesian DEA models for the first level of health attention in the Caja Costarricense del Seguro Social (CCSS), she found out that for the period 2004-2010 the average technical efficiency was between 83.58% and 110.29%, even some of the health areas reached super efficiency levels. Morera-Salas (2015) estimated technical efficiency of Costa Rican hospitals for the 2012-2013 period; the author concluded that 70% of hospitals had the margin to improve resources management. In an application oriented to environmental economics, Sneessens (2011), estimated technical efficiency for 37 Dos Pinos dairy bovine farms, the author concluded that the farms could reduce environmental impact by 20.6% parallel with an 18.8% cost reduction. And Segura, Loaiza, and Valverde (2015), estimated the technical efficiency of the municipal aqueducts in Costa Rica.

Although the DEA method has not been applied to financial economics in Costa Rica, it has been widely used in other regions. For example, Pirateque, Piñeros and Mondragón (2013) use the DEA for studying the technical, cost and allocative efficiency for the Colombian banking system for the 2000-2012 period. The focus of the survey is on individual production functions to incorporate several financial inputs and outputs. The authors conclude that in the first years of 2000 decade, the efficiency levels were very low, nevertheless, in the following years, a remarkable improvement was observed, and local firms were more efficient than foreign ones.

Figueira, Nellis and Parker (2006) study the performance of several banking systems in the north and sub-Saharan Africa. The study is oriented to determine if the property of the banks is a driver of its efficiency. To reach the goal of the survey, the author employed performance ratios, stochastic frontier, and DEA method. The authors concluded that local private banks did not have higher efficiency levels compared to state banks, nevertheless, when the property of private banks was foreign was observed superior efficiency levels.

II. METHODOLOGY

The method used to estimate technical, and scale efficiency scores are the so-called DEA models, input-oriented with variable (BCC) and constant (CCR) returns to scale. Besides the efficiency levels, are estimated slack variables, which indicates the maximum reduction in the input to stay in an optimal condition. It is important to mention that the efficiency levels were estimated for each year during the period 2005-2015.

The model

The efficiency score with variables returns to scale is obtained through the following linear program.

$$\theta^* = \min \theta$$

Subject to:

$$\begin{cases} \sum_{j=1}^{n} \lambda_j z_{ij} \leq \theta z_{i0} \quad i = 1, 2, \dots, m; \\ \sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{r0} \quad r = 1, 2, \dots, s; \\ \sum_{j=1}^{n} \lambda_j = 1 \\ \lambda_j \geq 0 \quad j = 1, 2, \dots, n \end{cases}$$

Where, θ^* is an optimum scalar equal or lower than 1, λ is a $nx1$ vector of constants, z is a matrix of inputs with as many rows as inputs and as many columns as DMUs (Decision making unit, for this study the banks), y is a matrix of outputs with as many rows as products and as many columns as DMUs.

The efficiency scores with constant returns to scale can be obtained with the same model by taking out the convexity constraint $\sum_{j=1}^{n} \lambda_j = 1$. According to Schuschny (2007), the total efficiency is the product of the pure technical efficiency by scale efficiency, consequently scale efficiency is obtained by the following cocient.

$$SE = \frac{CCR\ Efficiency\ score}{BCC\ Efficiency\ score}$$

After solving the linear program is possible to estimate the slacks in the inputs, the slacks are defined in the following way:

$$s_i^- = \theta^* z_{i0} - \sum_{j=1}^{n} \lambda_j z_{ij} \quad i = 1, 2, \dots, m$$

$$s_r^+ = \sum_{j=1}^{n} \lambda_j y_{rj} - y_{r0} \quad r = 1, 2, 3, \dots, s$$

Given the above definitions, the slacks in the inputs are calculated through the following linear program.

$$\max \sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+$$

Subject to:

$$\begin{cases} \sum_{j=1}^{n} \lambda_j z_{ij} + s_i^- = \theta^* z_{i0} \quad i = 1, 2, \dots, m; \\ \sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{r0} \quad r = 1, 2, \dots, s; \\ \sum_{j=1}^{n} \lambda_j = 1 \\ \lambda_j \geq 0 \quad j = 1, 2, \dots, n \end{cases}$$

Slacks model provide information about the efficiency condition of each DMU. If the optimum scalar θ^*=1 and s_i^-= s_r^+ = 0 the DMU is strongly efficient. If θ^*=1, but $s_i^- \neq 0$ and $s_r^+ \neq 0$, the DMU is weakly efficient, which means the DMU is efficient, although it has the possibility to improve its score by decreasing some inputs. The results are obtained through the linear programming add-in for spreadsheets Solver. The results of scale efficiency, pure technical efficiency and slacks are presented as the simple average of all DMUs for each year for the period 2005-2015.

The sample, sources, and variables

All data required to calculate efficiency levels was annual and was gotten from the General Superintendency of Financial Institutions of Costa Rica website (SUGEF by its initials in Spanish), the data was taken from the balance sheet and income statement in financial analysis format for 12 private banks and 4 state banks.

TABLE 1
SAMPLES

Type	Bank	Sample	Type	Bank	Sample
State Bank	Banco Popular	2005-2015	Private Bank	Banco General	2007-2015
State Bank	Banco Crédito Agrícola	2005-2015	Private Bank	Banco Improsa	2005-2015
State Bank	Banco de Costa Rica	2005-2015	Private Bank	Banco Lafise	2005-2015
State Bank	Banco Nacional	2005-2015	Private Bank	Banco Promerica	2005-2015
Private Bank	BAC San José	2005-2015	Private Bank	Prival Bank	2010-2015
Private Bank	BCT	2005-2015	Private Bank	Scotiabank	2005-2015
Private Bank	Cathay	2005-2015	Private Bank	Citibank	2005-2015
Private Bank	Davivienda	2005-2015	Private Bank	CMB	2015

Source: own elaboration

The variables selected as inputs and outputs were defined according to the intermediation approach employed by Benston, Hanweck and Humphrey (1982), Murray and White (1983), H.Y Kim (1986), M. Kim (1986), and Mester (1997). The following table shows the way in which the inputs and outputs were elaborated[2].

TABLE 2
VARIABLES

Output	Loans	Loans with aging <= 90 days
		Loans with aging > 90 days and legal collection
	Investments	Investments in securities
Input	Labour	Staff expenses
	Capital	Goods of net use
	Deposits	Short term deposits (Interest bearing)
		Long term deposits (Interest bearing)
		Current account deposits (Interest bearing)
		Short term deposits (Non-Interest bearing)
		Other short term liabilities with the public (Non-Interest bearing)
		Other long term liabilities with the public (Non-Interest bearing)

Source: own elaboration

2 The changes in the chart of accounts implemented in 2008 do not affect the results for the 2005-2007 period due to the models are based on aggregate accounts not in speficic items, the re-classification of sub-accounts does not modify the inputs and outputs as aggreagated items.

There is the possibility of no homogeneity in the results, nevertheless the DMUs are not classified into homogeneous groups due to by grouping, the sample size can be reduced and consequently the discriminatory power of the models will be diminished. Zhu (2014), suggests that the number of DMUs should be two or three times the number of inputs and outputs together to avoid a power reduction in the models. Then, to analyze more homogeneos results is applied the the Modified Thompson Tau (MTT) statistic for determining outliers. The MTT statistic is given by:

$$\tau = \frac{\delta(n-1)}{\sqrt{n}\sqrt{n-2+\delta^2}}$$

Where n is the sample size and δ is a t-student distribution with α=0.05 and n-2 freedom degrees. An outlier is any efficiency score θ associated to a Δ that is bigger than $\varphi^{*}\tau$, where $\Delta_i = \left|\theta_i - \overline{\theta}\right|$ and φ is the standard deviation of the sample (see appendix 4). The outliers are taken out from the simple average for the aggregate banking system.

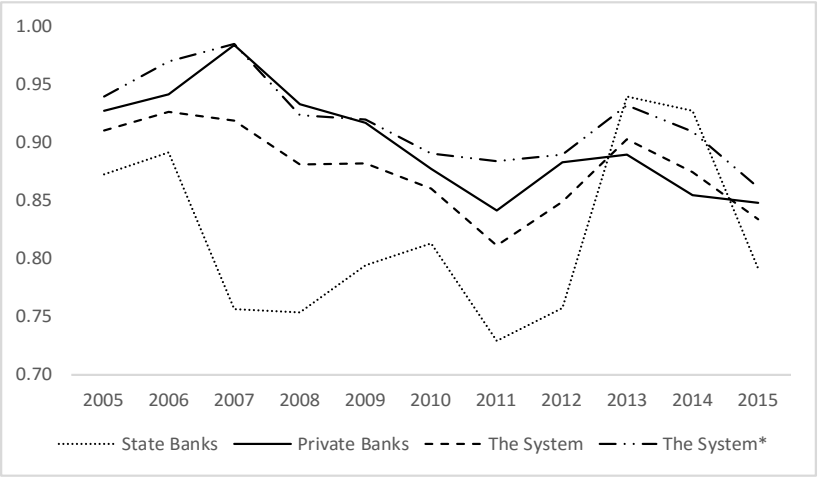
III. RESULTS

Efficiency scores

The application of DEA methodology to Costa Rica banking system reflects several important facts to highlight. The results of CCR model for the period 2005-2015 points out that private banks were more efficient than state banks, being above of the average of the system. The gap between the state and private banks is from 2007 to 2009, after that period the efficiency average for both groups of banks followed a similar trend, as a consequence of the high increase of state banks efficiency during 2012 and 2013, as can see observed in the chart 1.

The chart 1 shows a suggestive behavior of efficiency levels during the financial crisis period, in which both groups of banks decreased its scores, state banks in a more accelerated way than private banks. Nevertheless, the chart is very suggestive is not possible state a formal causal relation.

CHART 1
TECHNICAL EFFICIENCY COSTA RICAN BANKING SYSTEM 2005-2015
INPUT-ORIENTED CONSTANT RETURNS TO SCALE



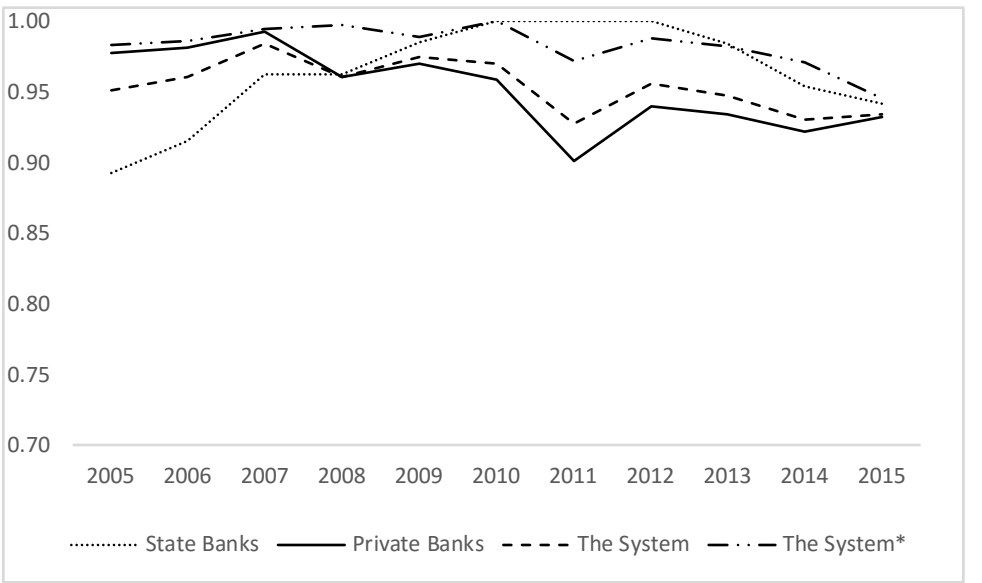
*Without outliers
Source: own elaboration

Regarding the individual CCR scores, it is important to mention that the ranking is led by two small banks, Banco General and Banco BCT. The CCR model works assuming constant returns to scale; this means that not necessarily big banks as BAC San José or Banco Nacional can reach efficiency levels by its size. The ranking shows that the only one state bank above of a 0.80 score is the Banco Crédito Agrícola de Cartago, the rest of them occupy the latest positions (see Appendix 1).

From the variable returns to scale perspective, the results show the opposite situation than CCR, starting 2008 until 2014 the average efficiency of state banks is higher than private banks, even reaching three consecutive years the maximum score of 1 as can be observed in Chart 2. This situation suggests that there is a substantial effect of the scale efficiency on the total technical efficiency scores.

The individual BCC results show another reality of efficiency levels for Costa Rican banks, as already stated by the DEA theory, all BCC scores are bigger than CCR. The ranking is led by Banco BCT, Banco General, BAC San José, and Davivienda from the private side. Something new in this ranking is that includes the two state banks that reached the maximum score of efficiency, Banco Nacional and Banco Popular (see Appendix 2).

CHART 2
TECHNICAL EFFICIENCY COSTA RICAN BANKING SYSTEM 2005-2015
INPUT-ORIENTED CONSTANT RETURNS TO SCALE



*Without outliers
Source: own elaboration

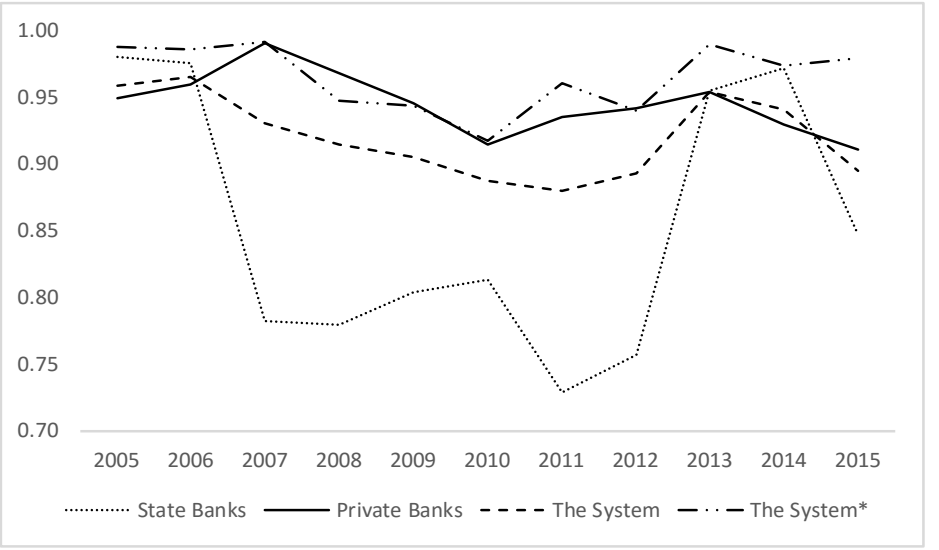
According to Chapin and Schmidt (1999), a DMU has two ways to be inefficient. First, it produces the output with more inputs than necessary or even being on the variable returns to scale efficiency frontier; the DMU provides a smaller or larger output than the efficient scale.Under that situation, the ratio of output produced per input is not maximized, the point in which is maximized is where CRS and BBC intersect, it means efficiency scale is 1.

For the period analyzed was observed that state banks were the DMUs with bigger scale inefficiencies, as was noticed in BCC results, state banks presented the maximum efficiency score of 1 for several periods reaching higher scores than CCR. Nevertheless, they are not minimizing the inputs

because of scale inefficiencies. The central gap is observed during the 2006-2012 period in which reached a minimum level of 0.73. The private counterparty presented more stable result for the whole time, reaching a minimum level of 0.91 in 2010 and 2015, as can be observed in Chart 3.

From the individual perspective can be highlighted that the Banco General and Banco BCT, were the only banks that operated under optimum scale for the whole period analyzed, it means for the 11 years the CCR and BCC results were 1. From the state side the, the most efficient bank is the Banco Crédito Agrícola de Cartago with an average of 0.94 occupying the position 10 in the ranking. Followed by Banco Popular ranked 12, Banco Nacional ranked 13 and Banco de Costa Rica in the position 15 out of 16 DMUs (See Appendix 3).

CHART 3
SCALE EFFICIENCY COSTA RICAN BANKING SYSTEM 2005-2015
INPUT-ORIENTED



*Without outliers
Source: own elaboration

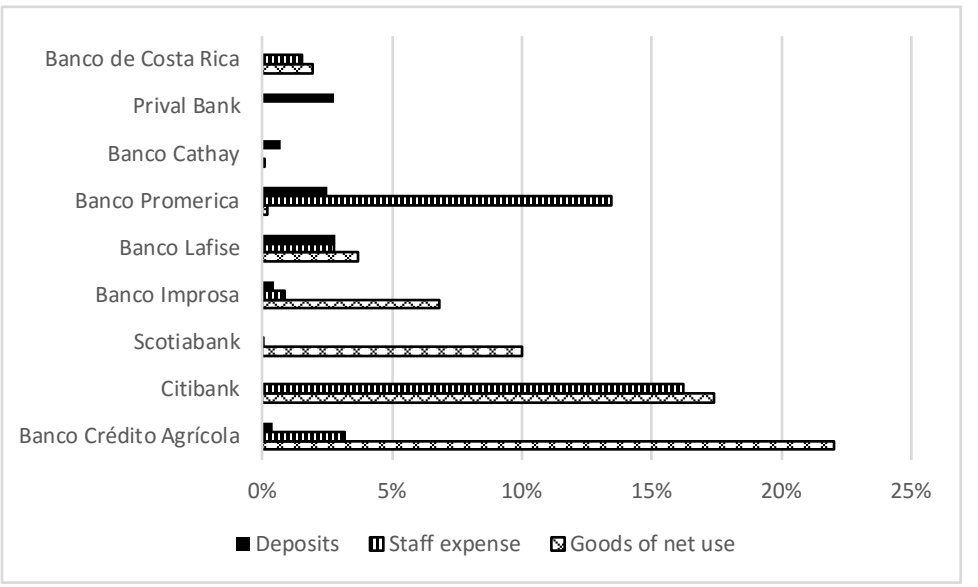
Slack variables

The analysis of slack variables shows several facts, the use of slacks allowed to determine that for the period studied six out of sixteen banks accomplish the strong efficiency condition; it means they do not need any input reduction to reach the efficiency frontier, they have achieved a Pareto optimal condition. These institutions are Banco Nacional de Costa Rica, Banco Popular y de Desarrollo Comunal, BAC San José, Banco BCT, Banco General and Davivienda. It is important to mention that these six institutions achieved the strong efficiency condition under variable returns to scale. Although, some of them are scale inefficient. A remarkable fact is the outstanding performance of Banco BCT and Banco General, which for the whole period studied were on the technical and scale efficiency frontier with no slacks in their inputs.

The results indicate the goods of net use as the input with more possibilities to be reduced; this fact is more visible in private banks than state banks, seven out of nine banks with slacks are private. Nevertheless, the maximum reduction in goods of net use for the period analyzed is shown by Banco Crédito Agrícola de Cartago with 22% followed by Citibank with 17%.

Regarding staff expense, is observed that the inefficiency is present more in private banks that state banks, Citibank and Banco Promerica are the ones that could implement staff reduction, of 16% and 13% respectively, to reach efficiency frontier. State banks do not arrive at a possible reduction of 5%. Regarding the deposits reduction, is remarkable that the output of the model should not be read literally as the deposits frequently work like funding for loans. Consequently, instead of a deposits reduction could be interpreted as the best management of deposits. The slack in deposits could be used to generate more revenue by increasing credit or generating more investments. For the Costa Rican banking system was not observed significant slacks in deposits for the period analyzed.

CHART 3
SLACKS COSTA RICAN BANKING SYSTEM 2005-2015
INPUT-ORIENTED



Source: own elaboration

IV. CONCLUSIONS

First is important to highlight that the conclusions must be read carefully as the DEA models are not able to capture drivers of efficiency such as management strategy, special projects or similars. In general, no clear trend shows significant improvements in the efficiency of the whole banking system during the period analyzed. Although, it was possible to determine that private banks were, in average, more efficient than state banks. This fact means private banks were more talented to produce credit and investments with less staff expense, deposits, and property plant and equipment.

For the period analyzed, private banks were, in average, more efficient than state banks under constant returns to scale. Under variable returns to scale, state banks reached high-efficiency levels. Nevertheless, this fact is offset by scale inefficiencies; wich means state banks do not operate on the optimal production plant size. Regarding efficiency scores, the Banco BCT and Banco General present the higher ones for constant returns to scale, variable return to scale and scale efficiency with no slacks so that they can be classified as the most efficient banks for the 2005-2015 period.

It was determined that the goods net use was the input with the bigger slacks, this means the banks out of the efficiency frontier have more property, plant, and equipment than the required to

produce the output levels they present. Regarding staff expense and deposits, the first presents slacks in seven banks; nevertheless, just Banco Crédito Agrícola de Cartago and Citibank were higher than 5%. In the case of the latest, there is no evidence of inefficiencies.

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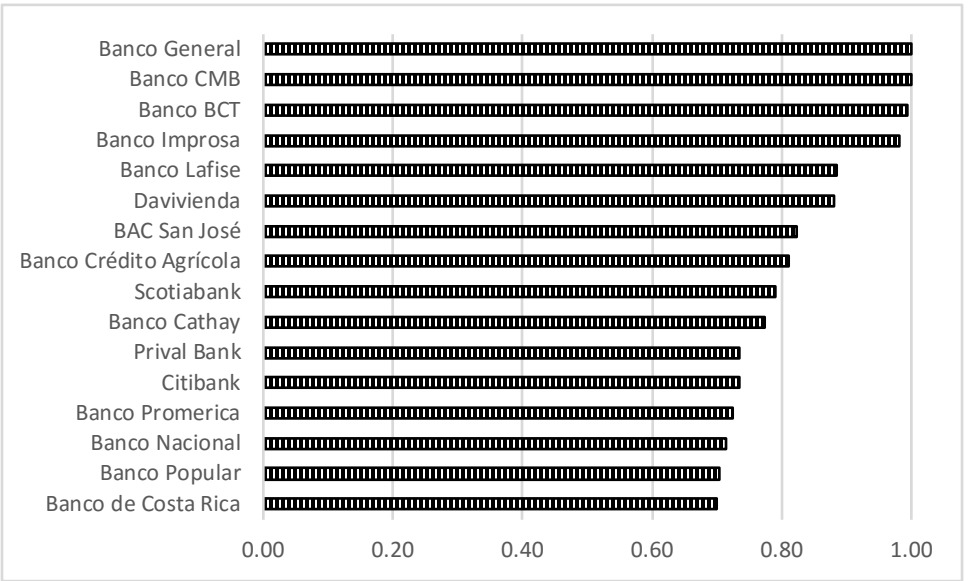
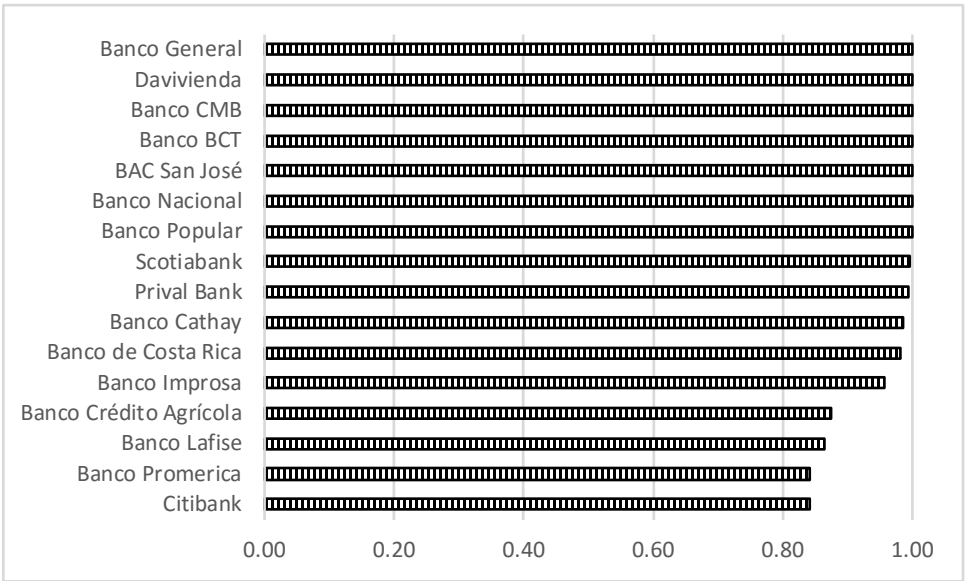
APPENDIX

APPENDIX 1
AVERAGE TECHNICAL EFFICIENCY COSTA RICAN BANKS 2005-2015
INPUT-ORIENTED CONSTANT RETURNS TO SCALE



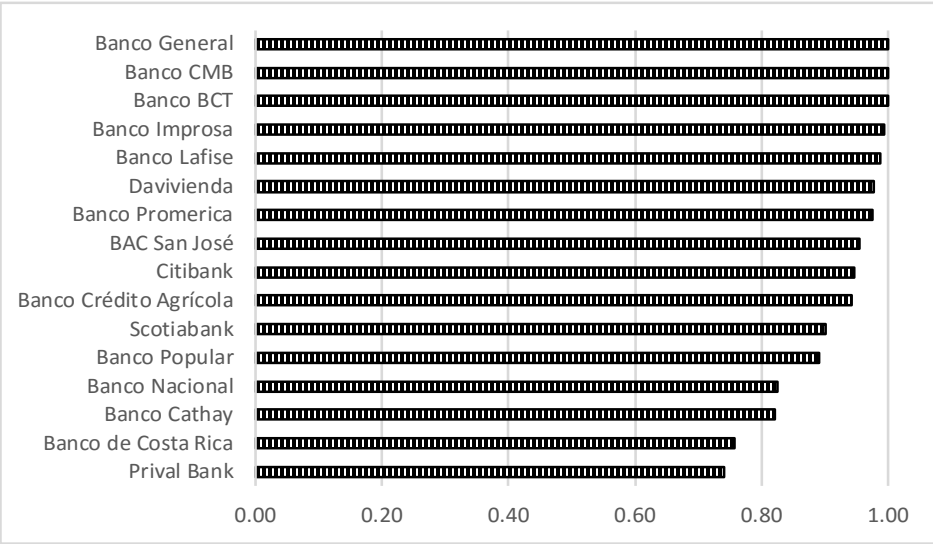
Source: own elaboration

APPENDIX 2
AVERAGE TECHNICAL EFFICIENCY COSTA RICAN BANKS 2005-2015
INPUT-ORIENTED VARIABLE RETURNS TO SCALE



Source: own elaboration

APPENDIX 3
AVERAGE SCALE EFFICIENCY COSTA RICAN BANKS 2005-2015
INPUT-ORIENTED



Source: own elaboration

APPENDIX 4
OUTLIERS (INEFFICIENT DMUS)

CCR MODEL										
2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
BCAC	BCAC	BCAC	BCR	BCR	BCR	BNCR	BNCR	LAFISE	Citibank	PRIVAL
	BAC	BCR	CATHAY	BNCR	Citibank	Citibank	BCR	Citibank	LAFISE	LAFISE
		BPDC				BCR				
BCC MODEL										
2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
BCAC	BCAC	BCAC	LAFISE	PROMERICA	PROMERICA	Citibank	LAFISE	LAFISE	LAFISE	LAFISE
			CATHAY		Citibank	IMPROSA	PROMERICA	Citibank	Citibank	Citibank
			BCR				IMPROSA			BCAC
SCALE EFFICIENCY										
2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
BAC	BAC	BCAC	BCR	BCR	CATHAY	PRIVAL	BNCR	BCR	PRIVAL	PRIVAL
CATHAY		BCR	BCAC	BNCR	BCR	BNCR	BCR	CATHAY	CATHAY	BCR
		BPDC				BCR		SCOTIABANK		BNCR
										SCOTIABANK
										CATHAY

Source: own elaboration