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INDUSTRIAL SECTOR EXPORTS IN COLOMBIA: EFFICIENT FRONTIER ANALYSIS

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ABSTRACT

In this paper, a comparative analysis is carried out among the industrial sectors in Colombia that have the most employees during 2000-2011. A dynamic simulation is used, and a Data Envelopment Analysis (DEA) is applied in order to obtain an overall index of technical efficiency in Colombia's industrial sectors for the use of resources. Similarly, an industrial sector efficiency ranking for exports is drawn up. This index determines the presence of unused resources, which is useful to devise strategies to support exports. The analysis is based on a Monte Carlo simulation forecast to determine the average values of the period for the input variables: number of businesses, employees, assets, and energy used to produce the output variables. That is, gross production and exports. The purpose is to compare the effectiveness of the factors of production to generate exports, and determine the possibility of improving inefficient sectors. The goal is to participate in the internationalization process in a proper way.

JEL: C51, G32, D22, C61, F14

KEYWORDS: Dynamic Simulation, Financial Analysis, DEA, Exports

INTRODUCTION

In the current scenario of economic integration and free trade liberalization, the analysis of sectorial efficiency constitute a dynamic area of research, since the competitiveness of a country or region is linked in direct way with efficiency gains that leads to improvements in productivity. During the period 2000-2011, industrial sector in Colombia accounted for an average of more than 13% of gross domestic product (GDP), 56% of total annual exports, and 13% of the employed population. Nevertheless, this sector has experienced a period of decline in their relative importance in the economy and the export's growth rate was lower than total exports rate, which may some disadvantages to articulate it to the world's current export conditions of industrial sector.

From the economics' perspective, the concept of efficiency takes into account the lowest amount of inputs (capital, raw materials, man hours, machine hours, and so on) to get to a certain amount of outputs (profits, production, value added, goals met, etc.). Therefore, efficiency involves using society's resources as efficiently as possible to meet individual wants and needs (Samuelson & Nordhaus, 2002). It also involves the best possible use that a society makes of limited resources (Gregory, 2004). Similarly, achieving the highest production at the lowest possible cost is considered efficiency (Pinzón, 2003), as well as the capacity of a system or economic agent to meet certain goals by using resources as little as possible (Simón, 2005). Previous empirical work have focused in the performance of industrial exports in Colombia. These studies show that exports have passed through a slow process of export diversification, which depend on natural resources and low-technology products (Lotero, 2007; Torres & Gilles, 2013). Using industry data, Loaiza (2012), estimates that productivity's growth is associated with the increase in foreign investment and tax incentives to the import of capital goods. At the sector level, Villalobos & Vallejo (2005), find that industrial agglomeration have positive effect on the technical efficiency in clothing sector. From a methodological viewpoint, DEA is an analysis model through which homogeneous decision making units can be compared with regard to inputs and outputs. This generates a production or relative efficiency measure. The basic principle is to calculate the relative technical efficiency of each unit by means of a ratio that results from the quotient between the weighted sum of the outputs and the weighted sum of the inputs. The weights are determined according to Pareto criteria, where each unit's efficiency, for the input version, must be less than or equal to the unit (Charnes, et al., 1978). In this context, the purpose of this study is to compare the technical efficiency of the industrial sector exports in Colombia using a DEA-CCR input-oriented model suggested by Banker et al. (1984). In order to achieve this objective, this paper is organized in four sections, as follows: section 2 gives a literature review about the efficiency, simulation and DEA models. Section 3 present the DEA technique. Section 4 contains the results industrial sector exports and section 5 presents conclusions.

LITERATURE REVIEW

Efficiency

The word "efficiency" comes from the Latin word *efficientĭa,* which means: production, force, action. From a long-term point of view, the concept of efficiency involves getting the maximum profit at the lowest possible cost (Farrel, 1957). According to management theories, the concept is approached as the proper use of resources or available means of production. It is expressed by means of the equation $E=P/R$, where P are the resulting products, and R the resources used (Chiavenato, 2004). It is also defined as the achievement of goals with the minimum use of resources (Koontz & Weihrich, 2004). In other words, getting the best results with the lowest investment (Robbins & Coulter, 2005), or working in such a way that resources are used more properly (Reinaldo, 2002). All of the above leads to inferring that, in management sciences, efficiency is approached as a relation between the resources needed by an enterprise and the goals reached. The common ground is that there is efficiency when there is a minimum use of resources to reach a goal, or when greater results are obtained with fewer resources. It must not be confused with effectiveness, which means the extent to which goals and objectives are achieved. This means that effectiveness deals with the task of reaching intended goals, whereas efficiency means the best use of sources. Therefore, effectiveness is limited to the capacity to achieve a goal without taking into account the best use of resources in the process. As a consequence, it is possible to be effective without being efficient. The ideal condition is to be effective and efficient at the same time.

Thus, the concept is made up of two elements: technical efficiency and allocative efficiency. The focus of the former is the use of human resources or capital in the production of goods and services (Trillo, 2002), whereas the latter considers the concept of maximizing profits and minimizing costs in a production unit (Hernández de Cos et al., 1995). Based on the previous proposals, this paper uses the general definition of efficiency as the best use of available resources to get the desired results. Consequently, an entity, institution, organization or person is "efficient" when they get the desired results by means of the best use of the resources they have.

Simulation

Simulation is taken to mean the development of a system's logical-mathematical model to imitate the operation of a real process or system over time. Simulation requires the generation of a system's artificial history in order to observe that history and infer the system's operational characteristics through experimental manipulation. Two basic steps are needed in a simulation: 1) model development, and 2) experimenting. The former involves formulating logical equations that represent the system, and executing a computer program. After validating the system's model, the simulation study's second phase entails experimenting with the model in order to evaluate the system's response to fluctuations in some input variables. The words "system" and "model" are very important in the previous definition. A system is understood as the collection of variables that interact with each other within certain limits to achieve a goal. On the other hand, the model is a representation of the system's objects, and it expresses the activities in which such objects are involved (Azarang & García, 2006). The well-known Monte Carlo sampling gave birth to simulation methods. The Monte Carlo model was a technique used by J. Von Neumann and other researchers and research military units during World War II. Since the mid 1940's, the procedure has been successfully applied in diverse business and scientific activities. The Monte Carlo model is a random process used to choose sample values based on a probability distribution. Such values are later used as inputs or operational values for a simulation model. Simulation is a means that can adapt to the analysis of many situations. Therefore, the pros and cons of using simulations are detailed in *Table 1*.

Table 1: Pros and Cons of Simulation

Pros	**Models can be modified to analyze diverse scenarios.**
	It is cheaper to improve a simulated system than a real system.
	It is easier to understand and view simulation methods than purely analytical methods.
	Analytical methods involve many assumptions and simplifications, whereas simulation models analyze more complex or detailed systems.
	In some cases, simulation is the only way to get a solution.
Cons	It takes a lot of time to develop and validate simulation models.

This table shows a summary about pros and cons of simulation. Source: Azarang & García (2006).

Data Envelopment Analysis (DEA) Models

DEA is a way to measure efficiency. It is based on the generation of an efficiency frontier whose starting point is a set of observations of a given event without the estimation of production functions. That is, a functional relation between inputs and outputs is not necessary. It becomes an excellent non-parametric alternative to obtain information from a set of observations. Parametric methods aim to obtain the best adjustment of the observations by generating a hyperplane. On the other hand, the purpose of DEA is to optimize each analysis unit's efficiency measure, and create an efficient frontier. Since it would be based on real data, it would be efficient and feasible based on the Pareto criterion (Charnes *et al.* 1957). The procedure first involves creating an empirical production frontier, and then evaluating the efficiency of each observed unit that is not limited to the efficiency frontier. From this point of view, it is a parametric model because it does not assume the existence of an input/output functional relation. It is not statistical because it does not assume that efficiency adjusts to any sort of probability distribution as do the input and output consistency tests with the production frontier implemented by Hanoch & Rothschild (1972) (The tests mentioned above have the sole purpose of proving the validity of certain hypotheses about the production function, such as quasi-concavity, monotonicity and homothetic, based on the observations about inputs and data avoiding any parameterization of the production function (Hannoch & Rothschild, 1972:256).), and Sengupta (1987).

The evaluation criterion is based on the hypothesis that a productive unit belongs to the production frontier when it generates more out of an output without producing less out of the rest, and without consuming more inputs. In other words, it is efficient when it uses less out of an input, without using more out of the rest, and it generates the same products (Charnes & Rhodes, 1981). In the comparison, the efficient and technically homogeneous unit may not be real, but the linear combination of other real units. This characteristic is in line with what was proposed by (Farrell, 1957), and it features two assumptions: first, the possibility of using supplies continually. Second, the efficiency frontier is convex. The first assumption guarantees that the inputs are divisible, whereas the second guarantees that the linear combination of two or more units belonging to the feasible group also has this characteristic. When a group of real efficient units is combined to produce another fictitious efficient unit, it is considered as a reference group that enables the application of improvement strategies of inefficient units in comparison with efficiency degrees actually achieved.

In both cases, there are two options to measure efficiency: the first one is called input-oriented, and it is based on confirming the amount of inputs consumed in order to get the same output. The second one is output-oriented, which aims to reach the maximum output with the inputs. Choosing the method depends on the particular characteristics of the problem under study. The models have been widely implemented in multiple organizational and social scenarios. In finance, for instance, there is an application to measure the productivity efficiency of textile sector companies' current resources.

The purpose is to devise plans to enlarge installed capacity and apply for credit from the financial sector (Restrepo & Vanegas, 2009); in the same line (Ayela, 1993). In hospital management, the performance of 45 university hospitals in Brazil is analyzed in order to study the situation of such units through the technical efficiency achieved with a DEA model (Frainer, 2012). Likewise, the technical efficiency of primary care in Costa Rica during 2004-2010 is studied through traditional DEA models and Bayesian methods (Salazar, 2012). Another study is applied over a panel dataset comprised of 21 milk farms located the South Basin Abasto de Buenos Aires, Argentina (Arzubi y Berbel, 2002) In the social sphere, a model to evaluate the impact of information asymmetries on the management of social organizations is developed. To this end, DEA models were assessed based on the pillars of information economics in order to express the goals of the members of an organization: principal and agent. The multipliers estimated are understood as assessments allocated by the director and the agent of the social processes. A DEA model with asymmetrical information (AI-DEA) was developed and applied to incorporate the differences in these assessments. It was applied to the system of federal universities in Brazil. The Ministry of Education (MEC) is the director, and the presidents of the universities are considered federal agents. It was found that the DEA model enabled the evaluation of the impact of information asymmetries on the management of federal universities (Franca, 2013).

METHODOLOGY AND DATA

The model employed to measure export efficiency is DEA. With it, a concrete indicator of an economic unit (company or sector) can be obtained in relation to the best results from the rest of units in the group of observations. Setting a standard of comparison with the best results guarantees getting such results by improving a company's process and management. The units of measure are independent of the variables used in DEA models In order to make the technique more operational, and adjust it to the reality of the problem addressed, the version suggested by (Banker et al., 1984), known as the DEA-CCR input-oriented version, will be used. We consider the structure of the DEA-CCR mathematical model in order to be able to determine both the technical efficiency index of each sector, and the weightings allocated to the several inputs and outputs. The notation is as follows:

$$Min_{\theta,\gamma,\delta^+,,\delta^-}\ Z_0 = \theta - \varepsilon(I\delta^+ + I\delta^-)$$
$$Subject\ to:$$
$$\gamma Y = Y_{0+}\delta^+ \qquad (1)$$
$$\gamma X = \theta X_0 - \delta^-$$
$$\vec{1}\gamma = 1$$
$$\gamma, \delta^+, \delta^- \geq 0$$

The industrial sector is represented by the sub-index *0*; X and Y represent the input and i output r amounts of the sector j respectively; λ reflects the weightings (unknown) allocated to the input i and output r of the sector being evaluated. Finally, θ represents the efficiency rate of the evaluated sample unit. Thus, by using a DEA model applied to the industrial sectors with the most employees in Colombia, a relative productive efficiency frontier is drawn up. In order to evaluate the units that are nor efficient, a comparison is made

with those units that are efficient, and therefore, belong to the frontier. The units are taken to be homogeneous. This means that they use similar inputs to produce the same outputs.
The result is an indicator of the factors' total productivity. This indicator is developed based on the quotient between the output and input weightings. This non-parametric technique features the special characteristic of determining the weightings used in an exogenous way. That is, the measuring technique allocates it by itself without the need to assume any kind of functional form. For the study, these weightings are determined by means of a mathematical programming model which, in its formulation, presents the relative nature of the measure obtained.

By solving the mathematical model thus defined, the values of the variables γ can be determined As a consequence, the productivity rate θ allocated to the sector evaluated can be determined as well. The process is repeated for each of the j sectors. A productivity measure will be obtained for all of them. It is important to point out that the sector whose productivity is being calculated is both in the target function and in the restrictions. This guarantees that there will always be a solution to the problem. The restrictions found are universal. That is, every company may use the same set of weights to evaluate its competitiveness, and the maximum competitiveness value obtained by any company will be 1. In short, by calculating such weightings, the various output (input) levels can be reduced to a single scale value called virtual output (virtual input). This is nothing more than the result of adding the various outputs (inputs) produced (used) by a company through the application of the weights obtained in the fractional problem. The DEA method becomes a tool able to provide a synthetic index of the sector's productivity. It takes into account the multiple dimensions and variables of production. Thus, a comprehensive vision of them can be accomplished. This is how this study, which tries to determine the best export structure for the sectors under study, achieves an adequate approach to the estimates of efficiency.

Variables Used in the Input-Oriented DEA-CCR Model

In order to develop the proposed index, a relation needs to be established between the inputs (number of firms, employees, assets, energy consumed) and outputs (exports, gross production of the industrial sectors that generate the highest rate of employment. We use annual data during the period 2000-2011. The variables used are described below:

Number of businesses (NB): the number of businesses registered in the country per industrial sector.
Employees (E): the number of employees reported by the companies of each sector in the Annual Manufacturing Survey (AMS).

Assets (AT): the monetary value of assets of the industrial sectors in thousands of millions of Colombian pesos.

Energy Consumption (EC): the energy consumed in kilowatt-hours (kW/h) by the industrial sector.
Exports (EX): the monetary value of exports in millions of dollars
Gross Production (GP): the monetary value of each industrial sector in thousands of millions of pesos

In order to compare the industrial sectors in Colombia, disaggregated data by sector is necessary. The information provided by Departamento Nacional de Estadística (DANE, 2012) solves this need with the studies of firms. All variables were expressed in Colombian pesos, except the exports in dollars.

Table 2: Sectors with the Most Employees

Sector	Sector's Description
CIIU15	Production of Foodstuffs and Beverages
CIIU24	Manufacturing of Chemical Substances and Products
CIIU17	Manufacturing of Textile Products
CIIU25	Manufacturing of Rubber and Plastic Products
CIIU26	Manufacturing of Other Non-Metallic Mineral Products
CIIU36	Manufacturing of Furniture; Manufacturing Companies
CIIU28	Manufacturing of Products Made of Metal, except Machinery and Equipment
CIIU29	Manufacturing of Machinery and Equipment
CIIU22	Editing, Printing and Record Playing Activities
CIIU21	Manufacturing of Paper and Paper Products

This table presents the International Standard Industrial Classification for industrial sector and their description. Source DANE.

Table 3: Input and Output Data per Industrial Sector for 2011

	Inputs				Outputs	
Sector	NB	E	AT	EC	EX	GP
	Sectors Analyzed with over 20,000 Employees					
CIIU15	1,771	152,675	27,407	3,102	4,768	53,715
CIIU24	827	75,554	13,496	1,769	3,053	23,390
CIIU18	1,021	60,705	1,672	130	540	5,197
CIIU25	775	53,208	6,557	1,198	751	8,099
CIIU17	419	45,972	4,635	897	564	4,873
CIIU26	499	38,502	12,022	1,716	470	9,687
CIIU28	740	37,162	2,066	241	278	4,339
CIIU36	698	33,976	1,610	195	375	3,231
CIIU22	683	33,115	2,859	181	186	4,322
CIIU29	585	31,246	1,928	148	409	3,652
CIIU19	410	21,146	602	94	260	1,574
	Sectors with Fewer than 20,000 Employees Are Not Analyzed					
CIIU21	184	17,767	6,453	1,515	550	6,045
CIIU31	181	16,816	1,641	152	318	3,186
CIIU34	208	16,229	1,322	126	416	5,751
CIIU27	186	15,576	7,741	2,787	4,404	9,764
CIIU20	202	6,502	616	79	29	788
CIIU35	58	6,487	422	30	41	2,267
CIIU23	114	6,213	14,388	906	5,152	40,911
CIIU33	90	4,095	214	19	77	353
CIIU16	4	1,071	511	15	7	678
CIIU32	18	577	23	3	55	44
TD	9,683	674,920	108,191	15,304	22,272	191,966

This table shows the inputs (NB: number of firms, E: employees, AT: assets, EC: energy consumed) and outputs (EX: exports, GP: gross production of the industrial sectors that generate the highest rate of employment during the period 2000-2011.Source: Annual Manufacturing Survey (2011).

RESULTS

Applying the data envelopment analysis implies the definition of a utility function. That is, the description of two outputs and four inputs. For the outputs, the EX and GP variables were used. Regarding the inputs, they are incorporated as general factors that determine efficiency: number of businesses, employees, amount of assets, electric energy consumed.

Table 4: Results of the DEA-CCR Input-Oriented Model

Sector	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
CIIU15	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CIIU18	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CIIU24	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
CIIU17	0.5603	0.5786	0.5406	0.5302	0.5534	0.5497	0.6212	0.8117	0.8443	0.6360	0.5659	0.5627
CIIU25	0.5917	0.6329	0.6322	0.6093	0.6260	0.7553	0.7443	0.7045	0.7314	0.6338	0.6812	0.6050
CIIU26	0.6699	0.7238	0.7335	0.7402	0.7274	0.6897	0.7177	0.7503	0.7102	0.6698	0.6812	0.7152
CIIU36	0.6694	0.6126	0.6630	0.6630	0.6337	0.6871	0.9571	0.7328	0.9341	0.8980	0.9005	0.8474
CIIU22	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	0.9713
CIIU28	0.7461	0.7938	0.8316	0.8316	0.8575	0.9362	0.9712	1.0000	0.9883	0.8885	0.9005	0.8665

This table exhibits the results of the DEA-CCR Input-Oriented Model; the sector CIIU15, CIIU18 and CIIU24belonging to the production frontier. And CIIU17, CIIU25, CIIU26, CIIU36 and CIIU28 have been inefficient in the period 2000-2011. Source: developed by the authors based on the AMS 2011 data on Risk Simulator

Table 4, shows that the sectors CIIU15, CIIU18 and CIIU24 are on the production frontier. On the other hand, the sectors CIIU17, CIIU25, CIIU26, CIIU36 and CIIU28 have been inefficient during 2000-2011. It is important to note that CIIU22 is out of the efficiency frontier in 2011, and the improved efficiency of CIIU36, which in the last five years reached levels of over 80%. For inefficient sectors, the probability mass function was determined in order to be able to perform the simulation. The results are shown in Figure 2 and Figure 3 in appendices.

Table 5: Results of DEA-Input-Oriented for 2011

Sector	***NB***	***E***	***AT***	***EC***	***EX***	***GP***
CIIU15	1,771.0	152,675	27,407	3.102.5	4,767.8	53,715
CIIU24	827.0	75,554	13,495	1.768.7	3,053.2	23,389
CIIU18	1,021.0	60,705	1,671.6	130.45	539.55	5,197.1
CIIU25	434.74	32,191	3,967.3	441.74	751.22	8,099.3
CIIU17	**235.78**	**18,688.9**	**2,608.5**	**321.52**	**564.27**	**4,872.8**
CIIU26	319.40	27,535	4,942.9	559.53	859.87	9,687.5
CIIU28	510.57	32,201	1,790.1	177.21	419.0	4,339.2
CIIU36	462.0	28,790	1,364.6	142.34	375.20	3,312.5
CIIU22	510.25	32,166	1,781.2	176.20	417.53	4,322.4
CIIU29	585.0	31,246.	1,927.7	148.17	409.16	3,652.2
			Improvement Percentages per Sector			
CIIU15	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
CIIU24	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
CIIU18	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
CIIU25	*43.91%*	*39.50%*	*39.50%*	*63.12%*	*0.00%*	*0.00%*
CIIU17	***43.73%***	***59.35%***	***43.73%***	***64.17%***	***0.00%***	***0.00%***
CIIU26	*35.99%*	*28.48%*	*58.89%*	*67.39%*	*83.13%*	*0.00%*
CIIU28	*31.00%*	*13.35%*	*13.35%*	*26.41%*	*50.77%*	*0.00%*
CIIU36	*33.81%*	*15.26%*	*15.26%*	*27.16%*	*0.00%*	*2.52%*
CIIU22	*25.29%*	*2.87%*	*37.70%*	*2.87%*	*124.03%*	*0.00%*
CIIU29	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*

This table shows as sector 17 –highlighted in black – must have an NE input of 236 for it to reach the efficient border. Thus, the current basis is reduced by 43.73%, which means 183 fewer businesses. The number of employees must be about 18,688, which is a reduction of 59.35%. The total amount of assets must go from 4,635 million to 2,208. This is a reduction of 43.73%s. The EC would go from 897 to 321. This is a reduction of 62.52%. Source: developed by the authors based on the AMS (2011) data on Risk Simulator

Table 6: Input Reduction in Numbers to Reach the Efficiency Frontier

	NB	E	AT	EC	EX	GP
CIIU15	0	0	0	0	0	0
CIIU24	0	0	0	0	0	0
CIIU18	0	0	0	0	0	0
CIIU25	340	21,016	2,590	756	0	0
CIIU17	**183**	**27,283**	**2,027**	**576**	**0**	**0**
CIIU26	180	10,967	7,079	1,156	390	0
CIIU28	229	4,961	276	64	141	0
CIIU36	236	5,185	246	53	0	81
CIIU22	173	949	1,078	5	231	0
CIIU29	0	0	0	0	0	0

This table presents the input reductions in numbers to reach the efficiency frontier. The sector 17 –highlighted in black – must have an NE input of 236 for it to reach the efficient border, which means 183 fewer businesses. The number of employees is equivalent to the loss of 27,283 jobs in the sector. The total amount of assets must go to 2,027 million less in assets. The EC would go to 576,000 million pesos less in consumption. Source: developed by the authors based on the AMS (2011) data on Risk Simulator

The sectors CIIU25, CIIU17, CIIU26, CIIU28, CIIU36 and CIIU22 have been inefficient in 2011. The efficiency was determined for the period 2000-2011. However, for illustration purposes, the results are presented in Table 5, but the analysis per sector is carried out for 2011, and only for CIIU17. The rest of the sectors are analyzed in a similar way. According to Table 3, which shows input and output information for 2011, CIIU17 has the following inputs: 419 businesses; 45,972 employees; assets are worth 4,635 million; and there was a consumption of 897,000 million in energy. This generated 564,000 million dollars worth of exports, and a gross production of 4,873 million. The results of the DEA model are shown in Table 5. According to these, sector 17 –highlighted in black – must have an NE input of 236 for it to reach the efficient border. Thus, the current basis is reduced by 43.73%, which means 183 fewer businesses. The number of employees must be about 18,688, which is a reduction of 59.35%. This is equivalent to the loss of 27,283 jobs in the sector. The total amount of assets must go from 4,635 million to 2,208. This is a reduction of 43.73%, which means 2,027 million less in assets. The EC would go from 897 to 321. This is a reduction of 62.52%, which means 576,000 million pesos less in consumption. The other sectors are analyzed similarly with the information in Table 4, Table 5 and Table 6.

Table 7 features the comparison of sectors. It shows that the efficient sectors have a value of 1.0 when cross-checked. On the other hand, the inefficient sectors are compared with the efficient ones. Thus, the degree of inefficiency of, for instance, sector CIIU17, becomes evident. It should adopt the administrative practices of CIIU24 to come close to the production frontier, since it is at 28.65% of CIIU24. Likewise, Figure 1 on the right shows the efficiency present the results for CIIU17 during 2000-2011. It has always been below the efficiency frontier. It had values of over 80% in 2008, but in 2001, it sank to historical levels, and it has 56.27%. The charts for all the inefficient sectors can be viewed in Appendix 2.

Table 7: Comparison of Sectors and Weights

	CIIU15	CIIU24	CIIU28	CIIU29
CIIU15	1.0000			
CIIU24		1.0000		
CIIU17		0.2865		
CIIU25		0.3615	0.1576	
CIIU26		0.4312		
CIIU36	0.0590	0.0369	0.5817	
CIIU28			1.0000	
CIIU29				1.0000
CIIU22	0.0131	0.0029		0.8278
CIIU21		0.2932		

This table shows that the inefficient sectors are compared with the efficient ones. Sector CIIU17 should adopt the administrative practices of CIIU24 to come close to the production frontier, since it is at 28.65% of CIIU24.Figure 1 below shows the efficiency results for CIIU17 during 2000-2011. It has always been below the efficiency frontier. Source: developed by the authors based on the data provided by AMS 2000-2011

Figure 1: CIIU17 during 2000-2011

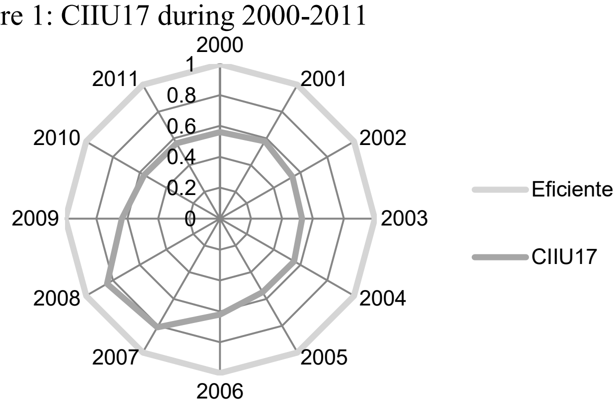


Figure 1 shows the efficiency results for CIIU17 during 2000-2011. It has always been below the efficiency frontier. Source: developed by the authors based on the data provided by AMS 2000-2011

CONCLUDING COMMENTS

We develop a comparative analysis among the industrial sectors in Colombia that generate the most employment during 2000-2011. A dynamic simulation has been used, and a Data Envelopment Analysis (DEA) was applied in order to obtain an overall index of technical efficiency in Colombia's industrial sectors in the use of resources. Similarly, an industrial sector efficiency ranking for exports is drawn up. This index determines the presence of unused resources, which is useful to devise strategies to support exports. Information was provided to determine technical efficiency improvement strategies the industrial sectors. It has illustrated CIIU17 sector, the main findings show outputs' increase and/or inputs' reduction in the required inputs to make sectors can achieve production's frontier for 2011. The CIIU17 sector has the following inputs: 419 businesses; 45,972 employees; assets for 4,635 million; and a consumption of 897,000 million in energy.

This generated exports for 564,000 million dollars and a gross production of 4,873 million. DEA's results model shows how the CIIU17 sector should have an NE input of 236 for it to reach efficient frontier. Thus, the current basis is reduced by 43.73%, which means 183 fewer businesses. The number of employees must be about 18,688, which is a reduction of 59.35%, this is equivalent to the loss of 27,283 jobs in the sector. The total amount of assets must go from 4,635 million to 2,208. This is a reduction of 43.73%, which means 2,027 million less in assets. The Energy Consumption would go down from 897 to 321, this is a reduction of 62.52%, which means 576,000 million pesos less in consumption. A 60% of analyzed sectors were inefficient.

The main finding, shows a high percentage of the sectors must reduce their inputs (NB, E, AT, EC) to reach the efficiency frontier of production, or increase their outputs without changing the combination of inputs. The findings are key to develop plans to enlarge installed capacity, and applying for credit from the financial sector. It is imperative to check which resources are not used, and the impact they have on the generation of value. In spite of the importance that the industrial sector has in the country's development, it has weaknesses related to technical efficiency that undermine its competitiveness.

Similarly, these weaknesses increase the sector's vulnerability before new globalization challenges posed by the world's dynamics. This study provides entrepreneurs with elements to understand the importance of managing technical efficiency. Likewise, entrepreneurs will find its interpretation by means of efficiency indicators that provide information about the productivity of the sectors' current resources. In view of the value generation concepts, every single inefficient sector is undermining the value of our economy.

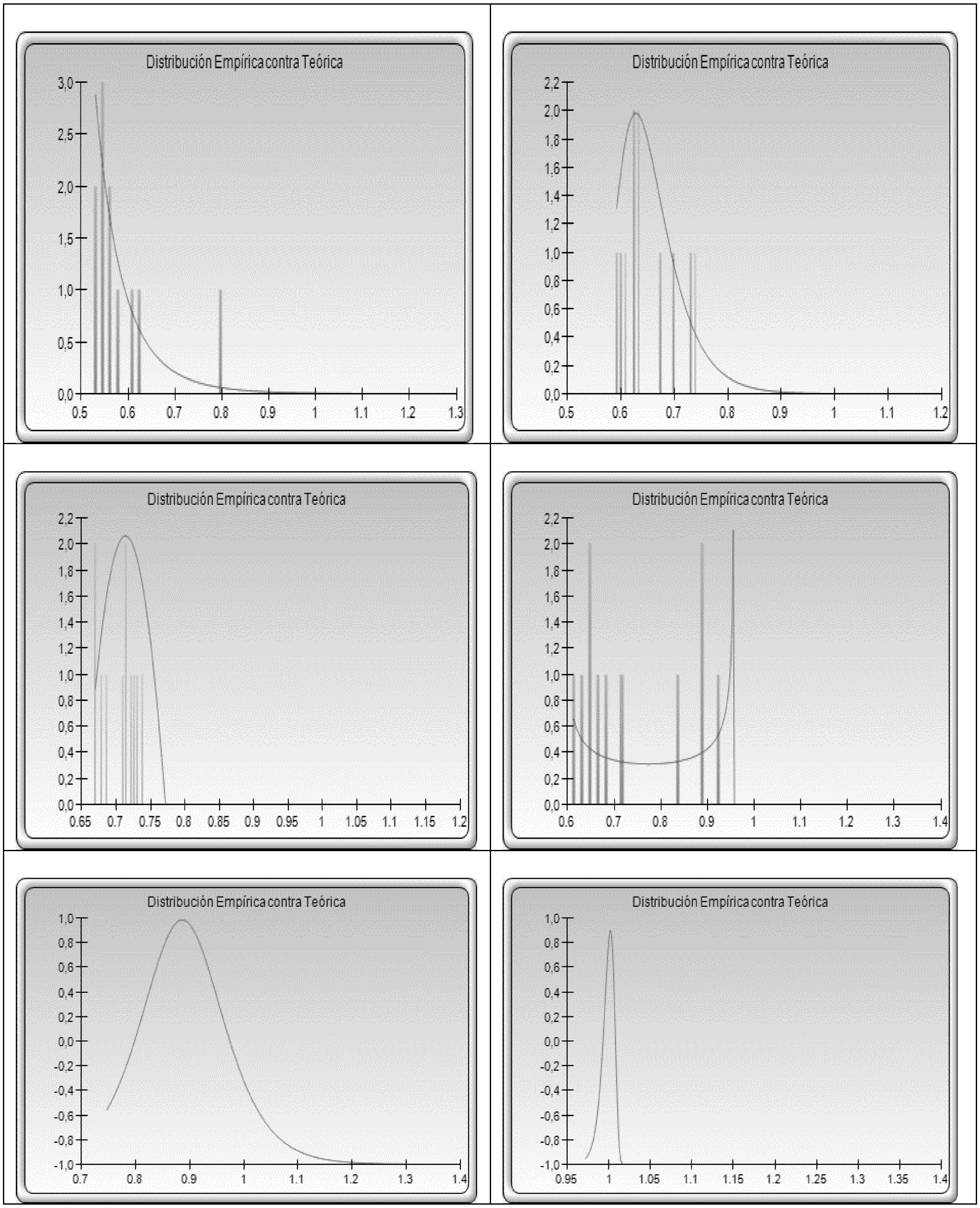
Despite the fact that EBITDA is deemed an appropriate measure to determine the generation of a company's value, problems arise when this is the only way to measure an organization's performance. One of the reasons is that it does not take efficiency into account. It is necessary to combine a company's financial performance with risk- and efficiency measures. This paper presents a non-parametric method to measure the latter. Risk-measurement is suggested as a complement to determine the real effect that it will have on value for stakeholders. Entrepreneurs must reflect carefully on the aspects mentioned above. They may be more important than the results obtained in the mere figure of cash flow and EBITDA. We conclude that inefficient sectors can improve efficiency with adopting strategic decisions suitable to obtain the best mix of resources. The spread of features of efficient firms allows improving business competitiveness the region.

Limitations: No information is available for total industrial sectors in the country for the analysis period. This situation forced to take the sample for firms with more than 20,000 employees. In the productivity analysis with DEA assumes that normal fluctuations and measuring errors are small compared to real differences between observed performances for decision making units. Comparing the results of two studies applied to different groups of samples is not significant, since the differences between the practices employed by units of each of the samples are unknown. And besides, the results are highly sensitive to the presence of measurement errors in the inputs and outputs.

Future Research: Intends to apply the model to measure efficiency companies in the sector in order to establish plans for improving export performance of firms to deal properly signing trade free agreements

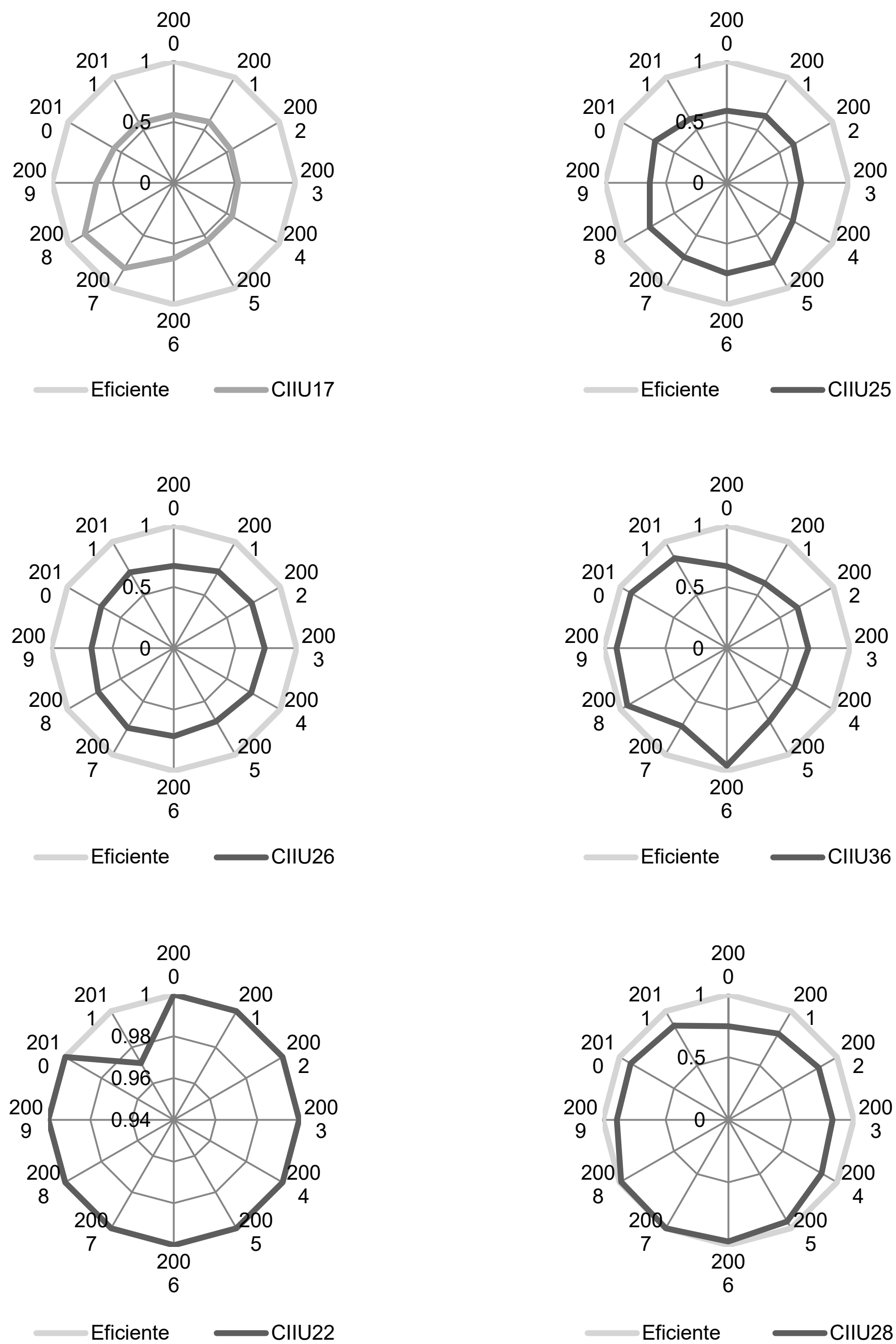
APPENDICES

Figure 2: Probability Distribution for the Inefficient Sectors



Source: developed by the authors on Risk Simulators

Figure 3: Graphic Summary of the DEA-CCR Results



REFERENCES

Arzubi, A., & Berbel, J. (2002). Determinación de índices de eficiencia mediante DEA en explotaciones lecheras de Buenos Aires. Investigaciones agropecuarias, 17(2).

Ayela P. & Muñoz, G. (1993). Generación de fronteras eficientes en el análisis financiero: una aplicación empírica. *Revista española de financiación y contabilidad*, *19*.

Azarang, M. & García, E. (2006). *Simulación y análisis de modelos estocásticos.* México: McGraw Hill.

Banker, R. D., Charnes, A. y C. W.W. (1984). Some Models for Estimating Technical and Scale Efficiencies in Data Envelopment Analysis, *Management Science. 30(9)*, 14.

Barnes, P., (1987). The Analysis and Use of Financial Ratios. *Journal of Business. Finance and Accounting 14*, 12.

Chiavenato, I. (2004). *Introducción a la teoría general de la administración* (Séptima ed.). McGraw-Hill Interamericana.

DANE (2012). Encuesta Anual Manufacturera (EAM). Bogotá.

Farrel, M. J. (1957). The Measurement of Productive Efficiency. Journal of the Royal Statistical Society, 120(3), 253-290.

Frainer, D. (2012). *A eficiência técnica de Hospitais Universitários Federais Brasileiros no primeiro semestre de 2001*. Universidad Federal de Santa Catarina, Brazil. Recuperado a partir de https://repositorio.ufsc.br/handle/123456789/87033

Franca, J. (2013). *Um modelo para avaliar o impacto da assimetria de informação na gestão de organizações sociais com aplicação às universidades federais brasileiras*. Universidad Federal de Santa Catarina, Santa Catarina. Recuperado a partir de https://repositorio.ufsc.br/handle/123456789/101670
Gregory, M. (2004). *Economía* (Tercera Edición ed.). España: McGraw-Hill Interamericana.

Hanoch, G. & Rothschild, M. (1972). Testing the Assumptions of Production Theory,. *Journal of Political Economy* (80), 256-275.

Hernández de Cos, P., Argimón, I., & Gonzaléz-Paramo, J. (1995). ¿Afecta la titularidad pública a la eficiencia empresarial? Evidencia empírica con un panel de datos del sector manufacturero español. *Documento de trabajo*. España: Banco de España.

Koontz, H. & Weihrich, H. (2004). *Administración una perspectiva global* (Decimosegunda ed.). McGraw-Hill Interamericana.

Loaiza, O. (2012). Un estudio acerca de los determinantes de la productividad y la ineficiencia técnica en la industria colombiana, 1992-2007. Tesis de Maestría, Universidad Nacional de Colombia, Medellín.

Lotero, J. (ed). (2007). *Desarrollo espacial, productividad y competitividad comercial durante la apertura de los noventa*. Medellín: Centro de Investigaciones Económicas, Universidad de Antioquia.

Reinaldo, O. (2002). *Teorías de la administración.* International Thomson Editores S.A. de C.V.

Restrepo, J. & Vanegas, J. (2009). Análisis del perfil financiero de las pymes del Valle del Aburrá y su acceso al crédito: una aplicación empírica. *Ingeniería Industrial. Actualidad y Nuevas Tendencias*, n. 3, p. 43-54.

Robbins, S. & Coulter, M. (2005). *Administración* (Octava ed.). Pearson Educación.

Samuelson, P. & Nordhaus, W. (2002). *Economía* (Decimoséptima ed.). España: McGraw Hill Interamericana.

Sengupta, J. (1987). Production Frontier Estimation to Measure Efficiency: A Critical Evaluation in Light of Data Envelopment Analysis. *Managerial and Decision Economics, 8*, 93-99.

Simón, A. (2005). *Diccionario de Economía* (Tercera ed.). Andrade.

Torres, D. & Gilles, E. (2013). *Análisis de la política comercial y su impacto en las exportaciones industriales (1990-2011)*. Universidad Jorge Tadeo Lozano, Bogotá.

Trillo, D. (2002). Análisis económico y eficiencia del sector público. *VII Congreso Internacional del CLAD sobre la Reforma del Estado y de la Administración Pública*. Lisboa, Portugal.

Villalobos, M. & Vallejo, J. (2005). Diferencias regionales en la eficiencia técnica del sector confecciones en Colombia: un análisis de fronteras estocásticas. *Innovar Revista de Ciencias Administrativas y Sociales*, 26, 90-105.

Salazar, Y. (2012). Frontera eficiente de producción en el primer nivel de atención en salud: modelo DEA ajustado por métodos bayesianos (info:eu-repo/semantics/doctoralThesis). Universidad de las Palmas Gran Canaria, Las Palmas Gran Canaria. Recuperado a partir de http://www.tdx.cat/handle/10803/116867

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