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Estimation of efficiency in public expenditure in education: A case study for Medellín
(English translation)

Degree work

to opt for the title of

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Dedication

To our parents,
Beatriz Hincapié, Miguel Solano,
Marlene Lara and Carlos Palacio for
training us as great people and
professionals for the future.

Abstract

This research estimates the efficiency of public education expenditure for the 16 communes of the city of Medellín, using a two-step semi-parametric model. In the first stage, a data enveloping analysis (DEA) method is used to estimate the efficiency scores, using the average results of the standardized Saber 11 tests as the output. Then, in the second stage, those efficiency values are used to calculate the effects of non-discretionary variables on efficiency. Among the results, we found the inefficiency scores of the communes are linked to variables like per capita income, the number of public schools and, to a lesser extent, the homicide rate per 100,000 inhabitants. Furthermore, we found none of the commons was efficient in relative terms.

Key words : public expenditure, education, efficiency, DEA.

Summary

This research estimates the efficiency of public spending on education for the 16 communes of the city of Medellín, using a semi-parametric model in two stages. In the first stage, a data envelopment analysis (DEA) method is used to obtain the efficiency scores using the average results of the Saber 11 standardized tests as a product. the values obtained to calculate the effects of non-discretionary variables on efficiency. Among the results, it was found that the inefficiency of the communes is associated with variables such as per capita income, the number of public educational institutions and, to a lesser extent, the homicide rate per hundred thousand inhabitants. In addition, in relative terms it was found that none of them is efficient in terms of public spending.

Keywords : public spending, education, efficiency, DEA.

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1. Introduction

In recent years, education has been gaining importance as one of the engines for economic development and improvement in terms of quality of life for historically marginalized populations. So much so, that in the Sustainable Development Goals, agreed in 2015 by the United Nations and which must be met by 2030, objective number 4 is "Guarantee an inclusive, equitable and quality that promotes lifelong learning opportunities for all", since access to education derives economic benefits such as the appearance of desirable job opportunities, better salaries and higher levels of productivity; and social, which lead to more equitable, inclusive and better informed societies in daily decision-making (ONU, 2021). However, despite the fact that it has become a fundamental right, access to it and the quality provided are not enough, especially in developing countries, which often have remote rural populations, inequality of access, low coverage of the secondary level, competitive disadvantages in the number of teachers and low levels of private investment.

That is why governments allocate a proportion of their budget to education, in order to reduce gaps, improve educational quality, and achieve greater coverage among those who cannot access private education, either because of resources or external factors. However, despite the fact that public expenditure in education has gained momentum over the years in order to generate a greater impact on educational quality and increase coverage and infrastructure, the amounts allocated are not always efficient, either for political reasons that involve corruption; factors of the economic environment of the inhabitants; or simply the programs on which the system is based are not being effective.

In order to provide further evidence on the efficiency of public spending on education, this study aims to analyze the case of the communes of Medellín (Colombia). The foregoing, using the average results of the Saber 11 tests, as evidence of educational performance and estimating a Data Envelopment Analysis (DEA) model to calculate the relative efficiency of education spending by commune. In addition, in a second stage, a truncated model is estimated using non-discretionary variables, such as per capita income, educational institutions, and the homicide rate per hundred thousand inhabitants, in order to find the effect that these have on the efficiency scores of the communes.

The findings show that none of the communes of Medellín is efficient in spending on education, however, Commune 11 – Laureles Estadio is the one that presents the closest score to it and is the reference for the other ones. On the other hand, Commune 10- La Candelaria is the one with the worst performance during the four years analyzed, so it is necessary to establish improvement strategies for this commune to improve the allocation of spending. Regarding the second stage, the effects of non-discretionary variables on efficiency turned out to be as expected, per capita income and educational institutions have a positive effect on it, while the homicide rate worsens efficiency scores of the communes.

This work is divided into 6 parts. In the second section, a brief review of the literature is carried out, which compiles different works that have addressed the subject; in the third section the data are presented; the fourth section presents the methodology used for the research development; the fifth section presents the results obtained; and finally in the sixth section some final comments are presented as a conclusion.

2. Literature review

Since the appearance of works such as Barro (1990) and Romer (1994), interest in education as part of technological development and as a means to achieve greater economic growth has gained importance, mainly in endogenous growth models. Barro (1990) is one of the first authors to establish the bases of public spending in the case of this type of model, including government tax distortions, productive spending directed towards technology and others; leaving evidence that public spending can increase consumption and economic growth. On the other hand, Romer (1994) talks about private investment and total factorial productivity, comparing the differences between public and private investment. On this point, the author argues that public expenditure is part of a more general set while (specific) private investment values more the efficiency of the firm and production.

It is then, how education generates not only economic but also social changes that create more equitable and better informed societies and makes investment by the government necessary in this type of areas to reach populations that might be economically disadvantaged. Angelopoulos, Malley, and Philippopoulos (2007) examine the importance of public education spending under human capital externalities. The above, using a dynamic general equilibrium model where human capital was the engine for endogenous growth in the long term and government spending on education was given by externalities in it. The authors find that

public expenditure in education promotes growth and well-being; and that the positive welfare effects of education spending are through human capital externalities.

Along the same lines, Barrientos (2020) carried out a study in the countries of the Andean zone, made up of Bolivia, Colombia, Ecuador and Peru for the period 2000 to 2015, in which he sought to determine if the public spending on education generated some type of externality in the economic growth of these countries. In the document, the author found that this actually generated positive externalities on economic growth, despite the fact that each one of the States of the Andean zones developed under different social and political contexts. For her, the link between education and economic growth, among other things, will depend on the type of social policies implemented and the characteristics of the labor market.

However, the effect of government investment in education in all countries is not the same, so the literature has found it important to analyze the efficiency of public spending on education at a multilevel. - country to compare its influence on educational quality. Herrera and Pang (2005), carry out a study covering 140 countries, in which they measure the efficiency of public spending for developing countries, implementing a semi-parametric model of Envelope Analysis. of Data (DEA). They find that countries with higher levels of spending have lower efficiency scores and that urbanization is positively associated with efficiency scores, but that income distribution has an effect. negative on them.

Afonso and Aubyn (2006) carry out a study similar to the previous one, however, it focuses especially on the expenditure on educational provision of 25 OECD member countries, including performance variables such as the PISA tests. Among their findings is that there are more important factors which the government does not have under its control, such as the family context and the income of the parents. Likewise, Arias and Torres (2018) who sought to measure the efficiency of public spending on secondary education in 37 developed and developing countries using monetary and non-monetary variables, found robust evidence that supports the idea that educational performance in developing countries can improve if resources are used efficiently, but they acknowledge that this may not be the only problem they have.

In the case of the studies carried out only for one country, Cunningham, Cunningham, Halim, and Yount (2019) in India, find through an estimation by panel data with fixed effects, that variables such as increase the number of enrollments; investment in infrastructure; uniform books and free lunches; and at least one woman as a professor at the institution, have positive effects on educational quality. In addition, Sobhee (2006) in Mauritius, sought to find the effects that exist on efficiency and equity when public expenditure in education is carried out, focusing mainly on changes in the Gini coefficient. , which in the results increases in the first instance, but then decreases due to the Kuznets hypothesis.

A study carried out in Brazil at the national level by Moraes, Manoel, Dias, and Mariano (2020), uses least squares to estimate the efficiency of investment in basic education in the country, taking as dependent variable the basic education performance index (IDEB). The results they arrive at allow them to conclude that the investment in education made by the States does indeed partially explain the results of the basic education development index, but after exceeding a certain limit. , spending ceases to have an effect on educational performance. On the other hand, Outeiro, Oliveira, and Oliveira (2020), carry out work in this same country but specifically for the State of Pará, considering a sample of 39 districts out of 144. They use a methodology DEA to verify if the allocation of public spending in public education is efficient, finding that the districts are allocating the resources received for primary education, but it is necessary to put more efforts to improve education. 'on, since the one that invests the most is not always the one that best distributes the resources or leads to the best results.

In Argentina, Epele, Chalela, and Puig (2013) analyze the relative efficiency of educational public spending of the jurisdictions of this country in primary education, using two non-parametric methods that are the Free Disposal Hull (FDH) and the DEA. This is done for the period 2003-2010, taking as an input the real expenditure per student in primary education and as products the inverse of the repetition rate at the primary level and the results of the ONE tests in mathematics and language of 6th grade . The authors find that Buenos Aires, Córdoba and Santa Fe and the Autonomous City of Buenos Aires (CABA) are the most efficient territories in relative terms.

Delving specifically into the Colombian case, Leon and Gutiérrez (2015) study the relative or absolute convergence between Colombian departments through growth theories. The authors use panel data with fixed effects to capture the inherent characteristics of each department, finding that there is relative convergence between them, but it is too low to have an established convergence horizon. On the other hand, Barrera and Gaviria (2003) study the efficiency of Colombian schools using a DEA model, with the purpose of understanding what leads to school productivity and how much is gained when efficiency is increased. Initially they do it for the case of Bogota, but seeing the disparity and the importance they extend their

investigation to a national level. Among the conclusions they reach for the case of Bogotá is that on average increasing the proportion of investment in education results in inefficiency, since an increase in spending does not necessarily imply better efficiency in education. production of test results or coverage. This differentiates the capital from the rest of the country, since money matters in the production of quality and quantity.

On the other hand, Pineros (2010) calculates the relative efficiency by departments in the provision and quality of education through the DEA methodology for the years 2002 and 2009. The author finds that, as soon as regards coverage, most departments have improved their efficiency, but the advances made in terms of educational quality are few. Benavides-Chamorro (2013), who also carries out his study at the departmental level, estimates the levels of efficiency and the determinants of educational quality for Colombia; finding that the departments furthest away from the center of the country obtain the worst results in efficiency while the opposite happens with the close ones, possibly explained by socioeconomic and political factors.

Among the studies carried out using multiple municipalities, Iregui-Bohorquez, Melo-Becerra, and Ramos Forero (2006) make an introduction to the problems and the functioning of the educational sector in Colombia and measure the impact on academic performance. Emic of factors associated with the school and the socioeconomic environment of the students using a stochastic frontier. They find that in the country the variables related to the infrastructure of the schools and the socioeconomic environment of the students have a positive and significant impact on their academic achievements; Therefore, in terms of efficiency, private schools enjoy more favorable environments because they focus on students with higher incomes and better social contexts. In addition, Galvis-Aponte (2015) evaluates the efficiency of municipal spending with resources from the General Participation System, using the DEA methodology. In his research, he finds that the densest capitals and municipalities have higher levels of efficiency than less populated areas; It is also an advantage for the municipalities to be located near the capitals, since it facilitates the mobility of teachers and results in a greater offer.

Regarding smaller geographical units, the case studies at the city level in the Colombian literature are scarce. An example of this is Gaviria and Barrientos (2001), who, despite not talking specifically about the efficiency of public spending, study the effects of the family environment and the characteristics of the school-on-school performance in Bogotá. based on the results of the 1999 ICFES tests. They acknowledge that, although the tests were modified in the year 2000, the figures they use are still valid and contain important information about the determinants of performance. of the students At the end of their research, they find that the education of parents affects the academic performance of their children and that this effect is transmitted mainly through the quality of the school; In addition, the differences between schools have a notable effect on performance.

Jiménez (2019) analyzes the efficiency of public expenditure, its effect on the coverage and educational quality of the baccalaureate during the period 2010 to 2016 in Cartagena, through a DEA methodology. He expresses that due to the absence of data on Saber test scores and the change in methodology during that period, he resorted to analyzing educational quality through repetition and dropout rates in official institutions. In the study, he finds that in 4 of the 7 years analyzed there were better percentages in terms of the efficiency of public spending in coverage and expresses the need to implement in the city an educational policy focused on the long term that allows to continue with projects created in administration changes.

The present investigation seeks to contribute to the literature, through a study that takes the communes that make up the city of Medellín as a unit of measurement to calculate the efficiency of public spending on education using the results of the Saber 11 tests. In addition to addressing non-discretionary variables in a second stage, which can positively or negatively affect the efficiency scores obtained, thus covering gaps in the national literature and serving as a example for future research involving smaller measurement units, such as other cities in the country.

3. Data

For this study, data from the 16 communes that make up the city of Medellín were used, which were obtained from various sources of information contained in table 3 of the Annexes. The 5 corregimientos were excluded because they continue to be populations with rural characteristics and some of the variables contained atypical data compared to the average for the communes, causing heterogeneity in the sample. On the other hand, originally, we wanted to analyze the period 2016 to 2019, but due to the absence of per capita income data by communes from 2018, in the second stage only observations of the 2016 and 2017, being clear that the results obtained should not be generalized for the other years, but they give rise to the consideration and importance of this variable in future research.¹

Table 1 summarizes the descriptive statistics of all the selected variables.

Table 1:

Descriptive statistics of the variables used 2016-2019

	Average	Standard deviation	Minimum	Maximum
Saber 11 Scores (2016-2019)	261.7	20.3	227.96	316.1
Per capita income* (2016-2017)	1,139,189	926,157.2	438,488.4	4,305,156
Budget* (2016-2019)	50,179,779,863.19	18,800,000,000	12,290,974,859.68	92,365,470,906.00
Homicides per hundred thousand inhabitants (2016-2019)	25.1	25.95	5.09	125.99
Official Institutions (2016-2019)	12.25	5.4	2	23

*Real figures at 2018 prices. **Source :**
Own elaboration.

As a dependent variable in the first stage, the average results of the Saber 11 tests per commune are used, which are prepared by ICFES and evaluate skills such as mathematics, Spanish, social sciences and citizenship skills, natural sciences and English. is. The results of this type of standardized tests are often used in the literature as indicators of educational performance and quality (Gaviria & Barrientos, 2001; Barrera & Gaviria, 2003; Crouch & Fasih, 2004; Afonso & Aubyn, 2006; Iregui-Bohorquez et al., 2006; Benavides-Chamorro, 2013; Galvis-Aponte, 2015; Arias & Torres, 2018; Gutiérrez-Garrido & Acuna-Duarte, 2019), because it is assumed that the performance A student's performance in an exam is good if the education he receives is good too.

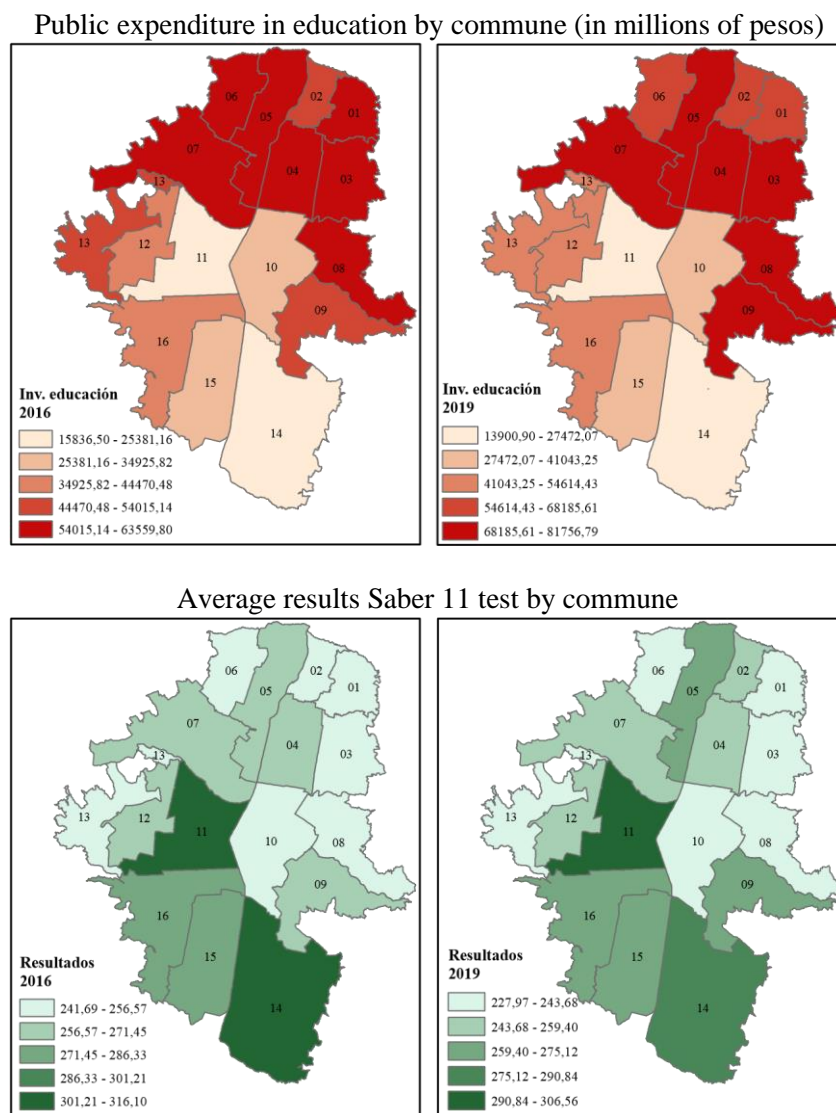
On the other hand, the education budget by commune is used as the only input in the DEA. The variable was constructed from the expenditure reports by communes for the years 2016 to 2019 published by the Medellín Mayor's Office on the city's open data page (MEData) and calculated at from the items that are allocated to the Ministry of Education, excluding expenses for higher education and early childhood.²

¹The decision to take per capita income, despite not being available for all years, is given by the importance and use given to it by multiple authors in the literature to determine effects on income. educational efficiency, see Afonso and Aubyn (2006); Sobhee (2006) and Arias and Torres (2018).

²For more information on the items, go to Table 4 located in Annexes.

Figure 1:

Comparison between expenditure in education and average results of the Saber 11 tests by Commune
2016 and 2019



Source : Own elaboration.

Figure 1 shows four maps, which contain information on public spending on education in millions of pesos and the average results of the Saber 11 tests during the periods 2016 and 2019. When analyzing them in detail, it can be seen that the communes with the highest public expenditure in education have the lowest scores in the Saber 11 tests, with the exception of Commune 5 Castilla, which has relatively good scores in comparison with on the others around her. On the other hand, the communes with lower budgets, such as Commune 11 - Laureles Estadio, Commune 14 - El poblado, Commune 15 - Guayabal and Commune 16 - Belen, are the ones that performed best in the Saber 11 tests. have. The foregoing shows a negative relationship, since in figure 4 located in the annexes, it can be seen that the education budget has had a constant to positive trend in most communes, while the average results of the Saber 11 tests have been decreasing over time for all of them, which should not be happening if investment in education is being efficient enough and is impacting educational performance.

Lastly, during the second stage, non-discretionary variables are used, that is, they are not directly controlled by the government in the short term. In the investigation, the per capita income of the spending unit, educational institutions, and homicides per hundred thousand inhabitants were selected for this purpose. Despite not having been previously used in the literature, the latter was included since it can affect the perception of household security and prevent the execution of programs and budget distribution efficiently.³

4. Methodology

4.1. DEA model

Regarding the methodological process, the *Data Envelopment Analysis (DEA) model* is used, which became popular from the seminal work of Charnes, Cooper, and Rhodes (1978). This allows calculating relative efficiencies from linear programming methods and performing analyzes on how to maximize inputs and outputs in order to find optimal points on the production possibilities frontier. In the present study, the only input is government spending on education and the only output is the results of the Saber 11 tests.

Relative efficiency is defined as a ratio between the output: Saber 11 tests, multiplied by their weighting; on the input, government spending on education, multiplied by its weight. Therefore, in this study we have that: y_j is the average result of the Saber 11 tests, for commune j and x_j is the government spending on education in commune j . Then, both u_r and v_i are the weights, where u_r is the weight for the output r and v_i is the weight for the input i , which in this case, since only one output and one input are used, would be u_1 and v_1 . On the other hand h_k will then be the relative efficiency of commune k , which is defined as DMU_k and this value will be bounded as follows: $h_k \leq 1$ in the model shown below.

The basic form of the DEA model is expressed as follows (Martic, Novakovic, & Baggia, 2009):

$$\text{Max } h_k = \frac{\sum_{r=1}^s u_r y_{rk}}{\sum_{i=1}^m v_i x_{ik}}$$

Subject to:

$$\frac{\sum_{r=1}^s u_r y_{rj}}{\sum_{i=1}^m v_i x_{ij}} \leq 1, \quad j = 1, 2, \dots, j_k, \dots, n$$

Where:

$$u_r \geq \epsilon, \quad r = 1, 2, \dots, s$$

$$v_i \geq \epsilon, \quad i = 1, 2, \dots, m$$

Rewriting the problem as:

$$\begin{aligned} & \text{Max } x\lambda\delta i_- \\ \text{SA} \quad & \delta_i y_i \leq Y\lambda \\ & x_i \geq X\lambda \\ & n^{-1} \lambda = 1 \\ & \lambda \geq 0 \end{aligned} \tag{1}$$

So, in the event that $h_k = 1$, the commune is efficient when it comes to allocating the inputs granted by the municipality to obtain a higher educational quality and therefore, it can obtain better results in the Saber 11 tests, while if it passes the On the contrary, if $h_k < 1$, the commune will be relatively inefficient in the way it allocates its inputs, so it is not gaining educational quality to generate the best possible performance in the Saber 11 tests. In general, it is expected to obtain results that are close to the production frontier.

³Authors such as Koppensteiner and Menezes (2019) and Cole and Gramajo (2009) deal with issues of the influence of violence and crime on education.

It should be noted that when the model is rewritten as in (1), the definition of relative efficiency changes, and now $h_k \geq 1$, however, the commune remains efficient when $h_k = 1$, however, if $h_k > 1$ commune k is said to be relatively inefficient.

In the DEA model there are two popular approaches that should be taken into account when estimating: Input oriented and Output oriented. According to Martic et al. (2009), there are two approaches to the analysis of DEA models. The first is the “output oriented” and the second is the “input oriented”. In the first case, a model is taken into account that wants to maximize the output (Saber 11 tests) controlling through the inputs (Government spending on education), in order to find the highest possible value of the Saber 11 tests without altering government spending. In the second, the model tries to achieve the same result of the Saber 11 tests, but maximizing the use of government spending on education, thus using the least amount of inputs to achieve the same test result. For the present study, the output-oriented model is considered since the aim is to find the best possible performance in the Saber Tests with the inputs that are allocated in the selected periods.

The next step is to correct the errors that have been previously recorded in the literature, since the DEA model has been criticized in large part because it can deliver biased results in small samples (Afonso and Aubyn, 2006), however it delves into this topic in the Bootstrap and non-discretionary variables subsection.

4.2. Tobit model

Since the units in the present case are communes of the city of Medellín, it is important to capture the characteristics that differentiate each commune; These must be aspects that the government cannot modify in the short term and are merely conditions of the commune, so they are non-discretionary variables. In addition, these variables allow us to delve deeper into the analysis of the determinants of the efficiency of each commune. It is for this reason that a second stage is taken into account in the estimation, which is a model truncated to the left at point one.

Similar processes, such as the studies carried out by Afonso and Aubyn (2006) and Arias and Torres (2018) have used Tobit in its second stage. In this exercise, the efficiency scores are taken as the dependent variable, and the non-discretionary variables as regressors, as shown in the equation.

(2)

$$\hat{\delta}_i = z_i\beta + \epsilon_i \quad (2)$$

Where $\hat{\gamma}_i$ is the estimated value of the efficiency in education of each Commune i calculated in the first stage, z_i is the vector of non-discretionary variables for each Commune i, and β is the coefficient associated with each of the non-discretionary variables that show the effect of these.

It should be noted that there is a second source of bias in the model, and therefore a solution must be found for it. This is caused by the size of the sample and the fact that the non-discretionary variables z_i are correlated with the error ϵ_i . This comes mainly from the correlation that exists between the non-discretionary variables and the outputs of the DEA model, which is known to have been the data used to calculate the efficiency scores obtained (Afonso and Aubyn, 2006). It is for the aforementioned that a bootstrap should be implemented that estimates β y σ_ϵ to correct the correlation problem. The procedure carried out is explained in the next subsection.

4.3. Bootstrap and non-discretionary variables

In this subsection, the problems that exist both in the DEA model and in the tobit that were mentioned in the previous subsections were corrected.

The DEA model may have serial correlation problems, as noted by Afonso and Aubyn (2006). This is because any disturbance in the observations that are very close to the border can cause the other observations to move closer to or further from the border than they should, which In the end it means that the communes are not in the place they should be.

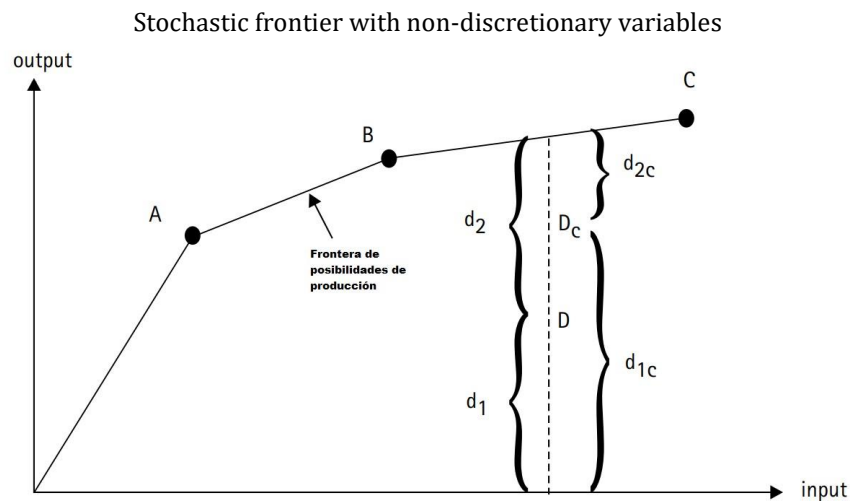
In the tobit model, ϵ_i is correlated with z_i , however, as the sample gets larger, the correlation tends to disappear. Due to what was initially mentioned, it becomes necessary to follow the methodological steps proposed by Simar and Wilson (2007), which are presented below:

1. Estimation of δ_i by solving (1).
2. $\hat{\delta}_i$ values using bootstrap (preferably with two thousand iterations).
3. Estimation of (2) by means of a truncated regression model with the maximum likelihood method.
4. Bootstrap, preferably with two thousand iterations, for tobit, finding the estimated values of $\hat{\beta}$ y $\hat{\sigma}_e$.

In this way, results can be obtained that correct the serial correlation that exists in the linear model ⁴, and thus obtain robust results according to what other authors have found (Afonso and Aubyn, 2006; Arias and Torres, 2018).

In figure 2 you can see the border that surrounds the DMU's, which in this case are the communes of Medellín, hence the name DEA and all the efficiency results must be below the border. of production possibilities. It should be noted that in the graph both *A* , *B* and *C* are efficient since they are on the frontier, while the DMU *D* , is not; this can be attributed to some bad environment characteristics in it. If the DMU *D* , were to improve its conditions, it could get closer to the frontier and the correction of these exogenous factors would be calculated as the score in *Dc* minus the score in *D* (Arias and Torres, 2018).

Figure 2:



Source : Afonso and Aubyn (2006, p.481).

5. Results

5.1. DEA Efficiency Results

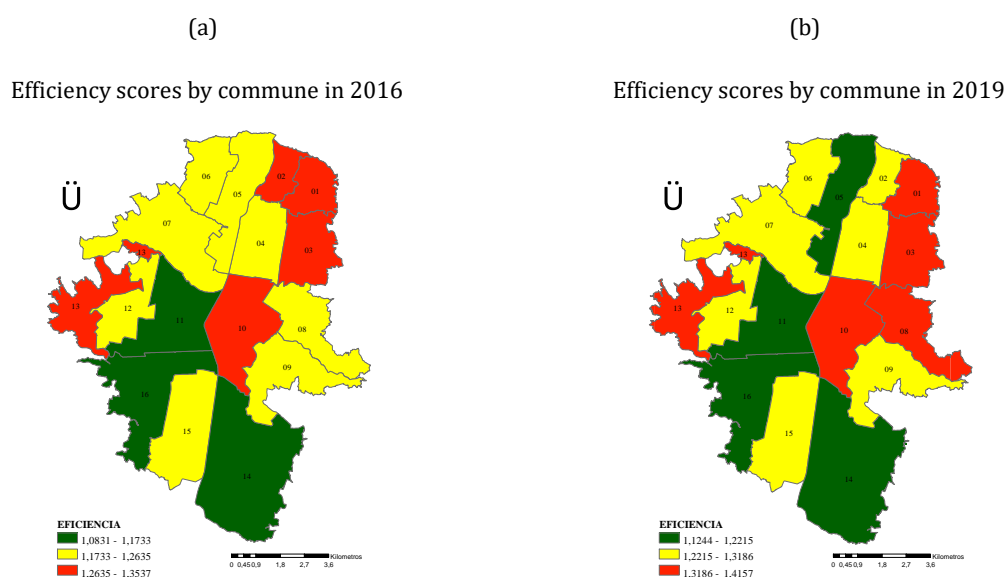
In this section we analyze the results obtained in the DEA after being corrected through a bootstrap to avoid biases ⁵. This was carried out using only one input and one product, these being the expenditure on education and the average results of the Saber 11 tests, respectively. It is worth remembering that the results are bounded from 1 to infinity, that is, the closer the score is to 1, the more efficient the commune is, while if the opposite happens, the community will tend to be less efficient. public expenditure in education.

The results contained in table 6 of the Annexes show that the scores of the communes have worsened over time, that is, that public spending on education became less efficient during Figure 3:

⁴Simar and Wilson (2007) delve further into the particularities of bootstrap, the number of iterations, the way in which it should be carried out and some examples.

⁵Go to Annexes to see a comparison between the results of the DEA model without correction and the corrected one.

Efficiency scores by commune



Source : Own elaboration.

Source : Own elaboration.

from 2016 to 2019. On average, the change in the efficiency scores of the communes was 4.48%, with the greatest change in efficiency loss being in Commune 7 - Robledo, which was around 7,33% and the lowest in Commune 2 - Santa Cruz with 2.2% between 2016 and 2019.

On the other hand, in figures 3a and 3b a classification of the communes can be observed according to their efficiency scores in the year 2016 and 2019 respectively, with the ones in green being the ones that are relatively closest to efficiency, the yellow ones average scores and the red ones the communes with the worst scores and that need vigilance. Geographically, it can be seen that there is no clear distribution of where the best scores are concentrated, despite the fact that there is a trend towards the center - south of the city during 2016, but that changes during 2019 with the inclusion of Comuna 5- Castilla to this category. On the contrary, the above does exist for the least efficient scores, which are mostly located towards the northeast of the city, becoming clearer during 2019. Finally, the mean scores are concentrated towards the northwest of Medellín.

The territory closest to being fully efficient is Comuna 11 - Laureles Estadio, which has the score closest to 1 in all the years analyzed, except for 2018, where Comuna 14 - El poblado managed to obtain better results. After Laureles Estadio, the aforementioned Comuna 14 and Comuna 16 - Bel'en follow in the ranking in third place, all of the above obtaining an average increase of 3.53% in inefficiency scores from 2016 to 2019. One of the arguments that could explain why they have better scores is that in these communes there is a greater presence of private schools, so public educational institutions must seek to obtain better academic results to be comparable with other competitors in educational quality, which influences the efficiency of public spending and contributes to the control of the adequate allocation of the budget.

On the other hand, the territory with the worst score is Comuna 10 - La Candelaria, which maintains this position for all the periods analyzed, despite having reported an improvement for 2017. After this, it is followed by Commune 3 - Manrique and Commune 1 - Popular, which have an average growth in their inefficiency scores (including La Candelaria) of 5.33%. Based on the above, it is evident the need to increase the surveillance of spending and the effect on these communes, since, despite having a general worsening throughout the city, they have maintained the worst scores from 2016 to 2019. Not ruling out the possibility that the above is also associated with other factors such as difficult socioeconomic contexts and low social commitment, which are preventing the budget from being effective in education.

Already among the few communes that managed to change their ranking between 2016 and 2019, which can be seen in table 6 in the Annexes, are Commune 15- Guayabal and Commune 2- Santa Cruz, passing the first position eighth to sixth and the second from thirteenth to tenth. This does not mean that they have had better efficiency results, it is simply that they did not have major changes in their score or that other

communes worsened their results, as is the case of Comuna 7 - Robledo and Comuna 8 - Villa Hermosa, who took eighth and thirteenth place respectively. As for the rest, they maintained the same places in 2019 compared to 2016.

Additionally, according to the results, Comuna 11 - Laureles Estadio functions as a benchmark for the others, that is, the latter use it as a model to follow in the way they allocate their budgets. At the beginning of the study, the possibility of transferring efficiency between communes was raised, however, there is no clear evidence of the existence of this, since the effect of having Commune 10 next to Commune 11 should act in the same way. positively about it, but this does not seem to happen according to the scores obtained. On the other hand, it is important to highlight that high investment amounts are not necessarily a factor to improve efficiency, on the contrary, in this case the three Communes with the scores closest to efficiency have budgets at education lower than those of the majority. So, the strategy must be how to invest, not how much to invest in education to reach the same result: educational quality.

5.2. Effect of non-discretionary variables on efficiency

In this section we discuss the results of the truncated regression model. After making the estimates of the tobit regression model, four models are obtained that serve to explain the impact of non-discretionary variables on the efficiency of public spending on education in the communes. It should be noted that model 1 and model 3 are uncorrected models, while model 2 and model 4 are bias-corrected models. In addition, the regressors shown in Table 2 were chosen from the review of other studies such as Afonso and Aubyn (2006), Iregui-Bohorquez et al. (2006), Galvis-Aponte (2015), Arias and Torres (2018) and the data available for this research. When interpreting the model, it must be taken into account that, when the coefficients are negative, there is an improvement in efficiency for each additional unit of the variable x .

This is due to the fact that the efficiency $\hat{\delta}_i \geq 1$ and the closer to 1, the more efficient it is. On the other hand, in general terms, it should be noted that the bootstrap correction shows estimates with lower degrees of significance than those of its counterpart. This is because after two thousand iterations in the bootstrap, the model finds the $\hat{\beta}$ y $\hat{\sigma}_\epsilon$ adjusted results, and therefore more robust results are obtained, correcting correlation problems.

Regarding the analysis, the income variable is widely accepted by the literature as one of the most important non-discretionary variables when evaluating efficiency in education (Afonso and Aubyn, 2006 and Arias and Torres, 2018). In the case of this investigation, when estimating the four models, it can be observed that in all of them the variable is significant at least 5% and negative coefficients are obtained with values close to zero, this is due to the fact that the values of efficiency have small changes by nature and in this way the variables do not need to have very large coefficients for the changes to be reflected. Therefore, communes with a higher per capita income have better efficiency scores, and therefore, better socioeconomic conditions that should generate better educational standards.

Regarding the homicide rate per hundred thousand inhabitants, it is observed that one more homicide generates an increase in the dependent variable of efficiency, therefore, the more homicides there are in the commune, the more inefficient it will be. to the educational budget on it. This result makes sense and can be seen reflected in other articles such as Cole and Gramajo (2009) and Koppensteiner and Menezes (2019), where the authors show the negative relationship that exists between homicides or violence, and education. It should be noted that the homicides variable ceases to be significant when corrected in model 2, this suggests that the scarcity of data does not allow finding a greater significance, which entails having to discard the variable Simar and Wilson (2007). Finally, in the educational institutions variable, a negative and significant coefficient can be observed in the four models, with a statistical significance of at least 10%. In this case, the greater the number of educational institutions the commune has, the better its efficiency score will be. Regarding the literature, the effect of inputs on educational efficiency has been debated and although there are inconclusive results, there are studies that argue that improvements in educational material or physical plant tend to improve quality in some cases (Glewwe and Kremer, 2006 and Cunningham et al., 2019).

Table 2:

Table of results of the tobit model 2016-2017

	1	2	3	4
Per capita income (hundreds of thousands of pesos)	-6.37e-03 (0.000)***	-6.02e-03 (0.004)***	-6.83e-03 (0.000)***	-6.43e-03 (0.04)**
homicides	0.0009469 (0.000)***	0.0008916 (0.3)		
Educational institutions	-0.00425 (0.013)**	0.00449 (0.027)**	-0.00482 (0.017)**	-0.00517 (0.06)*
intercept	1.3252 (0.000)***	1.3455 (0.000)***	1.3602 (0.000)***	1.3675 (0.000)***
Observations	32	32	32	32

*p < 0.1; **p < 0.05; ***p < 0.01 Source

: Own elaboration.

6. conclusions

In this study, the efficiency of public spending on education in the city of Medellín was estimated, taking as evidence the average results of the Saber 11 tests of each commune during the period 2016 to 2019. For this, it was used a Data Envelopment Analysis (DEA) model, using as the only input the budget allocated to education for each commune and as a product the average results in the Saber 11 tests. In addition, in a second stage, We proceeded to estimate a tobit using non-discretionary variables, such as per capita income, educational institutions and the homicide rate per hundred thousand inhabitants, in order to find the effect that these had on about efficiency. It is worth mentioning that due to the absence of per capita income data by communes, this last stage could only be carried out for the years 2016 to 2017, making it impossible to assess the impact in more recent years. , but leaving a possibility for future studies in which it is possible to have all the data or a proxy for them.

The results of the first stage indicate that none of the communes of the city is relatively efficient for any of the years analyzed. However, Commune 11- Laureles Stadium is the closest to being so with the score closest to 1, and which according to the model works as a reference for the other communes. Then follow Commune 14 - El Poblado and Commune 15 - Belen, which, like the first, have the presence of a greater number of private schools and better socioeconomic conditions, for which reason Its good performance could be attributed to an attempt by public institutions to be comparable to their competitors in educational quality, which can indirectly influence the efficiency of public spending and contribute to the control of allocation. adequate budget. On the other hand, Commune 10 – La Candelaria is the territory with the worst scores during the four years analyzed, which sends out an alert message and makes it necessary to establish improvement strategies in this commune for the allocation of spending, since, compared to other communes with unsatisfactory results, its budget is low, as are the scores it has obtained in the Saber 11 tests in recent years.

Regarding the findings of the truncated regression model, the relationship between the selected variables and the efficiency scores was as expected. An example of the above is the positive relationship that income exerts on the efficiency of public spending, as had been previously verified in other investigations and which makes it necessary to generate long-term strategies that promote not only investment in education, but also the improvement in the socioeconomic conditions of the communes. On the other hand, the inclusion of the homicide rate reflects that it can become an important factor, since

crime variables usually have a negative effect on education (Cole and Gramajo, 2009; Koppensteiner and Menezes, 2019), and in this case it was found that the efficiency score was negatively related to the number of homicides in the commune. Finally, it should be noted that the communes of the city of Medellín are heterogeneous in terms of the number of educational institutions, so that despite the fact that in this study there are indications of a positive effect on efficiency, it is necessary that other studies determine in which communes or in which cases it is true that a greater number of institutions makes a commune more efficient and in which cases it is not.

Lastly, during the previous government, the Mayor's Office of Medellín, within its development plan "Medellín Cuenta Con Vos 2016-2019", launched the SaberES strategy, which sought to improve the quality of the city through the management of different programs with which it was intended to improve the performance of students in standardized tests of students from educational institutions and facilitate their access to educational institutions superior (Secretaría de Educación de Medellín, sf). For future studies, it would be interesting to carry out an impact evaluation on this type of programs and the incidence that they have had in the different communes, using in turn the efficiency of public spending on education in order to verify its effectiveness and achieve a broader picture of what is happening in the city. Additionally, during this study, there were data limitations regarding certain variables due to the unit of measurement used; however, future research is recommended to verify the effect of other variables on the efficiency scores of the communes.

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7. Annexes

Table 3:

Description of variables used

Classification	Variable	Origin	Variable description	Calculation
Crime	Homicides per hundred thousand inhabitants (Annual)	Information Subdivision (2021) Municipality of Medell'ın. courtesy of Medellin How Are We Going	Number of murders per hundred thousand inhabitants in the communes	Number of homicides committed in a year divided by the number of inhabitants of the commune and multiplied by one hundred.
Education	Educational institutions	Own elaboration based on data from the Mayor's Office of Medell'ın	Number of official institutions by commune. Those that are managed by private companies but financed by the State are not included.	They were calculated from the institutions that reported enrolled since 2016 in any degree they had enabled and filtered according to the commune of location. The margin of error is between more and less one institution, however, they remain close to the general report of those existing in Medell'ın. In addition, there may be variations because some have a double seat.
monetary	Budget allocated to MEData (2021) education		Sum of money allocated by the municipality in billions of pesos. For the case study, items referring to higher education and early childhood were eliminated.	Sum of the items reported. In most communes it corresponds to administrative expenses, structural improvements and educational support programs.
Education	Average Scores Tests Know 11	ICFES (2021). Courtesy of Medellin How are we doing	Average score obtained by students from public institutions in each commune of the city	Simple average of the results
monetary	Average per-capita income of the spending unit	Administrative Department of Planning (2021) based on the Great Integrated Household Survey (GEIH). Courtesy of Medell'ın Como Vamos	Current disposable income value of the expense unit imputed for home ownership, and divided by the number of people that make it up DANE and DNP (2012).	Average of the data obtained among those surveyed by commune

Source : Own elaboration.

Table 4:

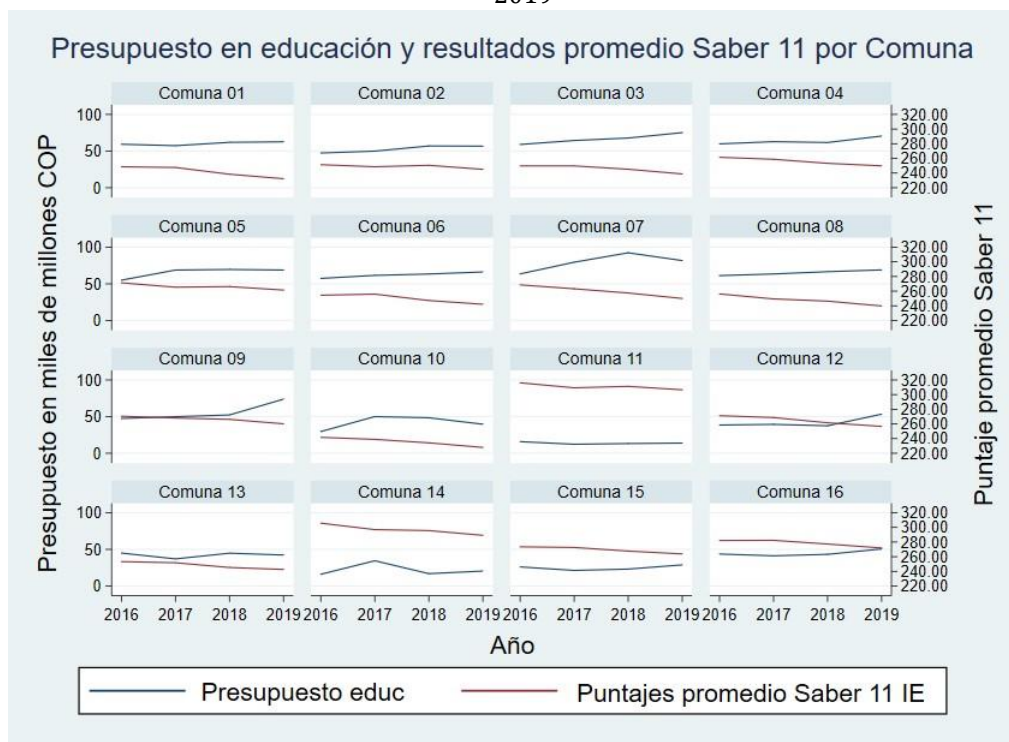
Summary of investment items in education

Rubros
Adaptation and maintenance of educational infrastructure
Contributions for free education
Administrative support to educational institutions
Attention to populations with special educational needs, disabilities and exceptional talents
Comprehensive care for early childhood in initial education and support for pedagogical processes in basic and secondary education
Procurement of the provision of educational services
Development of strategies for inclusion in the school system
Development of strategies for permanence in the school system and PAE
Human development and labor well-being of teachers and managers
Institutional development to strengthen educational management
Development of reading plan and school libraries
Development and strengthening of cognitive abilities
Provision of school furniture
Endowment in public institutions
Education with relevance and quality for students
Quality education for the inhabitants (different communes)
Strategies for access and permanence in education for boys, girls and young people
Training of teachers, educational agents and students
Training for competency assessment
Strengthening formal education
Strengthening of the school as a protective environment
Strengthening of information technologies
Institutional strengthening for educational decentralization
Institutional strengthening, pedagogical advice and improvement plans
Strengthening and continuity of environmental practices and complementary education
International Baccalaureate Implementation
Implementation of complementary education
Implementation of educational development plans
Insufficiency in educational quality
complementary day
Education quality laboratory
Improvement of educational quality (multiple actions)
Knowledge Olympics
Payment of property leases for educational institutions
Payment of incentives to teachers fortnightly
Payment of teaching staff
Payment of public services of educational institutions
Payment of administrative staff of educational institutions
City of Medellín Awards for the quality of education
Promotion and support for pedagogical processes in educational institutions

Source : Own elaboration.

Figure 4:

Evolution of public expenditure in education and average results of the Saber 11 tests by Commune 2016 - 2019



Source : Own elaboration.

Table 5:

Results of the estimation of the DEA model without correction							
DMU	2016201720182019				Ranking 2016	Ranking 2019	Variation 2016 - 2019
Commune 1- Popular	1.271576569	1.276607478	1.32595875	1.360867432	fifteen	fifteen	7.02%
Commune 2 - Santa Cruz	1.257398217	1.271506852	1.2617764	1.289798653	13	10	2.58%
Commune 3 - Manrique	1.265708915	1.265631313	1.289111804	1.323700998	14	14	4.58%
Commune 4 - Aranjuez	1.208773058	1.221618212	1.248049767	1.265148889	9	9	4.66%
Commune 5 - Castilla	1.164806114	1.19092238	1.187317093	1.208813138	5	5	3.78%
Commune 6 - October Twelve	1.242360867	1.234847695	1.278642325	1.305300094	eleven	12	5.07%
Commune 7 - Robledo	1.177028082	1.200817188	1.227628923	1.264128047	8	8	7.40%
Commune 8 - Villa Hermosa	1.233597505	1.267369338	1.282974963	1.318048441	10	13	6.85%
Commune 9 - Buenos Aires	1.168536588	1.178976219	1.187251146	1.214897354	7	6	3.97%
Commune 10 - La Candelaria	1.307875994	1.322851147	1.349623993	1.386557077	16	16	6.02%
Commune 11 - Laureles Stadium	1	1	1	1.019418276	1	1	1.94%
Commune 12 - The America	1.165495063	1.176367609	1.208456267	1.231506893	6	7	5.66%
Commune 13 - San Javier	1.247928713	1.255583471	1.288694282	1.302823486	12	eleven	4.40%
Commune 14 - The Town	1.033724826	1.06434704	1.069282996	1.092881651	2	2	5.72%
Commune 15 - Guayabal	1.155774632	1.1594978	1.180832994	1.198340278	4	4	3.68%
Commune 16 - Bel'en	1.120468772	1.119583182	1.139847743	1.162481233	3	3	3.75%

Source : Own elaboration. Beef

Table 6:

estimation of the corrected DEA
results of the model

DMU	2016	2017	2018	2019	Ranking 2016	Ranking 2019	Variation 2016-2019
Commune 1- Popular	1.285374193	1.291023833	1.339707594	1.374848185	1515		6.96%
Commune 2 - Santa Cruz	1.276481799	1.2890689	1.276161327	1.304591788	1310		2.20%
Commune 3 - Manrique	1.279527488	1.278416851	1.301813549	1.336437634	1414		4.45%
Commune 4 - Aranjuez	1.221763387	1.234141084	1.261026788	1.277467654	99		4.56%
Commune 5 - Castilla	1.178763222	1.20258754	1.198910217	1.220650135	44		3.55%
Commune 6 - October Twelve	1.256382348	1.247724843	1.291673974	1.318302321	1111		4.93%
Commune 7 - Robledo	1.189004371	1.212290335	1.239271006	1.27617366	68		7.33%
Commune 8 - Villa Hermosa	1.246519033	1.280275933	1.295715999	1.330947775	1013		6.77%
Commune 9 - Buenos Aires	1.18618203	1.19527045	1.202544384	1.22662159	55		3.41%
Commune 10 - La Candelaria	1.35370014	1.341052841	1.369296975	1.415667542	1616		4.58%
Commune 11 - Laureles Stadium	1.083124697	1.171032324	1.120331527	1.124444024	11		3.81%
Commune 12 - The America	1.191419377	1.201361475	1.236765074	1.24690886	77		4.66%
Commune 13 - San Javier	1.268627122	1.285704132	1.310210222	1.326984839	1212		4.60%
Commune 14 - The Town	1.117744194	1.093703524	1.149109688	1.156251554	22		3.45%
Commune 15 - Guayabal	1.204398628	1.222615653	1.23885644	1.241978943	86		3.12%
Commune 16 - Bel'en	1.140084618	1.141393489	1.160163202	1.178200772	33		3.34%

Source : Own elaboration.