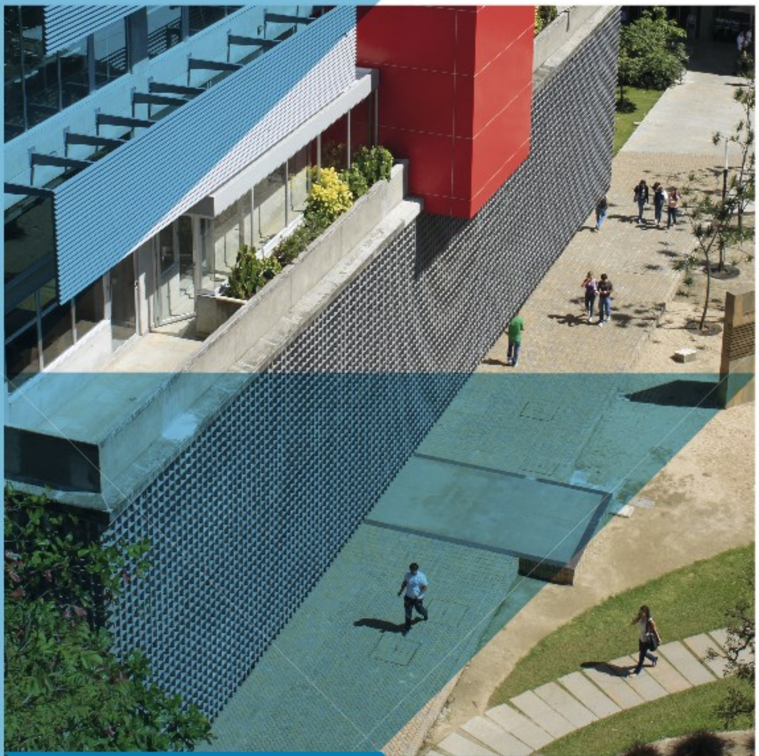

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Diego Restrepo-Tobón, Jim Sánchez-González

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Universidad EAFIT

Measuring Profit Efficiency of Colombian Banks: A Composite Nonstandard Profit Function Approach

Diego Restrepo-Tobón[*],
Jim Sánchez-González[†]

Center for Economics and Finance Research, School of Economics and Finance
EAFIT University, Medellin, Colombia

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Abstract

We analyze the profit efficiency of the Colombian banking industry during the period 2001 - 2013. Unlike previous studies, we estimate revenue and cost efficiency separately and then compute profit efficiency as a composite measure of both cost and revenue efficiency. This approach overcomes the mis-specification problems of the traditional nonstandard profit function approach used in most of the literature regarding profit efficiency. We find that profit efficiency improved during the period under analysis mainly because gains in revenue efficiency. In addition, and in contrast with previous studies but in line with economic intuition, we find that while revenue and cost efficiency tend to be negatively correlated, each correlates positively with profit efficiency. Thus, improving either revenue efficiency or cost efficiency has a positive impact on profit efficiency.

Keywords: Profit Efficiency, Revenue Efficiency, Cost Efficiency, Nonstandard Profit Function, Stochastic Frontier

JEL Classification: D24, G21, G34, L13

[*]Associate Professor of Finance, EAFIT University, Colombia. Email:drestr16@eafit.edu.co
[†]MSc. in Finance student at EAFIT University, Colombia. Email: jsanch83@eafit.edu.co

1 Introduction

During the last two decades, Colombian financial sector experienced a significant consolidation process. From 1990 to 2007 more than 124 mergers and acquisitions took place. The number of banks decreased and their overall size increased during that period (ANIF, 2006; Garcia Suaza & Gomez Gonzalez, 2010). Policymakers, academics, and market participants explain this consolidation process as the result of potential benefits from exploiting economies of scale, increasing productivity, as well as increasing market power.

The literature concerning the microeconomic factors explaining the consolidation process of the Colombian banking industry is limited. As shown in section 2; no study investigates, systematically, the relation between cost, revenue, and profit efficiencies of Colombian banks. The available evidence permits to draw non-definitive conclusions regarding profit efficiency and its relation with the Colombian banking industry consolidation process. To our knowledge, this is the first paper investigating such a relation for the Colombian banking industry.

The most recent works addressing the efficiency of Colombian banks are Almanza Ramirez (2012); Cruz Diaz (2012); Quintero Otero and Garcia Rico (2006), and Estrada and Osorio (2004). Only the latter analyzes profit efficiency using the Nonstandard Profit Function (NSPF) approach developed in Humphrey and Pulley (1997) which has become the dominant method to estimate profit efficiency in the banking industry. The NSPF approach disregard the assumption of perfectly competitive markets in favor of the, more realistic, assumption that banks enjoy some degree of monopolistic power (Berger, Humphrey, & Pulley, 1996, Humphrey & Pulley, 1997, and Berger & Mester, 1997). Likewise, Berger and Mester (1997) argue that the NSPF is more appropriate for modeling banks' optimizing behavior because banks have more flexibility in choosing output prices than output quantities.

In the NSPF framework, banks maximize profits choosing output prices and input quantities while taking input prices and output quantities as given. The solution to the maximization problem yields the NSPF–a function of input prices and output quantities. However, the NSPF approach conceal how revenue and cost efficiencies contribute to profit efficiency. In this paper, we use a new method to estimate profit efficiency proposed by **?** named the Composite Nonstandard Profit Function (CNSPF). This method falls within the NSPF framework but makes explicit the links between revenue, cost, and profit efficiency. Explicitly, in the CNSPF approach, profit efficiency is a composite measure of cost and revenue efficiencies.

In the next section, we review the literature regarding the estimation of efficiency of Colombian banks. In Section 3, we present the methodology and the econometric model we use to estimate our efficiency measures. Briefly, we estimate revenue and cost inefficiency using a nonstandard revenue function (NSRF) proposed in Berger et al. (1996) and a standard cost function. Using revenue and cost (in)efficiencies, we compute the profit efficiency (CNSPF) measure as the ratio between actual and optimal profits without estimating a profit function itself. In addition, we obtain estimates of the characteristics of the technology through the cost function (e.g., returns to scale, technical change, etc.) which is not possible from the NSPF framework because it does not satisfy the duality results. In Section 4 we describe the data we use in the estimation and in Section 5 we present our empirical results. We conclude in Section 6.

2 Theoretical Framework

Colombian literature regarding banks efficiency focus mainly on estimating cost efficiency through different methodologies. Based on Humphrey and Pulley (1997)'s stochastic frontier model, Estrada and Osorio (2004) find that cost efficiency deteriorated from 1989 to 2003 while profit efficiency remained relatively stable. They conclude that the results are due to the existence of market power (specifically, collusive behavior and capture of oligopoly rents) in the Colombian banking industry. Yet, **?** show that the model used in Humphrey and Pulley (1997) is misspecified and consequently Estrada and Osorio's approach is also subject to the same criticisms. Hence, it is unknown if the evidence presented in their article (*"Effects of Financial Capital on Colombian Banking Efficiency"*) still holds when the correct model specification is used.

Quintero Otero and Garcia Rico (2006) show that financial liberalization contributed positively to cost efficiency for the Colombian banking industry from 1989 to 2003. However, they do not analyze the relationship between the efficiency and the consolidation process of the industry. Regarding the relationship between cost efficiency and consolidation processes, we find the studies of Castro (2001); Cruz Diaz (2012) and Almanza Ramirez (2012).

Castro (2001) investigates how cost efficiency changes as banks engage in mergers and acquisitions. He finds that after the consolidation processes of the 1990s, banks' cost efficient did not improve at all. Cruz Diaz (2012) gets a similar conclusion when she estimates X-Efficiency using a Distribution-Free Approach (DFA). Specifically, she finds that for eighteen Colombian banks during the 2008 - 2010 period there is no evidence to support that banks become more cost efficient after consolidation.

Using a different methodology but also analyzing cost efficiency, Almanza Ramirez (2012) uses a Data Envelope Analysis (DEA) approach to study technical and cost efficiency of Colombian banks from 1999 to 2007. He finds that variables like market concentration, financial development, and economic growth affect significantly the observed efficiency levels.

Gandur (2003b) attributes most of the efficiency gains in the Colombian banking industry from 1992 to 1998 to factors affecting the banking industry as a whole and to a lesser extend to bank-specific variables under the banks' control. Gandur (2003a) reviews all previous studies in the earlier literature on bank efficiency in Colombia. From his work, it is clear that only Estrada and Osorio (2004) investigate how mergers and acquisitions affected profit efficiency of banks. The other studies only focus on cost efficiency and some others in scale efficiency which we will pursue separately in another project.

In conclusion, the existing literature presents only weak evidence for the relation between profit and cost efficiency; and how these efficiencies affect the consolidation of the Colombian banking industry. To our knowledge, there is no study that investigate revenue efficiency for the Colombian banking industry. Besides, the existing literature regarding the relation among profits, revenues, and cost efficiencies of Colombian banks is, as much, very poor.

3 Methodology

In the Nonstandard Profit Function (NSPF) approach presented in Humphrey and Pulley (1997), banks maximize profits by choosing output prices and input quantities while taking input prices and output quantities as given. To estimate profit efficiency researchers add an efficiency term *ad hoc*, to then estimate efficiency using stochastic a frontier methodology. Analyzing U.S. commercial banks, **?** show that using such approach yields puzzling and contrasting results regarding the relation between profit, revenue, and cost efficiencies.

A more robust method to measure profit efficiency results by solving the maximization problem associated with the profit function (Eq. (1)). Since the revenue function and the cost function do not have parameters in common, maximizing equation (1) is equivalent to maximize the revenue function (Eq. (3)) and minimize the cost function (Eq. (4)).

$$\max_{p,x} \mathcal{L} = \sum_m p_m y_m - \sum_j w_j x_j + \lambda \left[A f(y, \theta \cdot x) - 1 \right] + \mu \left[g(\eta \cdot p, w) - 1 \right] \tag{1}$$

$$\max_{p,x} \mathcal{L} = \max_p \mathcal{L}_1 - \min_x \mathcal{L}_2 \tag{2}$$

$$\max_p \mathcal{L}_1 = \max_p \sum_m p_m y_m + \mu \left[g(\eta \cdot p, w) - 1 \right] \tag{3}$$

$$\min_x \mathcal{L}_2 = \min_x \sum_j w_j x_j - \lambda \left[A f(y, \theta \cdot x) - 1 \right] \tag{4}$$

From (3) and (4), the relation among maximum profit, maximum revenue, and minimum cost is given by:

$$\begin{aligned} \pi^a &= R^a - C^a \\ &= \sum p_m y_m - \sum w_j x_j \\ &= (1/\eta) \sum \eta p_m y_m - (1/\theta) \sum w_j \theta x_j \\ &= (1/\eta) \sum \phi_m(w, \tilde{y}) y_m - (1/\theta) \sum w_j \psi_j(\tilde{w}, y) \\ &= (1/\eta) R^*(w, y) - (1/\theta) C^*(w, y) \end{aligned} \tag{5}$$

Where π^a, R^a, and C^a stand for actual profit, actual revenue, and actual cost; while $R^*(w,y)$ and $C^*(w,y)$ represent maximum revenues and minimum cost, respectively. Thus, since $\eta \geqslant 1$ and $0 \leqslant \theta \leqslant 1$, actual revenues are a fraction of maximum revenues and minimum costs are a fraction of actual costs. Then, $0 \leqslant \eta^{-1} \leqslant 1$ is a measure of revenue efficiency and $0 \leqslant \theta \leqslant 1$ is a measure of cost efficiency. We can define profit efficiency as[1]:

$$\gamma(\eta,\theta) \equiv \frac{\pi^a}{\pi^*} = \frac{(1/\eta)R(w,y) - (1/\theta)C(w,y)}{\pi^*} = \frac{1}{\eta}\omega_1 + \frac{1}{\theta}\omega_2 \tag{6}$$

where $\omega_1 = R^*(w,y)/\pi^* \geqslant 0$ and $\omega_2 = -C^*(w,y)/\pi^* \leqslant 0$ with $\omega_1 + \omega_2 = 1$.

To estimate the cost and revenue efficiency, we use a translog functional forms[2] for the revenue and the cost functions and estimate revenue and cost efficiencies using stochastic frontier techniques.

The econometric specification we use is:

$$Ln\ Q_{it} = f(Ln\ y_{it}, Ln\ w_{it}, t) + \mu_{it} + \upsilon_{it} \tag{7}$$

Where:

$$\begin{aligned} \upsilon_{it} &\sim N(0, \sigma_\upsilon^2) \\ \mu_{it} &\sim N^+(0, \sigma_{it}^2) \\ \sigma_{it}^2 &= exp(\mathbb{Z}_{it}, \delta) \end{aligned} \tag{8}$$

Depending on the frontier being estimated, Q_{it} in equation (7) will be either $Revenue_{it}$, or $Cost_{it}$. The right-hand-side are outputs (y_i), input prices (w_i), and bank-specific characteristics (z_i). The estimated functions correspond to Nonstandard Revenue Function ($NSRF$), and the Cost Function ($Cost$). Additionally, υ_{it} is a normally distributed error term with zero mean and variance σ_υ^2; while μ_{it} is a one−side error term assumed to follow a half−normal distribution with zero mean and variance σ_{it}^2[3].

We follow the financial intermediation approach which regards banks as intermediary institutions using deposits, labor and physical capital to produce loans, investments, and other revenue-generating assets. The variables in the right-hand-side of equation (7) are:

- Outputs: Loans, investments, and other revenue generating assets.

[1] Using equation (5) and taking the ratio between actual (π^a) and maximum profits (π^*), we get the CNSPF efficiency measure presented in equation (6).

[2] The basic version of the translog function is $y = f(x_1, ..., x_n) = \alpha_0 \cdot \prod_{i=1}^{n} x_i^{\alpha_1} \cdot \prod_{i=1}^{n} x_i^{1/2\left[\sum_{j=1}^{n} \beta_{ij}\ Ln\ x_j\right]}$, which becomes $Ln\ y = Ln\ \alpha_0 + \sum_{i=1}^{n} Ln\ x_i + 1/2 \sum_{i=1}^{n}\sum_{j=1}^{n} \beta_{ij}\ Ln\ x_i Ln\ x_j$ after applying natural logs. For further details about this function's derivation and properties see Boisvert (1982).

[3] This assumptions are the standard ones in the literature; see for instance Kumbhakar and Lovell (2000)

- Inputs: Deposits, labor, and property, plant, and equipment.
- Input prices: Price of deposits (interest expenses over deposits), Price of labor (personnel expenses over total employees), and Price of capital (administrative expenses over property, plant, and equipment).

We also consider some variables to capture bank's particularities which have shown to induce heterogeneity biases when they are not considered in the efficiency estimation (Bos, Koetter, Kolari, & Kool, 2009). We include a dummy variable to differentiate if the bank is either national or foreign[4]; Credit Risk which is measured as the risky loans[5] over the total loans; Liquidity Risk is the proportion of liquid assets over total assets (a higher ratio is preferred because it makes banks more resilient in face of a crisis); Risk Exposure is the ratio between investments in securities compared to total assets; in this case, higher ratios mean more exposition to other institution's problems which is not desirable; finally, the Log of equity to account for banks' size.

4 Data

We compile information about banks' financial statements from the Superintendence of Finance of Colombia[6]. We include all Colombian banks with monthly information through the period 2001 - 2013 including banks that went bankrupt or merged with others within the period under analysis. We exclude, however, banks reporting negative values for assets, equity, outputs and prices[7]. We deflate all nominal values using the Consumer Price Index (CPI) published by the Administrative Department of National Statistics (DANE) which is updated in a monthly basis[8]. The final dataset is an unbalanced panel with 3,218 monthly observations for 32 banks.

Table 1 presents the summary statistics for the variables used in the stochastic frontier

[4] A bank is considered foreign if more that 50% of its assets are owned by an abroad subsidiary

[5] Colombian legislation requires that loans be classified into five categories according to the degree of expiration date of its amortization payments. The categories are: "A" if the payments are up-to-date, "B" if no payments have been done between one to three months, "C" if no payments have been done between three to six months, "D" if no payments have been done between six to twelve months, and "E" if no payments have been done in more than twelve months. In this context, risky loans for computing z_3 are those in the categories "D" and "E".

[6] Under Colombia's legislation banks are comprised to provide a copy of their financial statements to the Superintendence of Finance which is the main regulatory body for financial institutions in Colombia. These banks statements can be downloaded from the Superintendence of Finance's webpage at `https://www.superfinanciera.gov.co/jsp/loader.jsf?lServicio=Publicaciones&lTipo=publicaciones&lFuncion=loadContenidoPublicacion&id=60776`.

[7] Negative values in assets and equity are found when banks are in a closure or merging processes.

[8] The consumer price index can be got at `http://www.dane.gov.co/index.php/indices-de-precios-y-costos/indice-de-precios-al-consumidor-ipc`.

estimation. Inputs and outputs are computed as the nominal[9] value presented in each bank's balance sheet. We define three input variables: deposits (x_1); the number of employees (x_2); and property, plant, and equipment (x_3). Input prices (w_i) are computed as the ratio between the input associated and its nominal value.

Following the literature, we define three outputs: loans (y_1) which is the sum of real estate, consumption, and commercial loans; investments (y_2) which comprise all kind of titles and positions claimable by the bank; and other revenue generating assets (y_3) which is the difference between all bank's assets minus loans (y_1) and investments (y_2). Total *Revenue* is found in the balance sheets of each bank's financial statements and total *Cost* is the sum of each input multiplied by its price $\left(\sum_{i=1}^{3} x_i \cdot w_i\right)$.

As seen in Table 1, Colombian banking system is highly concentrated at the lowest percentiles. Around 50% of banks have assets of less than six billion Pesos (6×10^9); while some others have assets of about five times that amount (30×10^9). This concentration can also be appreciated in other components as equity, profits, and revenue. For instance, revenue is less than fifty million Pesos for half the banks while the others have more than four hundred million (that is up to seven times the revenue of the smaller banks).

To estimate profit, revenue, and cost efficiencies, we specify a model that represents bank's activities in terms of output, inputs, and the prices of such inputs. We follow the literature and model bank's activities using the balance sheet approach presented in C. W. Sealey and Lindley (1977). Under this framework, bank's balance sheets capture the essential structure of banks' core business. Liabilities–which are mainly composed of deposits and purchased funds–as well as physical capital and labor are considered as inputs. Financial assets (other than physical assets) are considered outputs. Thus, banks use labor, physical capital, and deposits to produce loans, investments in financial assets, and other financial services that generate revenues.

5 Results

5.1 Estimated Efficiencies

In Table 2 and Figure 1, we present the main results for the estimated revenue efficiency ($NSRF$), cost efficiency ($Cost$), and profit efficiency ($CNSPF$) for all, big, and small banks.[10] According to the results, on average, bank's revenues are 96.8% of their optimal level while cost are 83.1% of them.

Both revenue efficiency and cost efficiency increase with banks size (measured as the log of total assets) being big banks about three percentage points more revenue efficient

[9] Nominal values are in thousands and deflated with the Consumer Price Index which base year at the time of the study was 2005.

[10] Banks were classified as per their total assets. The biggest three banks (and categorized as big) comprise more than 55% of the total assets of all the industry at the end of the period under analysis (December 2013).

Table 1: **Summary Statistics**

Variable	**Mean**	**sd**	**Percentiles**				
			$\mathbf{5^{th}}$	$\mathbf{25^{th}}$	$\mathbf{50^{th}}$	$\mathbf{75^{th}}$	$\mathbf{95^{th}}$
Assets	9,120,000	10,500,000	664,000	2,790,000	6,120,000	10,600,000	31,400,000
Equity	1,110,000	1,600,000	93,300	261,000	601,000	1,190,000	4,360,000
Profit	107,000	164,000	1,290	11,700	47,000	125,000	413,000
Revenue	1,130,000	1,710,000	61,500	223,000	592,000	1,240,000	4,240,000
Cost	316,000	378,000	21,100	79,600	202,000	395,000	1,100,000
y1	5,540,000	6,910,000	430,000	1,600,000	3,310,000	5,790,000	21,000,000
y2	2,080,000	2,130,000	62,600	558,000	1,410,000	2,990,000	6,330,000
y3	1,500,000	1,860,000	113,000	446,000	863,000	1,750,000	5,440,000
x1	6,810,000	7,370,000	446,000	2,180,000	4,700,000	8,230,000	23,100,000
x2	3,819	4,096	190	1,089	2,819	4,688	11,000
x3	127,000	130,000	9,980	39,300	89,100	150,000	406,000
w1	0.0264	0.0177	0.0042	0.0123	0.0233	0.0369	0.0595
w2	33,900	45,200	4,035	12,800	23,900	38,400	84,800
w3	0.6821	0.5405	0.0899	0.2842	0.5546	0.9114	1.7646
z2	0.2859	0.4519	0.0000	0.0000	0.0000	1.0000	1.0000
z3	0.0444	0.0497	0.0000	0.0199	0.0284	0.0485	0.1708
z4	0.0760	0.0386	0.0365	0.0533	0.0684	0.0887	0.1426
z5	0.2333	0.1191	0.0673	0.1494	0.2124	0.3058	0.4684
z7	20.1908	1.1195	18.3508	19.3812	20.2142	20.9002	22.1951

Note: This table shows the average (Mean); standard deviation (sd); and the 5^{th}, 25^{th}, 50^{th}, 75^{th}, and 95^{th} percentiles. The final dataset is an unbalanced panel with 3,218 monthly observations, from January 2001 to December 2013, for 32 banks. The variables under consideration are: as outputs, Loans (y_1), Investments (y_2), and Other assets (y_3); as inputs, Deposits (x_1), Number of employees (x_2), Property, plant, and equipment (x_3); Input prices or associated cost is (w_i); and $Profits$, *Revenue*, and $Cost$. For addressing bank-specific characteristics we used: z_2, Dummy taking the value of one if the bank is foreign owned and zero otherwise; z_3, Credit Risk (Risky loans over total loans); z_4, Liquidity risk (Liquid assets over total assets); z_5, as Risk exposure (Securities over total assets); and z_7, as the natural log of the equity.Additionally, nominal values in y_1, y_2, y_3, x_1, x_3, $Profit$, *Revenue*, $Cost$, *Assets*, and *Equity* are in millions of Colombian Pesos and are deflated using the CPI.

and one percentage point more cost efficient. These differences in revenue and cost lead to a much bigger difference when comparing profit efficiency by banks size. Big banks are about eight percentage points more profit efficient than small ones. This result will be also confirmed when we analyze the marginal effect of bank-specific characteristics in section 5.3.

Table 2: **Summary Statistics for Estimated Efficiencies**

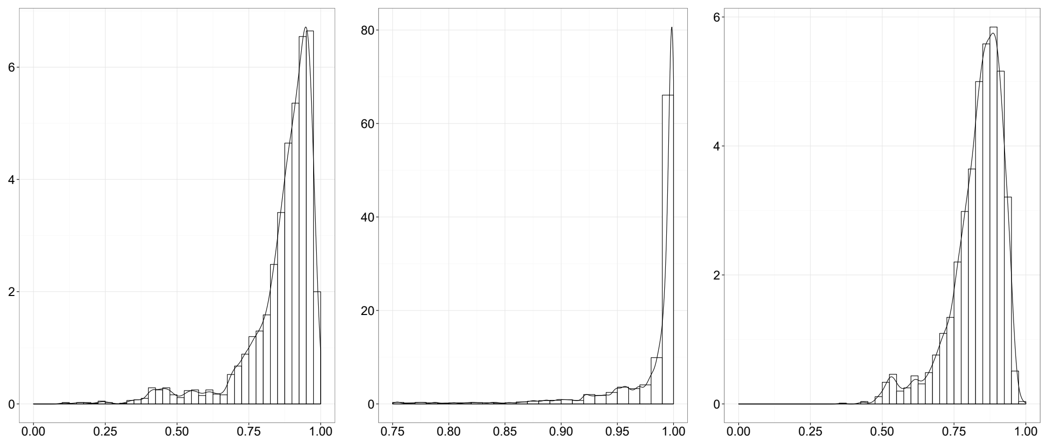
				Percentiles				
		Mean	**sd**	**5th**	**25th**	**50th**	**75th**	**95th**
NSRF	All	0.96798	0.07151	0.80683	0.97637	0.99558	0.99873	0.99991
	Big	0.99548	0.01364	0.99109	0.99684	0.99846	0.99943	0.99996
	Small	0.96327	0.07619	0.76867	0.96766	0.99392	0.99847	0.99988
Cost	All	0.83142	0.09139	0.63982	0.79315	0.85201	0.89557	0.93936
	Big	0.83764	0.05606	0.74490	0.79618	0.83834	0.88079	0.92434
	Small	0.83035	0.09611	0.61736	0.79223	0.85436	0.89725	0.94055
CNSPF	All	0.86548	0.12516	0.57507	0.83750	0.90327	0.94481	0.97498
	Big	0.93042	0.04505	0.85573	0.90314	0.94182	0.96264	0.98672
	Small	0.85436	0.13097	0.54748	0.82210	0.89435	0.93973	0.97187
CNSPF-NR	All	0.90642	0.07621	0.76819	0.87587	0.92256	0.95753	0.98450
	Big	0.93623	0.03734	0.86739	0.90897	0.94494	0.9646	0.98673
	Small	0.90132	0.07992	0.75496	0.86988	0.91821	0.95529	0.98416
CNSPF-NC	All	0.94792	0.11634	0.65103	0.96276	0.99329	0.99814	0.99986
	Big	0.99304	0.02255	0.98684	0.99542	0.99783	0.99926	0.99995
	Small	0.94019	0.12392	0.59907	0.95003	0.99028	0.99766	0.99980

Notes: This table shows the average (Mean); standard deviation (sd); and the 5th, 25th, 50th, 75th, and 95th percentiles of the estimated efficiencies for all, big, and small banks. Revenue efficiency ($NSRF$) and cost efficiency ($Cost$) are estimated using equation (7); while profit efficiency (CNSPF) is computed using equation (6). $CNSPF - NR$ and $CNSPF - NC$ are computed as profit efficiency $CNSPF$ assuming fully revenue efficiency and fully cost efficiency respectively; this is, either $\eta = 1$ or $\theta = 1$ in equation (6). The data used in the estimation is summarized in table 1 and comprises an unbalanced panel with 3,218 monthly observations for 32 banks and for a period of time ranging from January 2001 to December 2013.

At the bottom of Table 2, we present the results for profit efficiency assuming that banks are either fully revenue efficient (CNSPF-NR) or fully cost efficient (CNSPF-NC). This gives us an idea of which inefficiency weights more in profit efficiency in order banks know where they should focus if they want to improve its profit efficiency. As seen in the table, with no inefficiency in revenues, banks' profit efficiency would increase four percentage points to 90.6% while if banks were fully cost efficient the profit efficiency would increase to 94.8%. These results are similar if we control for banks size though for big banks the gains in profit efficiency after being fully revenue efficient are almost negligible (about half percentage point) while for small banks the improvement in profit efficiency is about five percentage points. Instead, being fully cost efficient increases profit efficiency in around six to eight percentage points for big and small banks respectively.

Furthermore, the empirical density distributions presented in Figure 1 allow us to see that most banks are around 80% to 90% profit efficient (see Panel 1a). Respect to cost

Figure 1: **Histograms and density plots of estimated efficiencies**



(a) CNSPF (b) NSRF (c) Cost

Note: Plot with the empirical density distributions of the estimated profit, revenue and cost efficiencies. For the definitions and information on the computation of the estimated efficiencies refer to the note at the bottom of Table 2

efficiency presented in Panel 1c, we found that must banks are about 90% efficient with the exception of a little cluster around 50% in efficiency. Revenue efficiency presents the higher concentration near the full efficient level of all three estimations with a mean of about 96.8% (Panel 1b). It is worth noting that these results are consistent with those found in the literature; banks are usually more revenue efficient than cost efficient.

Additionally to the summary statistics, in Table 3 we present the evolution of the efficiency estimates for the period under analysis. At a glance, one can perceive an efficiency deterioration in 2002 and 2003, followed by efficiency improvements until 2010 were a big 7.4% fall in cost efficiency affected profit efficiency in 4.1%. Finally, there has been some recovery in efficiencies in the last years. As a whole, profit and revenue efficiency have improved consistently throughout the years (The relative change from 2001 to 2013 was 3.9% and 0.8% respectively); while, cost efficiency deteriorated a little during the period; particularly in 2010 as we just mentioned.

In Table 4 we present the correlations between the efficiency estimates, and a measures of returns to scale (RTS), and technical change (TC). As we mentioned before, we found that both revenue and cost efficiency ($NSRF$ and $Cost$ respectively) are positively correlated with profit efficiency ($CNSPF$) though these two ($NSRF$ and $Cost$) are negatively correlated between them. The negative correlation between revenues and cost might be explain by the fact that when companies focus mainly in improving let us say, revenues, their cost will surely increase because the increase efforts in revenue generation. Furthermore,

Table 3: **Mean Efficiency Measures**

Year	CNSPF	%△	NSRF	%△	Cost	%△
2001	0.878592		0.991229		0.857107	
2002	0.808360	-7.994	0.926614	-6.519	0.841464	-1.825
2003	0.797337	-1.364	0.924794	-0.196	0.803213	-4.546
2004	0.829143	3.989	0.943954	2.072	0.809694	0.807
2005	0.857761	3.451	0.963188	2.038	0.810737	0.129
2006	0.869779	1.401	0.971501	0.863	0.818067	0.904
2007	0.873070	0.378	0.960858	-1.096	0.854453	4.448
2008	0.890030	1.943	0.974389	1.408	0.862376	0.927
2009	0.913148	2.597	0.985480	1.138	0.876153	1.598
2010	0.875882	-4.081	0.986737	0.128	0.811511	-7.378
2011	0.892365	1.882	0.993447	0.680	0.804462	-0.869
2012	0.915504	2.593	0.997262	0.384	0.843203	4.816
2013	0.913082	-0.265	0.999091	0.183	0.837300	-0.700
Total	**0.865476**	**3.926**	**0.967978**	**0.793**	**0.831418**	**-2.311**

Notes: This table shows annual means of the estimated efficiency measures and their change year to year. CNSPF stands for Composite Nonstandard Profit Function and is estimated using equation (6); NSRF and Cost are the respective efficiency measures for revenue efficiency and cost efficiency which were deducted from equation (5). The data used in the estimation is summarized in Table 1 and is composed of an unbalanced panel of 3,218 monthly observations for 32 Colombian banks from January 2001 to December 2013.

we also find that all efficiency measures are positively correlated with technical change and with returns to scale.

These results came to be what we expected according to the economic intuition regardless of some other studies that find the opposite.

Table 4: **Spearman Rank Correlations Coefficients**

	CNSPF	**NSRF**	**Cost**	**RTS**
NSRF	0.4908			
	(0.0154)			
Cost	0.4588	- 0.1101		
	(0.0157)	(0.0176)		
RTS	0.2250	0.2548	0.0313	
	(0.0172)	(0.0171)	(0.0177)	
TC	0.0105	0.1893	0.0152	- 0.0255
	(0.0177)	(0.0174)	(0.0177)	(0.0177)

Note: This table presents the sample Spearman Correlations between the different estimated efficiencies ($CNSPF$, $NSRF$, $Cost$), the Returns to Scale (RTS), and the Technical Change (TC). Additionally, we present the standard deviation between parenthesis. All correlations, except for CNSPF-TC and RTS-TC, proved to be statistically significant at a 99% confidence level. $CNSPF$ stands for Composite Nonstandard Profit Function, $NSRF$ for Nonstandard Revenue Function, and $Cost$ refers to the cost function; each function was estimated using equations (6), and (5) respectively. The sample comprises 3,218 monthly observations for 32 banks and for a period of time from January 2001 to December 2013.

5.2 Consequences of Revenue and Cost Inefficiencies

To understand how the different efficiencies affect banks' profits we calculate the forgone rents due to inefficiencies. We do it so by calculating the difference, in percent points, between the actual ROE[11] and the *efficient* ROE; this is, the expected ROE if banks were fully efficient.

$$ROE.CNSPF = ROE^{*} - ROE = \frac{Profit^{*} - Profit}{Equity} \tag{9}$$

[11] Return on Equity is the amount of the net income as a proportion of the total equity.

Similarly, the forgone rents due, exclusively, to revenue efficiency ($NSRF$) or cost efficiency are[12]:

$$ROE.NSRF = \frac{(Revenue^* - Cost) - Profit}{Equity} \tag{10}$$

$$ROE.Cost = \frac{(Revenue - Cost^*) - Profit}{Equity} \tag{11}$$

The results of this exercise are summarized in table 5. In the first section, we present the ROE for all, big, and small banks since that would be the reference point. Then we present the ROE accounting for each of the estimated efficiencies. In average, banks' returns are 9.32% of their equity with small banks having a slightly lower ROE than big ones. Now, if banks were fully profit efficient their ROE would increase to 20.37% (9.32% + 11.05%); though differentiating for banks size, small banks receive the biggest improvement in their ROE 12.22% while for big banks is just 4.97%. An explanation for this result may be that small banks are less efficient than big ones (see Table 2) hence improving efficiency have a bigger impact in their ROE.

Taking into consideration the gains if just one of the profit components (revenue or cost) were fully efficient, we find out that, being fully cost efficient would have an overall greater impact in ROE (7.02%) than being fully revenue efficient (4.03%). These results complement the ones previously presented in Table 2 where we show that being fully cost-efficient has a greater impact than being fully revenue efficient even after differentiating for banks' size. i.e. Being fully cost efficient increases small banks' ROE in 7.50% but increases just 4.52% if it is a big bank; similarly, small banks' ROE increase 4.71% if they are fully revenue efficient but barely increase 0.45% if it is a big bank. This is, again, what we expect given that big banks are more efficient than small ones in revenues as well as in cost.

Finally, we complement our understanding of the effects of revenue and cost inefficiencies over profit efficiency by analyzing the effect of one percent change in the revenue and cost efficiencies. For this, we start from equation (6) and calculate the change in profit efficiency ($CNSPF$) as

$$\begin{aligned} \triangle\%\gamma(\eta,\theta) &= \frac{\gamma'(\eta,\theta)}{\gamma(\eta,\theta)} - 1 \\ &= \frac{k_{(R)}\frac{1}{\eta}R(w,y) - \frac{1}{k_{(C)}\theta}C(w,y)}{\frac{1}{\eta}R(w,y) - \frac{1}{\theta}C(w,y)} - 1 \end{aligned} \tag{12}$$

[12]recalling that $Profit^* = Revenue^* - Cost^*$; where $*$ means the efficient level.

Table 5: **Forgone rents due to ROE Inefficiencies**

	Mean	**sd**	**Percentiles** 5^{th}	25^{th}	50^{th}	75^{th}	95^{th}
			ROE				
All banks	0.0932	0.0718	0.0067	0.0333	0.0806	0.1374	0.2250
Big	0.0949	0.0567	0.0098	0.0539	0.0879	0.1316	0.2007
Small	0.0929	0.0743	0.0058	0.0302	0.0782	0.1390	0.2331
			ROE.CNSPF				
All banks	0.1105	0.1441	0.0089	0.0309	0.0627	0.1253	0.4092
Big	0.0497	0.0395	0.0068	0.0189	0.0391	0.0686	0.1295
Small	0.1222	0.1537	0.0098	0.0347	0.0684	0.1450	0.4338
			ROE.NSRF				
All banks	0.0403	0.1134	0.0001	0.0008	0.0039	0.0233	0.1915
Big	0.0045	0.0123	0.0000	0.0003	0.0013	0.0031	0.0178
Small	0.0471	0.1225	0.0001	0.0010	0.0055	0.0296	0.2272
			ROE.Cost				
All banks	0.0702	0.0809	0.0076	0.0238	0.0466	0.0854	0.2202
Big	0.0452	0.0340	0.0066	0.0176	0.0372	0.0641	0.1139
Small	0.0750	0.0862	0.0078	0.0250	0.0486	0.0906	0.2417

Notes: This table shows the average (Mean), standard deviation (sd), and the 5^{th}, 25^{th}, 50^{th}, 75^{th}, and 95^{th} percentiles of the Returns on Equity (ROE) and the percentage points lost in ROE due to the inefficiencies. The first section is computed as the usual $ROE = Profit/Equity$ while the others (ROE.CNSPF, ROE.NSRF, and ROE.Cost) were computed using equations (9), (10), and (11).

where $\gamma^{'}(\eta,\theta)$ is the profit efficiency ($CNSPF$) after the change in revenue and cost efficiency and $k_{(R)} = k_{(C)} = 1.01$ because we are increasing both efficiencies in one percent. Of course, equation (12) computes the percent change in both revenue and cost efficiency; if we are interested in just one of the effects we get rid of the respective $k_{(R)}$ or $k_{(C)}$ making it equal to one. The results are summarized in Table 6 where we also reproduce the profit efficiency measures (top section) for easy comparisons.

For all banks, one percent increase in revenue efficiency will increase profit efficiency in 1.43%[13] while the same change in cost efficiency will have a smaller effect of 0.43%; besides, the combined effect of one percent change in both revenue and cost efficiency would make profit efficiency increase in 1.88%. Differentiating for banks' size we found again that small banks benefit more for improving efficiency. While big banks' profit efficiency increases 1.65%, small banks' efficiency increases 1.92%.

Table 6: $\triangle$% **in CNSPF for one percent change in NSRF and Cost efficiencies**

			Percentiles				
	Mean	**sd**	**5th**	**25th**	**50th**	**75th**	**95th**
Profit efficiency ($CNSPF$)							
All	0.8655	0.1252	0.5751	0.8375	0.9033	0.9448	0.9750
Big	0.9304	0.0451	0.8557	0.9031	0.9418	0.9626	0.9867
Small	0.8544	0.1310	0.5475	0.8221	0.8944	0.9397	0.9719
Change in CNSPF for 1% change in NSRF							
All banks	0.0143	0.0027	0.0115	0.0129	0.0138	0.0150	0.0196
Big	0.0132	0.0014	0.0113	0.0124	0.0130	0.0137	0.0163
Small	0.0145	0.0028	0.0116	0.0130	0.0140	0.0152	0.0201
Change in CNSPF for 1% change in Cost							
All banks	0.0043	0.0027	0.0015	0.0029	0.0037	0.0050	0.0095
Big	0.0032	0.0014	0.0013	0.0024	0.0030	0.0036	0.0063
Small	0.0045	0.0028	0.0016	0.0030	0.0039	0.0051	0.0100
Change in CNSPF for 1% change in both NSRF and Cost							
All banks	0.0188	0.0055	0.0131	0.0158	0.0176	0.0201	0.0295
Big	0.0165	0.0029	0.0127	0.0149	0.0161	0.0174	0.0228
Small	0.0192	0.0058	0.0132	0.0161	0.0180	0.0205	0.0305

Notes: This table shows the average (Mean), standard deviation (sd), and the 5th, 25th, 50th, 75th, and 95th percentiles of the change in profit efficiency ($CNSPF$) if either revenue ($NSRF$), Cost or both efficiencies increase one percent. This is computed using equation (12) and assuming an increment of one percent in the efficiencies ($k = 1.01$).

[13]Note that the changes are in percentage not in points. i.e. one percent increase in revenue efficiency will increase profit efficiency in 1.43% that is $86.55\% * 1.0143 = 87.79\%$.

We repeat the previous exercise but instead of analyzing the change in the efficiencies we compute the change in ROE due to one percent increase in either revenue, cost and both efficiencies. This is done, similarly, by multiplying the respective efficiency ($NSRF$ or $Cost$) in equations (9), (10) and (11) by $k = 1.01$. Table 7 presents the results and reproduces the ROE from Table 5 for an easier analysis.

In average, if banks increase their revenue efficiency in one percent their ROE would increase in 0.0049 percentage points to 9.81% while increasing cost efficiency would yield just 0.0013 percentage points to 9.45%. Jointly, the effect would be the sum of both changes and the resulting ROE would be 9.94%. Though this may seem a small change we must bear in mind that we are talking about the banking sector with average returns of 107 billion Pesos, hence an increment in ROE of 0.0062 percentage points is more than $650 million Pesos which is not a despicable amount.

Table 7: △% **in ROE due to one percent change in NSRF and Cost efficiencies**

			Percentiles				
	Mean	**sd**	**5th**	**25th**	**50th**	**75th**	**95th**
			ROE				
All banks	0.0932	0.0718	0.0067	0.0333	0.0806	0.1374	0.2250
Big	0.0949	0.0567	0.0098	0.0539	0.0879	0.1316	0.2007
Small	0.0929	0.0743	0.0058	0.0302	0.0782	0.1390	0.2331
			Change in revenue ($NSRF$) efficiency				
All banks	0.0049	0.0090	0.0000	0.0000	0.0000	0.0078	0.0229
Big	0.0005	0.0027	0.0000	0.0000	0.0000	0.0000	0.0000
Small	0.0057	0.0095	0.0000	0.0000	0.0000	0.0101	0.0240
			Change in cost efficiency				
All banks	0.0013	0.0022	0.0000	0.0000	0.0000	0.0020	0.0064
Big	0.0002	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000
Small	0.0015	0.0023	0.0000	0.0000	0.0000	0.0027	0.0066
			Change in both revenue and cost efficiency				
All banks	0.0062	0.0110	0.0000	0.0000	0.0000	0.0100	0.0292
Big	0.0007	0.0034	0.0000	0.0000	0.0000	0.0000	0.0000
Small	0.0072	0.0116	0.0000	0.0000	0.0000	0.0131	0.0304

Notes: This table shows the average (Mean), standard deviation (sd), and the 5th, 25th, 50th, 75th, and 95th percentiles of the percent points change in ROE if either revenue ($NSRF$), Cost or both efficiencies increase one percent. This is done by multiplying the respective efficiency ($NSRF$ or $Cost$) in equations (9), (10) and (11) by $k = 1.01$.

5.3 Analysis of Bank-Specific Characteristics

As mentioned before, we include time (t), a categorical variable for identifying foreign-owned banks z_2, Credit Risk (z_3), Liquidity Risk (z_4), Risk Exposure (z_5), and the Log of equity z_7 to address bank-specific characteristics. The estimated parameters for such variables are presented in Table 8. The number itself is not relevant but the sign of the parameter will define the direction of the marginal effects of that variable over the estimated efficiency. Thus, time (t and t^2 jointly) has a positive impact on revenue and cost inefficiency (this is, efficiency decreases with time) while size (z_7) has a negative impact on inefficiency (the bigger the bank the more efficient, in average, it gets).

Table 8: **Estimated Parameters for NSRF and Cost Inefficiency**

	NSRF		**Cost**	
Variable	**Parameter**	**sd**	**Parameter**	**sd**
t	0.13319	0.03497	0.03300	0.00530
t^2	-0.00224	0.00055	-0.00033	0.00006
z_2	5.43388	0.89295	-5.66488	-
z_3	40.76101	5.57120	0.61990	0.92016
z_4	-12.84099	5.06758	-5.74310	2.24920
z_5	-19.82396	3.54515	0.65986	0.57909
z_7	-0.47744	0.10088	-0.19211	0.01418
Log likelihood	-548.84443		1,358.12560	

Notes: This table shows the estimated parameters and the variance of inefficiency for the translog stochastic frontiers: NSRF, and Cost deducted in equation (7). For addressing bank-specific characteristics we used: z_2, Dummy taking the value of one if the bank is foreign owned and zero otherwise; z_3, Credit Risk (Risky loans over total loans); z_4, Liquidity risk (Liquid assets over total assets); z_5, as Risk exposure (Securities over total assets); and z_7, as the natural log of the equity.

We compute the marginal effects of the bank-specific characteristics as the partial derivative of the expected value of μ_{it} (presented in equation (8)) in terms of the bank-specific characteristic, z_k (Wang, 2002).

$$\frac{\partial E\left[\mu_i\right]}{\partial z_k} = \frac{z_i'\delta}{\partial z_k}\sqrt{(0.5/\pi)\, exp\left(z_i'\delta\right)} \tag{13}$$

Table 9 presents the results in elasticity form (except for *time*). According to the results, banks' revenue inefficiency increases in average 4.8% per year while cost inefficiency increases 8.6%; jointly, the effect in profit inefficiency is 9.5%.

Credit risk, as well, presents positive marginal effects; that is, one percent increment in credit risk (z_3) generates an increment of 0.95% and 0.01% in revenue and cost inefficiency respectively. On the other hand, liquidity risk (z_4) has a negative effect in both revenue and cost inefficiency. One percent increment in the ratio of liquid assets to total assets implicates a reduction in revenue and cost inefficiency of 0.50% and 0.17% respectively.

All in all, profit inefficiency increases over $Time$ and when Credit Risk (z_3) increases. Besides, liquidity risk (z_4), risk exposure (z_5), and size (z_7) have negative effects on inefficiency being the latter the one that weights more in profit inefficiency decreasing 0.98% when banks' size (measured as the natural log of the equity) increases one percent.

Table 9: **Marginal Effects of Bank Characteristics on Inefficiency Estimates**

	Inefficiency Measures					
	CNSPF		**NSRF**		**Cost**	
Variable	**Mean**	**sd**	**Mean**	**sd**	**Mean**	**sd**
$Time^*$	0.0952	0.1303	0.0484	0.1385	0.0860	0.0680
z_2	0.2111	0.5407	0.8093	1.3293	-0.4884	1.7218
z_3	0.2405	0.5401	0.9456	1.1964	0.0137	0.0242
z_4	-0.2433	0.1770	-0.4977	0.2609	-0.1687	0.1670
z_5	-0.3182	0.5515	-2.3507	1.2314	0.0670	0.0805
z_7	-0.9814	1.3103	-4.9134	0.7942	-0.4731	1.3204

Notes: This table shows the mean and standard deviation of the estimated marginal effects in elasticity form (except for time) on inefficiency. Bank-specific characteristics used are: time (which comprises the jointly effect of t and t^2); z_2, Dummy taking the value of one if the bank is foreign owned and zero otherwise; z_3, Credit Risk (Risky loans over total loans); z_4, Liquidity risk (Liquid assets over total assets); z_5, as Risk exposure (Securities over total assets); and z_7, as the natural log of the equity. The marginal effect is calculated using equation (13) following Wang (2002) and **?**.

6 Conclusions

Most of the research made for understanding Colombian banks' efficiency focus mainly in cost efficiency and how this one change under different situations like mergers and acquisitions, or analized through different econometric methodologies like Distribution-Free Approach (DFA) or Data Envelope Analysis (DEA). Up to our knowledge, just Estrada and Osorio (2004) attempt to investigate profit efficiency through stochastic frontier methodologies; however, they use a misspecified model which yields puzzling results. According to the authors, Colombian banks have a profit efficiency of around 80% and a surprisingly cost efficiency of less than 30% (Estrada & Osorio, 2004, p. 24-25); that's because instead of decomposing profit efficiency into revenue and cost efficiency, they followed the previous literature and just add an *ad hoc* error term.

Applying the correct specification model presented in **?**, we find that most of the Colombian banks are highly revenue efficient though not that much cost efficient; consequently, in average, Colombian banks have a profit efficiency of around 90%. We also find that since banks are more cost inefficient than revenue inefficient, focusing on improving cost efficiency would have a greater impact in improving overall profit efficiency and consequently would increase banks returns in a greater proportion in terms of the equity (ROE).

Additionally, we find that bank-specific characteristics like size, liquidity risk, and risk exposure have a positive impact on banks profit efficiency (the marginal effects in Table 9 are negative, hence it decreases inefficiency). This could be one of the causes behind the rise in merger and acquisitions lived in the last decades in Colombian banking sector (ANIF, 2006; Garcia Suaza & Gomez Gonzalez, 2010).

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