Estimation of the efficiency of the higher education in Colombia

Abstract— *This paper presents an estimation of the efficiency of private, public, accredited and non-accredited institutions of higher education (IHE´s) in Colombia. The results are associated with financial indicators and the installed human capacity of faculty and students, as well as environmental variables such as the geographical location of the institutions, their legal nature, whether they are high quality accredited or not, and the type of institution, be it universities or technical, technological or university institutions. This proposal seeks to use the theory of efficient frontier by parametric methods (stochastic frontiers analysis, SFA), which seeks to model an optimal combination of resources that, through the use of the installed capacity, allows for the greatest benefits. Considering the frontier of optimal combinations, the results of the estimation are compared for the different institutions in order to build a ranking of efficiency for 112 IHE´s at a national level. Finally, it was found that the average efficiency of IHE´s analyzed is 0.44; also, no evidence was detected that neither high quality accreditation, nor the type of institution, nor its legal nature could be statistically significant to determine the production efficiency of the IHE´s.*

Keywords- *Stochastic frontiers, Efficiency, Higher Education.*

1. Introduction

Education is one of the most powerful instruments for reducing poverty and inequality and lays the foundation for sustained economic growth (Unesco, 2015); therefore, it is one of the eight Millennium Development Goals, as a result of the Millennium Declaration globally approved by the Member states of the United Nations in 2000. The Objective 2 raises the need to achieve universal primary education, which is the basis for the major challenges in higher education, which ensures the development of countries.

According to the Ministry of National Education of Colombia (hereinafter MEN), education is defined as a "process of continuous training, personal, cultural and social, which is based on a comprehensive conception of the human person, their dignity, their rights and their duties "(MEN, 2009). Education not only allows the formation of human capital, but also an alternative for the production and transmission of knowledge, a promoter of technological change, a mechanism for social mobility and an engine of the economy.

The higher education system in Colombia has progressed significantly during the last decade. The enrollment rate has doubled and an increasing number of young people from low-income households have entered higher education. They have taken important steps to develop quality assurance. The country should continue to improve the quality and relevance of higher education and at the same time attract more students (OECD, 2016: 268). Now there is evidence that higher education institutions (hereinafter IHE) face numerous challenges and, like any company, they seek for efficient allocation of its human

and physical and financial resources. Also, this allocation in institutions is reflected in their level of quality; therefore, the objective of this study is to evaluate the level of efficiency of Colombian IHE through financial and statistical indicators.

The IHE are non-profit entities, this implies that profits obtained must be reinvested in the social purpose for which they are intended. If you make good use of financial resources, they can improve their technical, academic, administrative and infrastructure, and also improve the indicators mentioned above.

Efficiency means achieving goals set at the lowest cost and time possible, without wasting resources and with the highest level of quality possible; It is important to note that the level of efficiency also depend on the allocation of resources and opportunities in the environment (Ganga Contreras et al, 2014:. 131).

Now, the two most used ways to measure efficiency are data envelopment analysis (data envelopment analysis, DEA onwards) and stochastic frontier analysis (stochastic frontier analysis, hereinafter SFA). The main difference between these two methods is that the DEA, developed by Charnes, Cooper and Rhondes in 1978, is a nonparametric method that uses linear programming and evaluates the efficiency of a set of data inputs (inputs) and outputs (outputs), which generates an efficient frontier in the purport of Pareto. On the other hand, the SFA is the ability to obtain maximum benefit from a given quantity of inputs and technologies, ergo, determine a production function in which the distance is measured between the observations and the optimal value predicted by the model (Battese and Coelli, 1995).

In this paper we choose to use the method of SFA as set Scippacercola and Sepe in his article about the main components of analysis for efficiency rankings by SFA and DEA (2014), which concluded that, in light of the data for the first few stronger results than the second, because the SFA allows estimating a production function and set several models changing the dependent variable to the point of identifying the model with greater statistical relevance or acceptance is obtained. The objectives of this work, then, are aligned to the conclusion of these authors and the methodology by stochastic frontiers.

For the development of this work statistical and financial data were selected, between 2009 and 2014, for 112 Institutions of High Education, public and private, accredited and non-accredited in Colombia. The provision of information is a compilation from various sources such as the Directorate of National Taxes and Customs of Colombia (DIAN), MEN, the Colombian Institute for the Evaluation of Higher Education (ICFES), the Colombian Institute of Educational Credit and Technical Studies Abroad (Icetex), OLE (Labor Observatory for Education), the institutions involved, among others. Once selected data, the coefficients of technical efficiency for each IHE were found, the efficient frontier was established and proceeded to generate a ranking of IHE through the methodology of SFA (parametric method), in order to identify and differentiate whether there are environmental factors that affect the efficiency between them.

2. Higher education in Colombia

The system of higher education in Colombia is particularly complex, with a variety of suppliers and multiple programs of different levels and durations.

Higher education is offered in two levels: undergraduate and graduate. Undergraduate level has, in turn, three levels of training: technical and professional (relative to professional technical programs), technological (relative to technological programs) and professional (professional university programs on).

On the other hand, the education of postgraduate, comprises the following levels: specializations (relating to programs of professional technical specialization, technological expertise and professional specializations), master's degrees and doctorates.

Formal degree programs can be accessed by those people certifying the degree of Bachelor and the State examination: compulsory official testing that presented the graduates of secondary education and wish to continue with higher education (MEN, 2016).

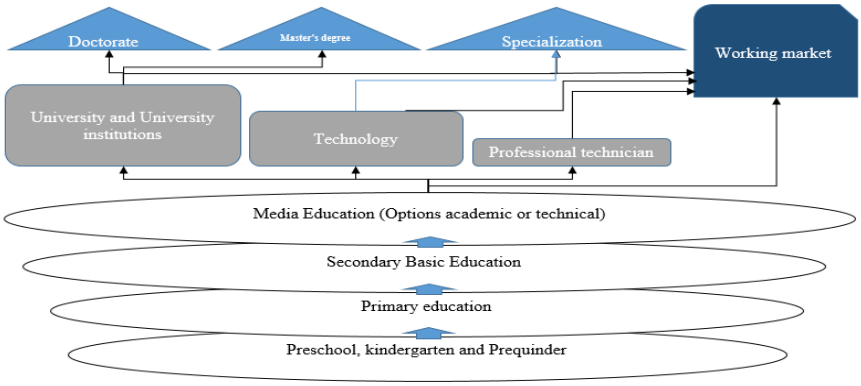


Figure 1 - Structure of the Colombian educational system

Source: elaboration of the authors from the Organization for cooperation and economic development, OECD (2016).

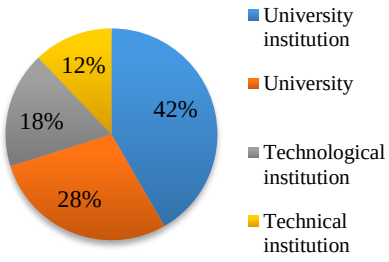
According to the Organisation for Economic Co-operation and Development, OECD (2016), there are 288 higher education institutions in Colombia, of which 28% are universities, ie academic institutions offering undergraduate and graduate programs; 42% are universities that offer undergraduate programs and specializations, but not masters; 18% is made up of technical institutions that offer technical and technological programs; and finally, 13% represents professional technical institutions offering vocational training programs for jobs or occupations. All this is defined by Law 30 of 1992 (Colombia, Congress: 1992) and Act 115 of 1994 (Colombia, Congress: 1994). Table 1 shows the character of the IHE is presented in Figure 1 and the percentages of participation.

Tabla 1 - *Character of the IHE*

Character	Official	Unofficial	Regime special	Total
University	31	50	1	82
University institution	16	92	12	120
Technological institution	6	39	6	51
Technical institution	9	26		35
Totales	62	207	19	288

Source: MEN, SACES (s. f.)

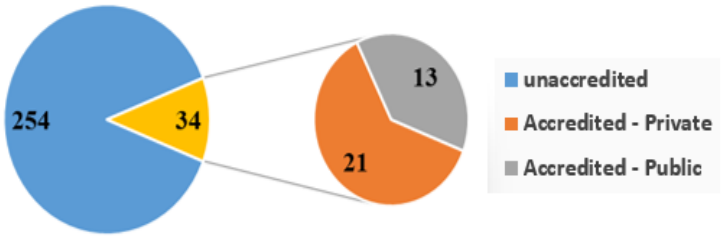
Graphic 1 - *Participation rates by Character of IHE*



Source: SACES – elaboration of the authors

Universities can be classified into accredited and unaccredited in high quality. According to the National Accreditation Council (hereinafter CNA), accreditation is a recognition by the state of the quality of higher education institutions and their academic programs. This recognition is given primarily to guide towards an ideal of excellence, high quality display through specific results, consolidated tradition, impact and social recognition (National Council of Higher Education, CESU, 2014). Of the 288 IHE, only 34, that is to say the 11.8%, were accredited on high quality in 2014, and of these 34, 61.8% are private and 38.2% are public (MEN, 2014). Figure 2 below shows the legal nature and accredited higher education institutions.

Graphic 2 - Nature legal e IHE accredited



Source: Elaboration of the authors from MEN, national system of higher education information, SNIES (s. f.) and MEN, National Accreditation Council, CNA (s. f.).

According to the System of Quality Assurance in Higher Education (SACES), academic programs offered in 2014 they totaled 10,508 in all levels of education, and of these only 904 were accredited in high quality, ie 8.6 % of total supply.

Table 2 – A*cademic programs by area of knowledge*

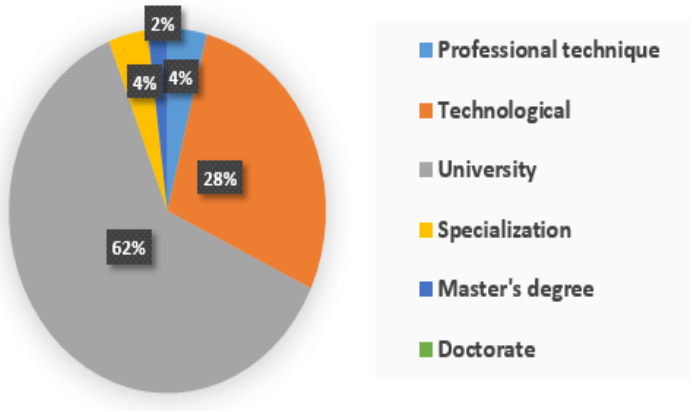
Area of knowledge	With record qualified		Of high quality (to. C.)	
	Number	% of participation	Number	% of participation
Economy. Administration. Accounting and related	2 959	28.2	143	15.8
Engineering. Architecture. Urban planning	2 585	24.6	288	31.9
Social Sciences. Law and political science	1 909	18.2	168	18.6
Health Sciences	1 065	10.1	107	11.8
Sciences of education	824	7.8	80	8.8

Fine arts	490	4.7	41	4.5
Mathematics and natural sciences	388	3.7	52	5.8
Agronomy, veterinary science and related	288	2.7	25	2.8
Total	10 508	100	904	100

Source: MEN, SACES (s. f.) and CNA (s. f.), with cut to December of 2014.

Of the 10,508 programs, 81.1% refers to subject areas such as Engineering, Architecture, Urbanism, Social Sciences, Law, Political Science, Health Sciences, Economics, Management, Accounting and related, among others. Of this total, 8.6% are accredited in high quality. As for the areas of knowledge, those with the highest rate of high-quality programs versus the number of qualified records are Mathematics and Natural Sciences (13.4%), followed by Engineering, Architecture and Urbanism (11.1%) and Science health (10.05%). Graphic 3 below shows the percentage share of the total enrollment by level of education.

Graphic 3 - *Percentage share of the total of the enrolment by level of education*



Of the total tuition revenue in 2013, 62% belongs to the level of university education, followed by 28% technologies and professional technical with 4.2%. If these participation rates are analyzed from a historical point of view, it is observed that the technological training has been increasing its percentage share of total enrollments (MEN, 2014).

Source: MEN, SACES (s. f.) and CNA (s. f.), with cut to March 2013.

3. Literature Review

For the preparation of this study the lifting of the state of the art concerning the measurement of efficiency mainly in the education sector and other sectors such as metallurgical, textile, health was conducted, among others. In this collection it was found that the methodologies used are Stochastic Frontier (SFA) and data envelopment analysis (DEA). In total 50 papers were reviewed, which were not included in this submission. Here in Table 3, the top five analyzed studies focused on the methodology used and results obtained are presented.

Table 2 - *Major works of reference*

Authors	Year	Methodology / country	Results
MEN and OEC	2016	Report and definitions Colombia	• Important reference because it analyzes the current situation of the education system of Colombia, since its structure and policies and statistics, comparing their results with member countries of the OECD.
L. A. Melo B., E. Ramos F. an P. O. Hernánde S.	2014	SFA Colombia	• The results indicate that there is a positive and significant response between academic achievement and variables associated infrastructure and teachers. The results also highlight the importance of environmental factors to explain the performance of the IHE. • This was one of the most important studies analyzed, to present the state of education in Colombia and a historical review of it, applying the methodology of SFA having as product quality and considering environment variables and socioeconomic characteristics of each IHE.
Melville L. Mcmillan and Wing H. Chan	2006	SFA and DEA Canada	• They use a Cobb-Douglas production function and considered two alternatives: the first assumes that environmental factors directly affect the form of the technology, and therefore are included directly as regresors in the production function; the second assumes that environmental conditions directly affect the technical efficiency of the producing units. • The efficiency technical, in average, varies among the 54 and the 80%. • The results of these models indicate that the treatment of the environment variables has a significant impact on the performance of the campuses. • Them campuses not official is could be benefiting from conditions of environment more favorable if is has in has that to these, in average, serve students of higher income.
Sergio Scippacercola and Enrica Sepe	2004	SFA and DEA Italy	• This work presents a comparison between stochastic frontier and DEA with the same input and output variables that are different. As well as the theoretical explanation of both models
James Jondrow C. A. Knox Lovell, Ivan S.Materov and Peter Schmidt	1982	SFA Holand	• Present a method to separate the error term of the model of stochastic frontier into its two components for each observation. This allows estimate the level of efficiency technical for each observation in the shows and eliminates large part of what had been seen as a disadvantage considerable of the model of border stochastic in relation to other models.

Source: elaboration of the authors

Of the 50 studies analyzed, 12 are from Colombia and 38 international; 21 use the Stochastic Frontier methodology 12 used data envelopment analysis, 6 use both methodologies and 11 other methodologies applied or were theoretical works or compilations.

4. Theoretical approach and methodology

In this paper the definition of productive efficiency proposed by Farrel (1957) is assumed, which relates the concepts of technical efficiency and allocation efficiency. This definition not only considers the realization of the maximum amount of

product, but also selecting the best combination of factors. Therefore, it means efficiency and the ability to produce any goods or services at a minimal cost efficiently and productively.

Differences arising between the theoretical maximum and that actually produce the IHE are known as technical inefficiency. These differences reflect that IHEs have not maximized their production level, that is to say, that the combination of input and output has not reached its peak production. Therefore, considering this theoretical production frontier is possible to define efficiency indicators for the production unit under study (Acevedo Villalobos and Ramirez Vallejo, 2005).

This definition of efficiency relates that a combination of all factors that are transformed to generate products. In the case of higher education, it is understood as a product that related to its name: to generate knowledge and competent people (MEN, 2009), which in this work is considered as the number of graduates in undergraduate and graduate students.

The model is made by panel data methodology looking troubleshoot cross-sectional data submitted by Schmidt and Sickles (1984), estimating the inefficiency term, which, although unbiased, is inconsistent; this is solved with panel data, because the technical inefficiency of each producer can be consistently estimated as the number of observations in each institution increases.

Another problem of cross-sectional data identified by Schmidt and Sickles is the decomposition of noise and inefficiency distance, which requires some assumptions, for example, that inefficiency is independent of the regressor, which depends on the context. On the other hand, the estimate data via panel has no assumptions about inefficiency, because it is the same all the time. Finally, this methodology does not require the assumption of independence between the technical inefficiency and the explanatory variable.

The two main models of panel data are the fixed effects and random effects, where the first allows dependency (endogeneity) between the regressor model and invariant components in the time of the error, while the second assumes that the regressor is completely independent (exogenous). As selection criteria between one model or another Hausman test is performed with the estimates obtained from each of these models.

A model production boundary provides a default value for the parameter estimates value with an error that is supposed to be a mixture of two components having a strictly non-negative and symmetrical distribution, respectively (Kumbhakar and Knox Lovell, 2000).

The theoretical specification of the production frontier is presented in equation 1.

$$Y_t^p = f(C_t^p; T_t^p; Z_t^p) \quad (1)$$

Where Y is the product of each institution p in each period t, C represents the vector of inputs of financial variables, T the vector of variables staff and Z vector corresponds to the environment variables or environmental.

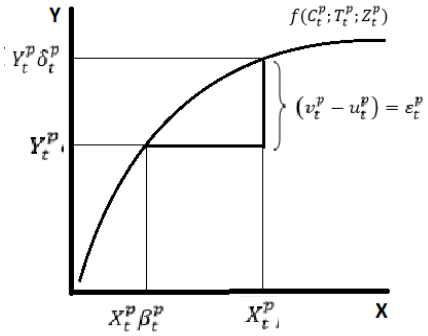
To determine the efficiency of the production function Cobb-Douglas that uses two components in its most basic form is described by capital and labor, from which can be estimated elasticities used. Where the error term (ε) enters the model geometrically. Thus, you can define the border, as shown in Equation 2.

$$Y_t^p = f\left(x_{1t}^p, x_{2t}^p, \ldots x_{kt}^p; \beta\right) exp(v_t^p - u_t^p)$$

$$ln\, Y_t^p = \alpha + \beta \ln(X_t^p) + V_t^p - U_t^p \quad (2)$$

Donde: $(v_t^p - u_t^p) = \varepsilon_t^p$

Gráphic 4 - *Frontier of production*



Where f is the production function in optimal conditions with the best allocation of resources, in our case the set of variables C, T and Z.

As claim Melo B., F. Ramos and Hernandez S. (2014), measuring it as a product called education is uneven because, contrary to other productive activities where homogeneous goods are created, in the case of education fixed amounts of inputs are transformed into individuals with different qualities (Hanushek, 1986: 1150).

Meanwhile, the input vector X_{kt}^p corresponds to the vector of factors, including *k* variables that provide information for each institution in each period t p over financial reporting and personnel of the IHE. After having found the total variables initially assumed in Table 4, within financial variables (the vector C_{kt}^p) in the final model were significant operational expenses and tuition income. As for the related personnel (vector T_{kt}^p), in the final model were significant number of academic teachers, the students and the teacher student relationship.

The Z_{kt}^p vector includes environment variables, which represent factors that do not directly affect the production function, but have an impact on the performance of IHE. They are taking into account factors associated with higher education institutions. i) The first considers the accreditation, which takes the value of 1 for higher education institutions that are accredited and zero for those who are not ii) the second corresponds to the legal nature, which takes the value 1: Four dummy variables are included for IHE that are private and zero for the public. iii) the third refers to the geographical location, which takes the value

of one for higher education institutions operating in the cities of Bogota, Cali and Medellin and zero for higher education institutions located in other cities. And finally iv) the nature of the IHE, being 1 if they are universities and zero if they are technical, technological and academic institutions.

As shown in equation 2, it is assumed that the error term (ε) has two components $\varepsilon_t = v_t - u_t$ for a production function, where v is a random variable and assuming that deviations from the border do not give errors measurement or outside the control of IHE. or, therefore, u it is the component measuring inefficiency; if an IHE is fully efficient, $u = 0$ and deviations from the border are completely random (Melo, Ramos and Hernandez, 2014: 26).

The model used is the approximation finally Battese and Coelli (1995), in which the environment variables are a function of inefficiency term (u_i), as shown in Equation 3 below.

$$\ln Y_t^p = \beta_0 + \sum_{k=1}^{nC} \beta_k^p \ln C_{k,t}^p + \sum_{k=1}^{nT} \beta_k^p \ln T_{k,t}^p + v_t - u_t\,, \qquad (3)$$

$$u_t \sim N\left[\delta_0 + \sum_{j=1}^{nZ} \delta_{j,t}^p\,, Z_{j,t}^p \sigma^2\right]$$

Where nC, nT y nZ is the number of parameters for the Financial vectors, staff and available, respectively environment.

The provision of statistical information is a compilation from various sources such as DIAN, MEN, ICFES, ICETEX, OLE and information published by each institution, for a total of 112 IHE, financial variables used were previously deflated to 2008 prices Table 4 below shows the model variables.

Table 3 – *Variables*

	Nemo technical	**Name of the variable**	**Description**	**Expected sign**	**Justification**
Variable of environment	Acr	Accredited	Value of 1 for the IESaccredited.	Positive	The accreditation of the IHE processes are sign of compliance in levels of superior quality, for what is expected to be more efficient to be recognized by the State.
	Priv	Private	Value of 1 for the private IHE.	Positive	IHE are non-profit, but his duty as private entities is to generate value, and for this they should take advantage of its resources.
	Ciud prin	Principal City	Value of 1 for the IHE that operate in Bogota, Cali and Medellin.	Positive	In the main cities is found the greater density of population and the main universities.
	Univ	Type of IHE	It refers to the character of the IHE, taking the value 1 for universities and 0 for technical, technological and university institutions.	Positive	The character of the University, for its recognition in the Middle, could be more efficient in the production of competent people.

	Nemo technical	Name of the variable	Description	Expected sign	Justification
Financial variables	Act	Active	It is good that it has and you can turn into money or equivalents.	Positive	To more active, more students must graduate, i.e., greater capacity of convert them in liquidity.
	Ps	Debt	Commitment that assumes an obligation to contract.	Negative	Each time it should produce less liquidity with resources from third.
	Pt	Equity	Set of goods that belong to a person, whether natural or legal.	Positive	The property belonging to the IHE should result in greater liquidity, i.e. efficiency.
	Ing	Operational income	Directly related to the production of a good or service which is the purpose of the universities.	Positive	While more efficient are the IHE, greater income to develop its object social.
	Matr	Revenue registration	Main source of income directly related with the subject social of the IHE. P	Positive	While more efficient are the IHE, revenue by fees to develop its main source of income.
	Uop	Operational utility	It is the related outcome of the exercise with the main activity of the IHE.	Positive	While more efficient are the IHE, best results to develop its corporate purpose.
	Egr_op	Operational expenses	It is the outflow of resources related to the main activity of the IHE.	Positive	To higher expenses, greater efficiency in terms of number of graduates in each IHE if resources are used.
	Ut	Net income	Reinvestment factor	Positive	While more efficient are the IHE, best results financial after complying with all their obligations financial and State.
	Gadmin	Expenditure administrative	Outputs of money associated with the administrative activities.	Negative	The IHE that used less resources in the management administrative are more efficient.
	Gdoc	Expenditure teaching	Outputs of money associated with activities academic.	Negative	The IHE that use fewer resources related to academic activities are more efficient.
	Mrop	Operating margin	Is the result related of the exercise with the activity main of the IHE regarding them income.	Positive	The IHE with best results related between its activity main and those revenues are more efficient.

	Nemo technical	Name Variable	Description	Sign expected	Justification
Personal variables	Prof	Teachers	Is has with information from the total of teaching unbundled in teaching of plant and teachers of Chair.	Negative	The IHE employing fewer teachers are more efficient
	Est	Students	It has information of the total number of students in undergraduate and postgraduate.	Positive	This variable has a direct relationship with the number of graduates.
	Est_doc	Students/teachers	It relates the number of students for each teacher.	Negative	This is a *proxy* related with the quality, to greater amount of teaching is the IHE would be more competent in the production of people competent.

Source: elaboration of the authors

5. Results

This section presents the results obtained from the equation 3. It is part of a specification that includes all the variables described in Table 5 and the expectations of the signs reported are presented there. The final model for which the explanatory variables have a significance level equal to or less than 5% is shown in Equation 4. The model of panel data finally used was fixed effects, determined after testing Breusch- Pagan and Hausman, the results and interpretations are presented in Tables 10 and 11 of the Appendix section.

$$\ln Grad = \beta_0 + \beta_1 \ln\left(\frac{Est}{Doc}\right) + \beta_2 \ln(Prof\ Cat) + \beta_3 \ln(Egre\ Oper) + \beta_4 \ln(Ing\ Matr) + \varepsilon \quad (4)$$

After extracting the expected value or the previous model, a linear regression was performed with the vector of environment variables to find factors can explain or, being defined regression for determinants of productive efficiency as shown in equation 5 .

$$u_t = \delta_0 + Acr + \delta_2\ Priv + \ \delta_3 Univ + \delta_4 Ciud_{prin} + \varepsilon_t \quad (5)$$

The results of the above regressions are presented in Table 5 and in Tables 12 and 13 in the Appendix section.

Table 4 - *Results of the model*

	Coefficient	Standard deviation	T	Expected sign
$\boldsymbol{\beta_0\ Constant}$	-0,075	0,862	-1,25	
$\boldsymbol{\beta_1 \frac{Students}{teachers}}$	-0,216	0,061	-3,53	-
$\boldsymbol{\beta_2\ Total\ students}$	0,227	0,088	2,56	+
$\boldsymbol{\beta_3\ Teachers\ Chair}$	-0,102	0,028	-3,59	-
$\boldsymbol{\beta_4\ Operational\ expenses}$	0,644	0,096	6,66	+
$\boldsymbol{\beta_5\ Tuition\ Revenue}$	0,027	0,006	-1,25	+

	Coefficient	Standard deviation	T	Expected sign
δ_0 *Constant*	0,444	0,036	12,29	
δ_1 *accredited*	-0,038	0,032	-1,16	+
δ_2 *Private*	0,021	0,031	0,69	+
δ_3 *Main city*	0,029	0,031	0,96	+
δ_4 *Caracter University*	-0,038	0,031	-1,24	+

Source: elaboration of the authors

The signs of the coefficients of the "inputs" resulting variables in the model are expected in the estimate. The number of students, operating expenses and tuition revenues have a positive impact on the results of the endogenous variable. And the number of academic teachers and teacher student relationship have a negative impact on results in the number of graduates of higher education institutions.

For the coefficients of the variables "environment", the expected signs are all positive. And for the "accredited" and "university status" factor the resulting value is negative, ie, it has a negative impact on the results obtained in productive efficiency. Despite the above results, this model is not conclusive to explain the production efficiency because the result was not statistically significant. Therefore, the production efficiency of the IHE is determined by internal factors of institutions, not by external factors.

When graduates (potential) efficient frontier relate to the actual graduates of 2014, it notes that is consistent with the fact that the error is considered geometric within a Cobb-Douglas function (v. Figure 5 in the Appendix section).

Comparing the number of graduates in 2014 against the number of graduates who may have been efficient frontier, it is concluded that the higher number of graduates is greater proportion relative to the efficient frontier. If the efficiency obtained by environment factors are grouped, the results shown in Table 6 are obtained.

Table 6 -*Results of efficiency clustered by the variable of environment*

		Average efficiency	Standard deviation	Efficiency minimum	Efficiency Max
Legal Nature	Public	0.420	0.141	0.252	0.866
	Private	0.454	0.151	0.057	0.873
Accreditation	Not accredited	0.452	0.158	0.057	0.873
	Accredited	0.423	0.118	0.245	0,738
Character	Technical, technological and university institutions	0.458	0.189	0.057	0.873
	Universities	0.434	0.113	0.245	0,738
Geographic location	Other cities	0.399	0.110	0.057	0.652
	Main cities	0.468	0.160	0.124	0.873
Total		0.443	0.148	0.057	0.873

As to the legal nature, they are more efficient than private IHE public IHE; however, private IHE have a higher standard deviation. It is noteworthy that accredited HEIs are not accredited more efficient than average. Similarly, higher education institutions that are technical, technological or universities are more efficient than so-called universities, although the former have a higher standard deviation. Finally, as expected, higher education institutions located in cities like Bogota, Cali and Medellin are more efficient than those located in other cities of Colombia average.

Table 7 shows the ranking of the ten most efficient IHE according to the estimated model is presented. The complete ranking of the 112 IHE analyzed are presented in Table 8 of the Appendix section.

Table 7 - *Efficiency ranking - first ten IHE*

Position	IHE	Efficiency
1	University Corporation for science and development, Uniciencia	0.872
2	Technological school Central technical school, ETITC	0.865
3	Tecnológico de Antioquia	0.827
4	Colombian Center for professional studies Foundation	0.826
5	University EIA	0.737
6	Corporation unified national higher education CUN	0.737
7	Fundación Universitaria Uninpahu	0.734
8	Universidad Católica de Colombia	0.706
9	Fundación Universitaria Maria Cano	0.705
10	Universidad EAN	0.686

Source: elaboration of the authors

The model shows that, on average, 112 IHE analyzed have an efficiency of 44.32%. If the results of efficiency are analyzed by percentiles (v. Table 9 in the Appendix section) is that 5% of IHE showed an efficiency of 25.65% below and 5% above efficiency of 73.6%.

Finally it is found that 50% of the IHE has an efficiency of between 34.8 and 51.07%.

6. Conclusions

This paper presents a brief description of the structure and composition of higher education in Colombia and levels of production efficiency for a sample of 112 IHE, with financial, personal and environment variables for the period 2009-2014 are determined, using techniques SFA and data panel.

The efficiency is estimated using a production function of the Cobb-Douglas type for the number of graduates of undergraduate and graduate, in accordance with the stated objective of the IHE by the MEN. The result of efficiency for the

sample varies between 0.057 and 0.873, where the value of 1 corresponds to the theoretical maximum production efficiency. For the sample the average of productive efficiency obtained was 0.443.

Apparently, the selection of the Cobb-Douglas function shows good results, as recommended by the studies reviewed. In Colombia the use of this function is recommended, since in this case it complies with the fact that the panel estimated residual data are geometric characteristics.

In attempting to explain the production efficiency obtained using environment variables it is that these are not statistically significant in the results obtained by the IHE; therefore, its inefficiency is largely due to factors not yet identified in this research, which pave the way for new jobs in this line. In addition, not enough evidence was found to conclude that high quality accreditation of higher education institutions is one of the determinants of their efficiency; This same situation occurs with the classification defined by Colombian law: colleges, universities, technical or technological.

From the results of this work the possibility to deepen the study of the efficiency of higher education institutions in Colombia including other factors in the study as the size of the IHE or its different segments or categories opens.

7. References

Acevedo Villalobos, M. C. y Ramírez Vallejo, J. (2005). Diferencias regionales en la eficiencia técnica del sector confecciones en Colombia: un análisis de fronteras estocásticas. *Innovar*, *15*(26), 90-105, julio-diciembre. Disponible en http://www.scielo.org.co/scielo.php?script=sci_arttext&pid=S0121-50512005000200006

Agasisti, T. y Johnes, G. (2009). Beyond frontiers: comparing the efficiency of higher education decision-making units across more than one country. *Education Economics*, *17*(1), 59-79. Disponible en http://eprints.lancs.ac.uk/45008/1/10.pdf

Battese, G. E. y Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*, 20, 325-332. Disponible en http://pages.stern.nyu.edu/~wgreene/FrontierModeling/Reference-Papers/Battese-Coelli-1995.pdf

Colombia, Congreso de la República (1992, 28 de diciembre). *Ley 30: Por la cual se organiza el servicio público de la educación superior*. Bogotá: Diario Oficial 40700. Disponible en http://www.alcaldiabogota.gov.co/sisjur/normas/Norma1.jsp?i=253

Colombia, Congreso de la República (1994, 8 de febrero). *Ley 115: Por la cual se expide la Ley General de Educación*. Bogotá: Diario Oficial 41214. Disponible en http://www.alcaldiabogota.gov.co/sisjur/normas/Norma1.jsp?i=292

Colombia, Consejo Nacional de Educación Superior, CESU (2014). *Acuerdo 03 de 2014: Por el cual se aprueban los lineamientos para la acreditación institucional*. Bogotá: Consejo Nacional de Acreditación, CNA. Disponible en http://www.cna.gov.co/1741/articles-186370_acuerdo_03_2014.pdf

Colombia, Ministerio de Educación Nacional, MEN (2009, 20 de julio). *¿Qué es la educación superior?* Disponible en http://www.mineducacion.gov.co/1621/article-196477.html

Colombia, Ministerio de Educación Nacional, MEN (2014, 30 de noviembre). *Estadísticas de educación superior*. Bogotá: Ministerio de Educación Nacional. Disponible en: http://www.mineducacion.gov.co/sistemasdeinformacion/1735/articles-212350_Estadisticas_de_Educacion_Superior_.pdf

Colombia, Ministerio de Educación Nacional, MEN (2016). *Revisión de políticas nacionales*. París: Organización para la Cooperación y el Desarrollo Económicos, OCDE. Disponible en http://www.oecd-ilibrary.org/education/revision-de-politicas-nacionales-de-educacion_1990021x

Colombia, Ministerio de Educación Nacional, MEN (s. f.). Consejo Nacional de Acreditación, CNA. Sitio web http://www.mineducacion.gov.co/1621/article-196486.html

Colombia, Ministerio de Educación Nacional, MEN (s. f.). Sistema de Aseguramiento de la Calidad de la Educación Superior, SACES. Sitio web http://www.mineducacion.gov.co/1759/w3-article-156291.html

Colombia, Ministerio de Educación Nacional, MEN (s. f.). Sistema Nacional de Información de la Educación Superior, SNIES. Sitio web http://www.mineducacion.gov.co/1759/w3-article-156293.html

Donoso D., S., Aguirre G, M., Espinoza B., C., Manríquez G., P. y Silva C., M. (1999). Análisis de la eficiencia de la educación básica mediante el método de fronteras estocásticas de producción: el caso de la comuna de Talca. *Estudios Pedagógicos*, 25, 21-49. Disponible en http://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0718-07051999000100002

Dufrechou, P. A. (2016). The efficiency of public education spending in Latin America: A comparison to high-income countries. *International Journal of Educational Development*, 49, 188-203, julio.

Farrell, M. J. (1957). The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society, Series A (General)*, *120*(3), 253-290.

Ganga Contreras, F., Cassinelli Capurro, A., Piñones Santana, M. A. y Quiroz Castillo, J. (2014). El concepto de eficiencia organizativa: una aproximación a lo universitario. *Líder*, 25, 126-150. Disponible en http://ceder.ulagos.cl/lider/images/numeros/25/5_Ganga.pdf

Hernández Falcón, D. de la C., Vargas Jiménez, A., Almuiñas Rivero, J. L. y García Cuevas, J. L. (2015). Los indicadores actuales de la eficiencia académica: necesidad de su perfeccionamiento. *Pedagogía Universitaria*, *20*(3), 53-62. Disponible en http://cvi.mes.edu.cu/peduniv/index.php/peduniv/article/view/690/pdf_65

Hopkins, D. S. (1990). The Higher Education Production Function: Theoretical Foundations and Empirical Finding. Capítulo 1 en *The Economics of American Universities*, Stephen A. Hoenack y Eileen L. Collins (eds.). Albany: State University of New York Press. Disponible en http://www.sunypress.edu/pdf/50215.pdf

Iregui, A. M., Melo, L. y Ramos, J. (2007). Análisis de eficiencia de la educación en Colombia. *Revista de Economía del Rosario*, *10*(1), 21-41, junio. Disponible en http://www.urosario.edu.co/economia/documentos/v10n1_iregui_melo_ramos/

Kumbhakar, S. C. y Knox Lovell, C. A. (2000). *Stochastic Frontier Analysis*. Reino Unido y Estados Unidos: Cambridge University Press. Disponible en http://catdir.loc.gov/catdir/samples/cam032/99031297.pdf

Lozano, F., Villa, E. y Monsalve, S. (1999). Competencia perfecta: equilibrio walrasiano y óptimo de Pareto. Capítulo 1 en S. Monsalve, *Introducción a los conceptos de equilibrio en economía*, pp. 13-94. Bogotá: Universidad Nacional.

Melo B., L. A., Ramos F., J. E. y Hernández S., P. O. (2014). La educación superior en Colombia: situación actual y análisis de eficiencia. *Borradores de Economía*, 808, 1-50.

Montoya Suárez, O. y Soto Mejía, J. (2011). Estimación de la eficiencia técnica de las economías de los departamentos cafeteros de Colombia aplicando la función Cobb- Douglas translogarítmica con fronteras estocásticas y datos de panel. *Scientia Et Technica*, *1*(47), 83-88. Disponible en http://revistas.utp.edu.co/index.php/revistaciencia/article/view/567/303

Moreira, V. H., Bravo-Ureta, B. E., Carrillo, B. L. y Vásquez, J. A. (2006). Medidas de eficiencia técnica para pequeños productores de leche del sur de Chile: Un análisis con fronteras estocásticas y datos de panel desbalanceado. *Archivos de medicina veterinaria*, *38*(1), 25-32. Disponible en http://www.scielo.cl/scielo.php?script=sci_arttext&pid=S0301-732X2006000100004&lng=en&nrm=iso&tlng=en

Navarro España, J. L., Maza Ávila, F. y Viana Barceló, R. (2011). La eficiencia de los hospitales colombianos en el contexto latinoamericano. Una aplicación de análisis envolvente de datos (DEA) en un grupo de hospitales de alta complejidad, 2009. *Ecos de Economía*, *15*(33), 71-93, julio-diciembre. Disponible en file:///C:/Users/Juan%20Arango/Desktop/Dialnet-LaEficienciaDeLosHospitalesColombianosEnElContexto-3974980.pdf

Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura, Unesco. (2015). *Podemos erradicar la pobreza. Objetivos de desarrollo del milenio y más allá de 2015*. París: Organización de las Naciones Unidas para la Educación, la Ciencia y la Cultura, Unesco. Disponible en http://www.un.org/es/millenniumgoals/

Organización para la Cooperación y el Desarrollo Económicos, OCDE (2016, 5 de febrero). *Revisión de Políticas Nacionales de Educación: La educación en Colombia*. Paris: Organización para la Cooperación y el Desarrollo Económicos (OCDE). Disponible en http://www.oecd-ilibrary.org/education/revision-de-politicas-nacionales-de-educacion_1990021x

Schmidt, P. y Sickles, R. C. (1984). Production Frontier and Panel Data. *Journal of Business & Economic Statistics*, *2*(4), 367-374, octubre. Disponible en http://pages.stern.nyu.edu/~wgreene/FrontierModeling/Reference-Papers/Schmidt-Sickles-JBES84-PanelSF_FE.pdf

Scippacercola, S. y D'Ambra, L. (2014). Estimating the Relative Efficiency of Secondary Schools by Stochastic Frontier Analysis. *Procedia Economics and Finance*, 17, 79-88. Disponible en http://ac.els-cdn.com/S2212567114008818/1-s2.0-S2212567114008818-main.pdf?_tid=ebc1102c-5c2c-11e6-85a4-00000aacb362&acdnat=1470526048_522611db269e6d6effd1ddb1c72cc55e

Scippacercola, S. y Sepe, E. (2014). Principal component analysis to ranking technical efficiencies through stochastic frontier analysis and DEA. *Journal of Applied Quantitative Methods*, *8*(4), 1-9, invierno. Disponible en http://www.jaqm.ro/issues/volume-9,issue-4/pdfs/1_SCIPPACERCOLA_SEPE.pdf

Ueasin, N., Liao, S.-Y. y Wongchai, A. (2015). The Technical Efficiency of Rice Husk Power Generation in Thailand: Comparing Data Envelopment Analysis and Stochastic Frontier Analysis. *Energy Procedia*, 75, 2757-2763, agosto. Disponible en http://ac.els-cdn.com/S1876610215012862/1-s2.0-S1876610215012862-main.pdf?_tid=ff5739b2-5c2d-11e6-97b7-00000aacb361&acdnat=1470526510_a72adcf0a6cc78bb45bbada9e5bfdfde

Valderrama Santibáñez, A. L., Neme Castillo, O. y Ríos Bolívar, H. (2015). Eficiencia técnica en la industria manufacturera en México. *Investigación Económica*, *74*(294), 73-100, diciembre. Disponible en http://www.sciencedirect.com/science/article/pii/S018516671500051X

8. ANNEXES

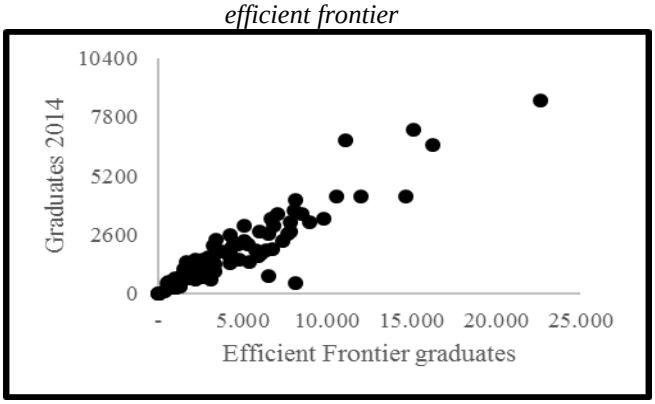
Table 8 -IHE Colombia efficiency ranking obtained with the proposed methodology

Position	IHE	Eficiency	Position	IHE	Eficiency
1	Corp. Universitaria de Ciencia y desarrollo	0,873	57	Universidad El Bosque	0,411
2	Escuela Tecnológica Instituto Técnico Central	0,866	58	Esc. Colombiana de Ing. Julio Garavito	0,410
3	Tecnológico de Antioquia	0,828	59	Universidad de Los Andes	0,409
4	Centro Colombiano de Estudios Profesionales	0,826	60	Universidad Distrital	0,408
5	Escuela de Ingeniería de Antioquia	0,738	61	Universidad de Nariño	0,406
6	Corporación Nacional de Educación Superior	0,737	62	Corporación Universitaria Rafael Núñez	0,406
7	Fundación Universitaria Uninpahu	0,735	63	Pontificia Universidad Javeriana	0,405
8	Universidad Católica de Colombia	0,706	64	Autónoma de Las Américas	0,404
9	Fundación Universitaria Maria Cano	0,705	65	Politec. Colombiano Jaime Isaza Cadavid	0,404
10	Universidad EAN	0,686	66	Universidad de La Amazonia	0,404
11	Universidad de Ibagué	0,652	67	Universidad Autónoma de Manizales	0,403
12	Politécnico Internacional	0,643	68	Universidad Incca de Colombia	0,400
13	Autónoma Latinoamericana Unaula	0,627	69	Universidad Mariana	0,398
14	Universidad Externado de Colombia	0,619	70	Universidad Católica de Oriente	0,393
15	Fundación Universitaria Luis Amigo	0,611	71	Universidad de Cundinamarca	0,384
16	Universidad Libre	0,610	72	Fundación Universidad Central	0,378
17	Universidad Autónoma del Caribe	0,602	73	Universidad Nacional	0,377
18	Fund. Univ. de Bogotá-Jorge Tadeo Lozano	0,590	74	Fundación Universitaria de Popayán	0,376
19	Fundación Tecnológico Comfenalco	0,566	75	Corp. Universidad Piloto de Colombia	0,373
20	Universidad del Tolima	0,556	76	Universidad de Sucre	0,371

Position	IHE	Eficiency	Position	IHE	Eficiency
21	Politécnico Grancolombiano	0,555	77	C. de Estudios Superiores María Goretti	0,368
22	Colegio Mayor de Cundinamarca	0,543	78	Colegio Mayor de Antioquia	0,368
23	Universidad Antonio Nariño	0,535	79	Fundación Universidad de América	0,357
24	Escuela Nacional del deporte	0,535	80	Universidad Pontificia Bolivariana	0,357
25	Universidad de Pamplona	0,522	81	Corporación Universitaria Minuto de Dios	0,357
26	Universidad La Gran Colombia	0,517	82	Universitaria Agustiniana	0,352
27	Inst Tecno Metropolitano	0,515	83	Universidad de La Sabana	0,352
28	Universidad Simón Bolívar	0,512	84	Corporación Universitaria de La Costa	0,349
29	Universidad del Valle	0,510	85	Universidad de La Salle	0,347
30	Universidad Manuela Beltrán	0,507	86	Fundación Universitaria Konrad Lorenz	0,344
31	Universidad Popular del Cesar	0,504	87	Universidad Industrial de Santander	0,340
32	Fundación Universidad del Norte	0,500	88	Universidad del Pacifico	0,338
33	Fundación Tecnológica Antonio de Arévalo	0,499	89	Universidad Surcolombiana	0,338
34	Fund. Universitaria Agraria de Colombia	0,499	90	Universidad del Cauca	0,324
35	Fundación Universitaria Los Libertadores	0,497	91	Universidad Tecnológica de Pereira	0,319
36	Universidad de Los Llanos	0,484	92	Universidad Ces	0,319
37	Fund. Universidad Autónoma de Colombia	0,483	93	Corporación Universitaria Remington	0,317
38	Cooperativa de Colombia	0,478	94	Universidad Autónoma de Occidente	0,317
39	Col. Mayor de Nuestra Señora del Rosario	0,476	95	Universidad de La Guajira	0,307
40	Colegio de Est. Superiores de Administración	0,468	96	Universidad Católica de Manizales	0,305
41	Universidad de San Buenaventura	0,462	97	Universidad ICESI	0,303
42	Universidad Pedagógica y Tecnológica	0,461	98	Unidad Central del Valle del Cauca	0,298
43	Universidad Militar Nueva Granada	0,454	99	Universidad de Antioquia	0,294
44	Fund. Universitaria Católica Lumen Gentium	0,452	100	Corporación Universitaria del Huila	0,294
45	Corporación Universitaria del Caribe	0,452	101	Fund. Univ. de Ciencias de La Salud	0,291
46	Corporación Universitaria Iberoamericana	0,447	102	Universidad del Magdalena	0,290
47	Unidades Tecnológicas de Santander	0,446	103	Universidad del Sinú	0,288
48	Fundación Universidad del Área Andina	0,442	104	Universidad de Cartagena	0,285
49	Corporación Universitaria Republicana	0,442	105	Institución Universitaria de Envigado	0,277
50	Universidad de Manizales	0,442	106	Universidad de Caldas	0,260
51	Universidad Santiago de Cali	0,441	107	Universidad del Quindío	0,252
52	Universidad EAFIT	0,438	108	Universidad Sergio Arboleda	0,245
53	Universidad Católica de Pereira	0,427	109	Corporación Universitaria Lasallista	0,228
54	Univ. de Ciencias Aplicadas y Ambientales	0,421	110	Fundación Universitaria Juan N Corpas	0,196
55	Universidad Autónoma de Bucaramanga	0,415	111	Corp. Universitaria Adventista UNAC	0,124
56	Santo Tomás	0,413	112	Fund. Universitaria Juan de Castellanos	0,057

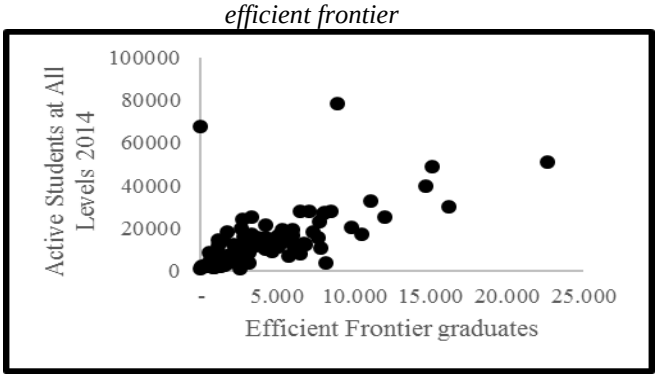
Fuente: elaboración de los autores

Gráphic 5 - *Relationship graduates real vs. Graduates in efficient frontier*



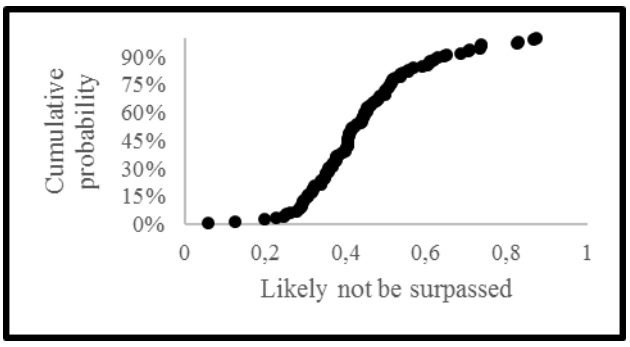
Source: elaboration of the authors

Gráphic 6 - *Relationship students vs. Graduates in efficient frontier*



Source: elaboration of the authors

Gráphic 7 - *Efficiency of cumulative density function*



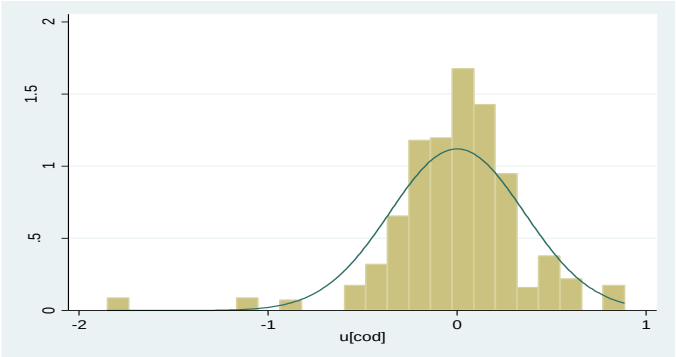
Source: elaboration of the authors

Table 5 - *Efficiency for percentile results*

P5	P10	P25	P50	P75	P90	P95	Media	Dev Est
25,65%	29,09%	34,84%	41,23%	51,07%	64,13%	73,61%	44,32%	14,82%

Source: elaboration of the authors

Gráphic 8 - Histogram of errors



Source: elaboration of the authors

Table 6 - *Test Breusch & pay Lagrange - multiplier of random effects*

	Var	sd= sqrt(Var)
grad	1,00687	1,00343
e	0,10774	0,32824
u	0,13113	0,36212

Test:	Var(u)=0
chibar2(01) =	371.80
Prob > chibar2=	0.0000

Regarding the Breusch-Pagan test, in this case is rejected the null hypothesis at 5%, which shows evidence of statistical heterogeneity not observed in the error term. This implies the need to use any of the methodologies that take into account the existence of constant over time effects.

Due to the result of the test previous is performed the regression through effects fixed and effects random, and through the test of Hausman, is obtained what of them two models is best, what is the best estimator.

Table 11 -*Hausman test*

Coefficients	(b)	(B)	(b-B)	SQRT (diag(V_b-V_B))
	faith	Re	Pbka	H.E.
est_doc	-0,2168111	-0,2405228	0,0237117	0,0236003
EST	0,2270505	0,48459	-0,2575395	0,0573602
p_cat	-0,1024724	-0,08779	-0,0146824	0,0089127
egr_op	0,6447669	0,481805	0,1629619	0,0804857
s.n.	0,0273529	0,0278742	-0,0005213	0,0021495

Test: Ho: difference of the coefficients not systematic

chi2(5) = (*b* – *B*)' [(*V_b* – *V_B*) ^ (–1)](*b* – *B*)
= 27.43
Prob > chi2 = 0.0000

As the value of the statistical is greater that the value that is reported in the table of values critical of the distribution X 2, is rejects the hypothesis null of estimators of effects random consistent, to a significance of the 5%, what shows that there is a strong evidence statistics of endogeneity. In this sense, the appropriate estimator is fixed to the inside of groups effects.

Tabla 7 – *Regression end by effects fixed*

R-sq: Obs per group:
Obs per group:
within = 0.2163
min = 2
between = 0.7625
avg = 5.4
overall = 0.7018
max = 6
F(5,485) = 26.77
corr(u_i, Xb) = 0.0884
Prob > F = 0.0000

grad	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
est_doc	-.2168111	.0615043	3.53	0.000	-.3376588	-.0959634
est	.2270505	.0887674	2.56	0.011	.0526343	.4014666
p_cat	-.1024724	.0285074	3.59	0.000	-.1584856	-.0464591
egr_op	.6447669	.0967633	6.66	0.000	.4546398	.8348939
matr	.0273529	.0061593	4.44	0.000	.0152507	.039455
_cons	-107.533	.8623017	1.25	0.213	-2.769638	.6189786
sigma_u	.46117403					
sigma_e	.32823635					
rho	.66375725					

F test that all u_i=0: F(110, 485) = 7.84 Prob > F = 0.0000

Tabla 8 – *Regression inefficiency with environment variables*

Number of obs = 112
F(5, 106) = 1.48
Prob > F = 0.2017
R-squared = 0.0654
Adj R-squared = 0.0213
Root MSE = 0.14661

u	Coef.	Std. Err.	t	P>t	[95% conf.	Interval]
acr	.0413555	.0359377	1.15	0.252	-.0298944	.1126055
priv	-.0233378	.032479	-0.72	0.474	-.0877307	.041055
univ	.04058	.032315	1.26	0.212	-.0234876	.1046476
ciud_prin	-.0279226	.0322458	-0.87	0.388	-.0918531	.0360079
act	-9.49e-09	4.21e-08	-0.23	0.822	-9.29e-08	7.39e-08
_cons	.5557975	.0363397	15.29	0.000	.4837505	.6278444