# Borradores de ECONOMÍA

Por: Ligia Alba Melo-Becerra,
Lucas Wilfried Hahn-De-Castro,
Dalma Sofía Ariza-Hernández,
Cristian Oswaldo Carmona-Sanchez

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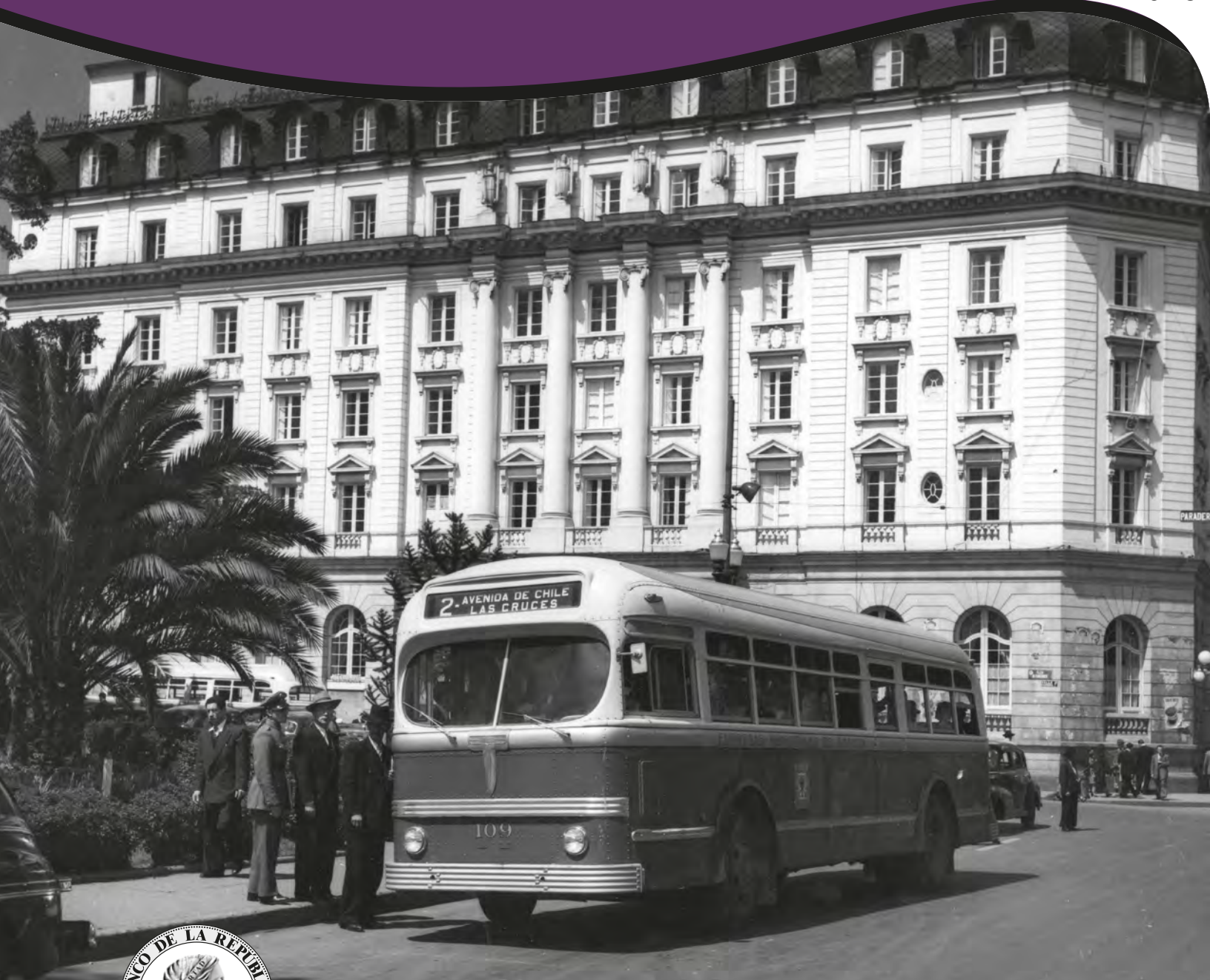
# Efficiency of Public Education in a Multiproduct Context: The Case of Colombian Municipalities♣

Ligia Alba Melo-Becerra[a]
lmelobec@banrep.gov.co

Lucas Wilfried Hahn-De-Castro[b]
lhahndca@banrep.gov.co

Dalma Sofía Ariza-Hernández[c]
dariza@dnp.gov.co

Cristian Oswaldo Carmona-Sanchez[d]
ccarmona@dnp.gov.co

## Abstract

This paper estimates the local efficiency of the public provision of education in Colombia between 2007 and 2014. The empirical analysis relies on a multiproduct function that assesses public performance considering two types of education products: quality and enrolment. Results for Colombian municipalities show efficiencies that vary between 10% and 90%, suggesting that better results in quality and enrolment in public education could be accomplished using the same resources. Sources of inefficiency are explored, such as institutional environment and fiscal autonomy. Differing regional patterns are observed for the cases of education quality and enrolment.

**Keywords**: Education, Technical Efficiency, Multiproduct Function, Colombia.

**JEL Classification**: C23, D24, H75, I20

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[a] Banco de la República, Bogotá, Colombia. lmelobec@banrep.gov.co
[b] Corresponding Author. Banco de la República, Cartagena, Colombia. lhahndca@banrep.gov.co
[c] Departamento Nacional de Planeación, Colombia. dariza@dnp.gov.co
[d] Departamento Nacional de Planeación, Colombia. ccarmona@dnp.gov.co

## 1. Introduction

Colombia has faced a decentralisation process since 1991 that has increased sub-national government resources and public responsibilities. The local authorities, both municipalities and departments, now direct a significant proportion of public expenditure to addressing the provision of education services, health care, and drinking water, among other social services. In the case of education, local authorities receive the highest percentage of resources from national transfers. According to Laws 715 of 2001 and 1176 of 2007, 58.5% of national transfers are destined to local public spending in education. Even so, the decentralisation of responsibilities has been partial.

Colombia is politically divided into 1.101 municipalities and 32 regional governments or departments (excluding Bogotá, its capital city). Few municipalities are allowed to manage all their resources at their will. There are certified and uncertified municipalities. The former are completely autonomous, while the later depend on the instruction of regional authorities. In particular, certified municipalities have the autonomy to directly manage the resources transferred from the National Government. These resources are allocated throughout a system of transfers called *Sistema General de Participaciones* or *SGP*. Uncertified municipalities are only allowed to manage the resources directed to improving the quality of education. Regional governments control the *SGP* resources assigned to pay municipal staff, such as teachers.[1]

The aim of this paper is to estimate local efficiency in the public provision of education in Colombia. The study of public performance contributes to an assessment of the fiscal costs associated with the inefficiencies of local authorities. Efficient resource allocation increases the social benefits acquired by higher quality and enrolment. The empirical literature has studied the efficiency in the provision of public and private education with several perspectives. The applications usually use parametric (Data Envelopment Analysis, DEA) or non-parametric methods (Stochastic Frontier Analysis, SFA) to estimate the efficiency of each observation. The

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[1] These resources are destined for the endowment of educational institutions, maintenance and infrastructure provision, among others (Law 715, 2001).

Decision Making Units (DMU) chosen are educational institutions such as schools (Ruggiero, 1996; Chakraborty, Biswas and Lewis, 2001; Bradley, Johnes and Millington, 2001; Iregui, Melo and Ramos, 2006), and countries (Afonso and Aubyn, 2005; Afonso and Aubyn, 2006; Afonso, Schuknechta and Tanzi, 2010).

The performance of local governments in the provision of public goods is of particular interest. For instance, Waldo (2007) evaluates the efficiency of Switzerland's public education system by municipality, Melo-Becerra (2012) studies the effect of decentralisation on the performance of education at the municipal level in Colombia, and Dollery and Johnson (2005) analyse the efficiency of local governments of Australia. De Sousa and Stosic (2005) assess the technical efficiency of 4,796 Brazilian municipalities, and Afonso and Fernandes (2007) estimate the relative efficiency of local governments in Portugal using as a measure of product as an aggregate indicator of municipal performance.

Previous works have tackled the estimation efficiency in education from a single-output perspective. But educational provision can be accomplished in two dimensions: quality and enrolment. Public resources, such as teachers, educational infrastructure, and school endowments, are managed simultaneously to produce education in both dimensions. For this reason, a multi-product perspective is necessary. We follow Kumbhakar's two-step procedure (2013), which allows us to estimate local efficiency of public education with an SFA. A product-maximisation approach is assumed instead of the cost-minimising alternative. Local authorities should maximise their educational outcomes with a given amount of inputs rather than minimise their associated costs. As outputs, both quality and enrolment indicators are chosen for municipal authorities.

The empirical analysis is performed for the period 2007-2014, and the results of the estimation are presented identifying possible causes of inefficiency for Colombian municipalities. It is noted that certified municipalities have higher efficiency measures based on both enrolment and quality indicators, as do the municipalities with more favourable institutional conditions. The results also

suggest regional patterns in educational efficiency that differ between models using the enrolment indicator and models using the quality indicator as dependent variable.

This document has four more sections. The second section draws on the methodology proposed by Kumbhakar (2013) to estimate efficiency in a multiproduct context. The third section describes the data for application to Colombian municipalities, while the fourth discusses the results obtained. Finally, the fifth section presents some concluding remarks.

## 2. Efficiency Estimation in a Multiproduct Context

Given the different responsibilities in the provision of public education at the local level, the estimation of technical efficiency should consider a variety of products. In this case, the products should measure the performance of public education in two dimensions: quality and enrolment. The inputs used by local authorities, such as teachers and infrastructure, may affect simultaneously the educational outcomes in both dimensions. In a multiproduct context, the SFA can be conducted by the application of a "distance function" (see Kumbhakar & Lovell, 2000; Coelli & Perelmann, 2000). However, it has recently been stated that the multiproduct approach leads to a system of parameters that cannot be fully identified (Kumbhakar, 2013; Tsionas, Kumbhakar & Malikov, 2015). For this reason, the solution of the system is endogenous, and alternative procedures to estimate the parameters have to be considered.

To resolve this issue, Kumbhakar (2013) proposes estimating efficiency in a two-step procedure. In the first step, an estimation of the multiproduction function is carried out. Inefficiency is not considered and instrumental variables are used as endogenous regressors. The residuals are obtained from this regression, and in the second step the efficiency values are estimated with SFA using the dependent product and the residuals. To identify whether this strategy contributes to solving the endogeneity issue, corresponding tests are run.

The multiproduct SFA relies on a Transformation Function as in (1):

$$A = f(\theta x, \lambda y) = 1 \tag{1}$$

where *x* and *y* are vectors with *J* and *M* products respectively; *A* captures shocks affecting productivity, and *f(θx, λy)* represents the transformation function, which incorporates the relationship between all inputs and outputs with a given technology of production. The parameters $\theta$ and $\lambda$ capture the technical inefficiency of production units. When $\theta < 1$, inputs could be reduced by a portion equal to *θ-1* and would still produce the same amount of product. When $\lambda > 1$, products may be increased by a portion equal to *λ-1* without increasing inputs. The functional form of production is assumed to be translog, but specification tests are made to compare results with a Cobb-Douglas function. Rewriting the input and output vectors as $\theta x = x^*$ and $\lambda y = y^*$, the translog production function is:

$$\ln f(x^*, y^*) = \sum_m \alpha_m ln y_m^* + \frac{1}{2}\sum_m \sum_n \alpha_{mn} ln y_m^* \, ln y_n^* + \sum_j \beta_j ln x_j^* + \frac{1}{2}\sum_j \sum_k \beta_{jk} ln x_j^* \, ln x_k^* +$$
$$\sum_m \sum_j \delta_{mj} ln y_m^* \, ln x_j^* \tag{2}$$

This function is standard for multiple products and inputs and takes into account all possible interactions between variables. In this case, output-oriented efficiency will be the focus of the study. Further assumptions about the parameters have to be made in order to obtain the estimable regression for the Output Distance Function, ODF (Kumbhakar, 2013). It is assumed that the source of inefficiency is only product oriented, so that $\theta = 1$. Products are assumed to be homogeneous of degree one, which means $\sum_m \alpha_m = -1$. Finally, it is assumed that the dependent variable does not interact with the other products or the inputs of the model: $\sum_m \alpha_{mn} = 0$ and $\sum_m \alpha_{mj} = 0$. The estimable ODF results to be as in Equation (3):

$$ln y_1 = lnA + \sum_j \beta_j ln x_j + \frac{1}{2}\sum_j \sum_k \beta_{jk} ln x_j \, ln x_k + \sum_{m=2} \alpha_m ln\hat{y}_m + \sum_j \sum_{m=2} \delta_{mj} ln x_j \, ln\hat{y}_m +$$
$$\frac{1}{2}\sum_{m=2} \sum_{n=2} \alpha_{mn} ln\hat{y}_m ln\hat{y}_n + u \tag{3}$$

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The dependent variable is chosen as one of the products. The remaining variables are included as regressors, normalised with the dependent product $\hat{y}_m = y_m/y_1$. Inputs and their interactions with other inputs and products are also included. The error term $u = -ln\lambda$ contains the output- oriented technical inefficiency parameter to be estimated. In order to solve the endogeneity of equation (3), Kumbhakar (2013) proposes the two-step procedure mentioned above. The first step is based on the estimation of (3) with instrumental variables for the inputs in a pooled regression to obtain the residuals. The instruments used for this exercise are the first and second period lags for each input. To identify whether this strategy contributes to solving endogeneity, the appropriated tests are used. The second step retrieves efficiency values for each observation by estimating an SFA regression between the dependent product and the residuals obtained.

## 3. Colombian Municipalities and their Education Provision

The data contains information on educational products, inputs, and other control variables for Colombian municipalities between 2007 and 2014. The products should measure the municipal performance in the provision of quality and enrolment in public education. Increasing educational enrolment is one of the functions allocated to local authorities. The Colombian education system is divided into three levels: preschool, basic (five grades of primary and four secondary, and middle (two final grades of secondary). Enrolment in preschool education is around 60%, while basic education is in 90%, according to official records. Middle education, at 40%, is the level with the lowest enrolment, and there is a considerable variation among municipalities. For this reason, enrolment in middle education is the variable chosen as a product to measure the provision of public education.

In turn, education quality is measured using the results of municipal tests performed at the end of secondary education, which are mandatory and are used as a requirement for admission to higher education. Scores are selected only for public schools. These tests, called *Saber 11*, are traditionally evaluated in eight areas of knowledge: Mathematics, Language, Social Sciences, Philosophy, Biology, Chemistry, Physics, and English. In 2014 there was a change in the test

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methodology, and since then only five areas have been evaluated: Mathematics, Critical Reading (the new "Language" area), English, Natural Sciences, and Social Competences. Three quality measures for municipal performance are proposed: the arithmetic mean of the scores including all the areas of knowledge, Mathematics, and Language. The three measures will be used independently as measures of quality in public education. Table 1 includes descriptive statistics for average scores in the three cases: Average, Mathematics, and Language.

Table 1. Descriptive statistics of municipal scores *Saber 11* from 2007 to 2014

| Scores | Observations | Mean | Std. Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Average | 8,024 | 44.05 | 3.04 | 32.92 | 58.48 |
| Mathematics | 8,024 | 44.44 | 3.52 | 20.44 | 61.64 |
| Language | 8,024 | 45.35 | 2.84 | 29.00 | 58.80 |

Source: Author's calculations based on information from *Instituto Colombiano para la Evaluación de la Educación*, ICFES

Given the change in methodology, the absolute value of scores may not be comparable in time. For this reason, the quality indicator will be the relative performance of each municipality every year. This variable is constructed in seven categories for each year as follows: Municipalities with a score under 2.5 standard deviations below the average are grouped in the lowest category (1); municipalities with a score between 2.5 and 1.5 standard deviations below the average are grouped in the next category (2); and so on. Finally, municipalities with scores over 2.5 standard deviations above the average are grouped in the highest category (7).

As inputs, three municipal variables are included. The first is the number of public teachers. Even when uncertified municipalities are not responsible for the direct payment of their staff, this variable affects educational outcomes of each municipality. The second variable is educational infrastructure, which is measured as the square meters of built area in primary and secondary public institutions. The third variable is the municipal monetary investment made in other inputs used to produce education. This includes expenditure on transport and food, costs for maintenance and endowment of schools, and contracts with private institutions to supply educational services.

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This variable is included in constant pesos of 2014. To avoid problems of heteroskedasticity, all inputs are normalised according to the number of students enrolled in official institutions at different levels of education across local authorities.

A group of control variables is also included in the first step of the model. These variables affect the provision of municipal education outside of the strict control of local authorities. The first group of control variables included is called the municipal "typology", which reflects the development context for each municipality. The National Planning Department (DNP) constructed the municipal typology by ranking municipalities according to seven categories, from 1 to 7, where higher categories reflect a lower level of development. Category 1 includes the municipalities with the most favourable conditions, while Category 7 includes the most unfavourable. The categories take into account six dimensions: social, economic, environmental, institutional, violence, and urban-regional indicators. Bogotá was excluded from the analysis, but for this exercise it was included in category A. Other controls are geographical region, a municipal rural indicator that reflects the spatial disparity of population, and the state of certification of each municipality. Table 2 summarises the descriptive statistics of inputs, outputs, and control variables.

Table 2. Descriptive statistics of input, output, and control variables, 2007 to 2014

| Variable | Observations | Mean | Std. Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Public teachers per student | 8251 | 0.05 | 0.01 | 0.02 | 0.16 |
| $M^2$ of infrastructure per student | 7980 | 2.18 | 1.71 | 0.00 | 19.58 |
| Municipal investment (Col pesos) per student | 8251 | 338.8 | 439.6 | 0.00 | 6649.8 |
| Typology | 8808 | 4.67 | 1.38 | 1.00 | 7.00 |
| Certification | 8808 | 0.05 | 0.22 | 0.00 | 1.00 |
| Rurality | 8805 | 0.57 | 0.24 | 0.00 | 0.98 |

Source: University of Los Andes and National Department of Planning

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## 4. Results

Results from the first stage of the estimation are shown in Table 3. Four models are estimated, which differ in the product chosen as dependent variable. The four versions of the model consider enrolment in middle education and relative measures in quality derived from scores in Mathematics, Language, and the average results of tests in all subjects. Endogeneity and specification tests are shown in Appendix 1. For educational quality, the most important input is the number of teachers per student, while for the enrolment it is infrastructure. Several studies suggest that smaller classrooms positively affect educational outcomes. For a review of this literature, see Krueger (2003). As for the control variables, more developed and certified municipalities tend to have better educational outcomes. There are also regional differences from models using quality and enrolment indicators.

The second step of the estimation uses the residuals obtained in the first step to estimate efficiency measures for each observation. This procedure is carried out for the three models that use the different measures of quality as dependent variables and for the model that uses enrolment. Descriptive statistics of efficiency estimates are presented in Table 4. Although the multiproduct model considers both quality and enrolment measures simultaneously, efficiency measures are relative to the specific frontier. Thus, we do not compare the efficiency measures obtained from the models using quality variables and the model that uses enrolment.

Comparisons can be made *within* the frontiers but not *among* them. For this reason, municipalities are compared within each frontier in order to explore the variables that may affect educational efficiency. Table 4 shows that Colombian municipalities may improve their educational outcomes by using the same amount of resources efficiently. This is particularly important for the case of educational enrolment, given that Colombian middle education only covers about 40% of its middle school-age population. A high level of disparity between municipalities is observed. The distribution of efficiency for each model is shown in Figure 1.

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Table 3. First step results: estimation of a multiproduct function for municipal education by dependent variable, 2007 to 2014

| Variables | Average Score | Mathematics | Language | Middle Coverage |
|---|---|---|---|---|
| Infrastructure ($X_1$) | -0.0308 | 0.00237 | -0.0632 | 0.527*** |
| | (0.0800) | (0.0804) | (0.0769) | (0.195) |
| Teachers ($X_2$) | 0.447*** | 0.406*** | 0.244** | -0.0367 |
| | (0.111) | (0.110) | (0.108) | (0.284) |
| Other inputs ($X_3$) | 0.0218 | 0.0128 | 0.0144 | -0.167*** |
| | (0.0192) | (0.0187) | (0.0182) | (0.0470) |
| Independet product ($Y_1$) | 0.677*** | 0.734*** | 0.606*** | -0.229*** |
| | (0.0862) | (0.0851) | (0.0789) | (0.0486) |
| $X_1 \times X_1$ | 0.00457 | -0.00183 | 0.0115 | -0.0977*** |
| | (0.0150) | (0.0150) | (0.0143) | (0.0367) |
| $X_1 \times X_2$ | -0.00433 | 0.00178 | -0.00357 | 0.111** |
| | (0.0187) | (0.0185) | (0.0182) | (0.0458) |
| $X_1 \times X_3$ | 0.00200 | 0.00401 | 0.00305 | 0.0199 |
| | (0.00521) | (0.00516) | (0.00495) | (0.0131) |
| $X_2 \times X_2$ | 0.0585* | 0.0413 | 0.0501 | -0.175** |
| | (0.0322) | (0.0317) | (0.0309) | (0.0748) |
| $X_2 \times X_3$ | -0.0127 | -0.0121 | 0.00178 | -0.0283 |
| | (0.00842) | (0.00829) | (0.00809) | (0.0214) |
| $X_3 \times X_3$ | -0.0116** | -0.0108** | -0.00266 | 0.00552 |
| | (0.00541) | (0.00531) | (0.00518) | (0.0129) |
| $Y_1 \times X_1$ | -0.00287 | 0.00556 | -0.00808 | -0.00160 |
| | (0.00689) | (0.00736) | (0.00672) | (0.00446) |
| $Y_1 \times X_2$ | 0.0894*** | 0.111*** | 0.0829*** | 0.0799*** |
| | (0.0240) | (0.0241) | (0.0228) | (0.0183) |
| $Y_1 \times X_3$ | -0.0193*** | -0.0206*** | -0.0123* | 0.0665*** |
| | (0.00635) | (0.00636) | (0.00642) | (0.00330) |
| Typology | -0.00865*** | -0.00417 | -0.0126*** | -0.104*** |
| | (0.00290) | (0.00285) | (0.00277) | (0.00679) |
| Certification | 0.0879*** | 0.0791*** | 0.0732*** | 0.0205 |
| | (0.0166) | (0.0164) | (0.0158) | (0.0416) |
| Rurality | 0.00680 | -0.0283 | 0.0197 | -0.502*** |
| | (0.0240) | (0.0239) | (0.0239) | (0.0597) |
| Region: *Orinoquía* | 0.178*** | 0.182*** | 0.193*** | -0.376*** |
| | (0.0205) | (0.0203) | (0.0195) | (0.0498) |
| Region: *Amazonía* | 0.245*** | 0.205*** | 0.268*** | -0.532*** |
| | (0.0211) | (0.0212) | (0.0201) | (0.0508) |
| Region *Pacífica* | 0.189*** | 0.131*** | 0.204*** | -0.351*** |
| | (0.0140) | (0.0140) | (0.0133) | (0.0325) |
| Region: *Andina* | 0.156*** | 0.140*** | 0.183*** | -0.0985** |
| | (0.0168) | (0.0168) | (0.0157) | (0.0420) |
| Constant | 2.466*** | 2.468*** | 2.026*** | 0.533 |
| | (0.232) | (0.226) | (0.220) | (0.589) |
| Observations | 5,319 | 5,321 | 5,314 | 5,350 |
| $R^2$ | 0.478 | 0.445 | 0.498 | 0.139 |

Source: author's calculations. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 4. Descriptive statistics of local efficiency in public education by dependent variable

| Variable | Observations | Mean | Std. Deviation | Minimum | Maximum |
|---|---|---|---|---|---|
| Average Score | 6.420 | 0,81 | 0,13 | 0,18 | 0,99 |
| Mathematics | 6.422 | 0,82 | 0,11 | 0,22 | 0,99 |
| Language | 6.413 | 0,82 | 0,12 | 0,18 | 0,99 |
| Middle coverage | 6.455 | 0,72 | 0,12 | 0,15 | 0,97 |

Source: Author's calculations

Figure 1. Distribution of local efficiency in public education by dependent variable
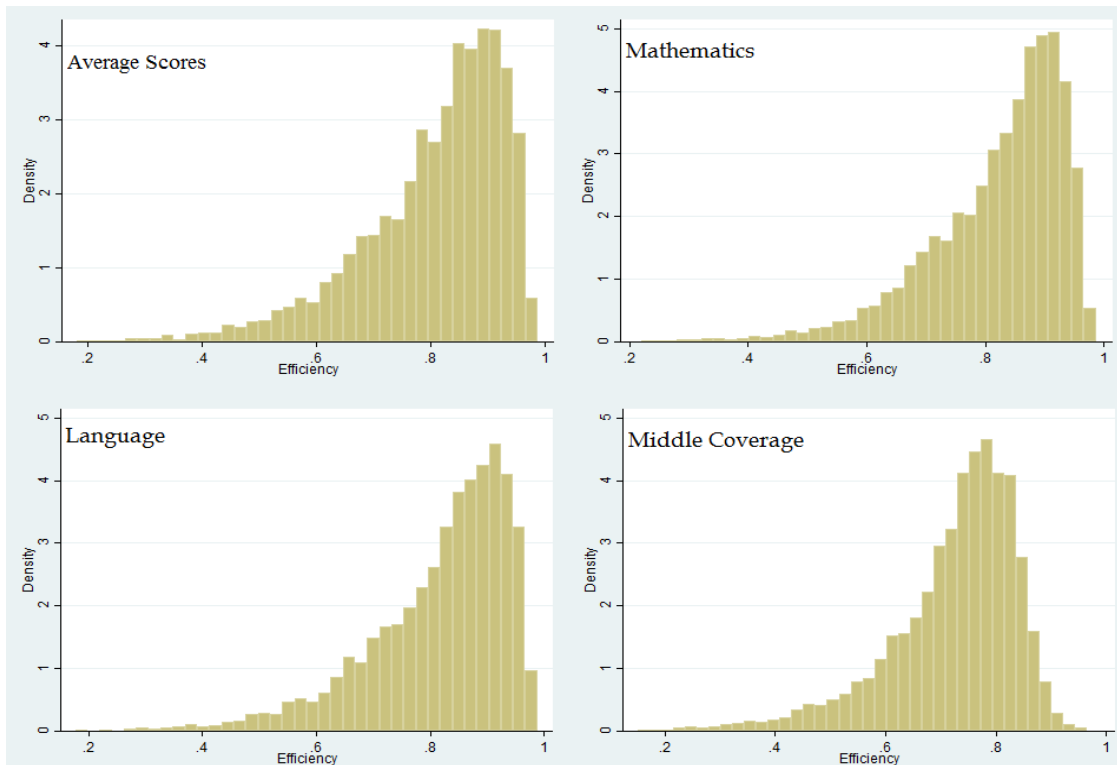


Source: Author's calculations

In a multiproduct context, the estimation of single product functions may deliver biased results. To understand the difference between the multiproduct and single product approaches, the latter versions of each model are also estimated. For the case of educational enrolment, the multi and single product versions produced similar estimations of efficiency: a mean of 70%. However, for the three cases of quality the single output versions produced efficiency estimations of at least 90%, which means 10% higher than the multiproduct approach. If education is to be produced

using a multiproduct function, as proposed in this document, the estimation of single output functions may bias the results.

Finally, efficiency results are presented with an exploration of possible causes of inefficiency. Regional patterns in local performance are observed, both for quality and enrolment measures. Given that efficiency in educational quality is estimated using three different measures, this section uses the results obtained with the average scores. Colombian municipalities are also grouped by the certification status of the municipality, development conditions, and dependence on national transfers.

## 4.1. Regional patterns

Colombia is a country with strong regional disparities. Some of the causes may be institutional, historical, and even geographical (Galvis & Meisel, 2013). Therefore, it is relevant to assess whether public performance also differs across regions. Regional patterns in the distribution of public efficiency for quality and enrolment of education are shown in Maps 1 and 2. As mentioned, for educational quality, the average core measure is chosen. Given that efficiency results are estimated for each year between 2009 and 2014, the mean efficiency in time is used to visualise regional patterns. The municipalities located in the first quartile of the distribution (the lowest efficiencies) are shown in a light colour, while those in the upper quartile (highest efficiencies) are shown in the darkest tone. Both maps show a difference between central and peripheral municipalities. In the case of educational quality, both the Caribbean (North) and Pacific (West) coasts show lower efficiency values compared to those in the Central Region. In the case of educational enrolment, municipalities located on the Caribbean coast perform relatively better, while municipalities on the Pacific coast have lower scores. The Southern Region, where the bigger municipalities are located, have relatively lower efficiencies in educational enrolment.

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Map 1. Local efficiency in the provision of high quality education, 2009 to 2014
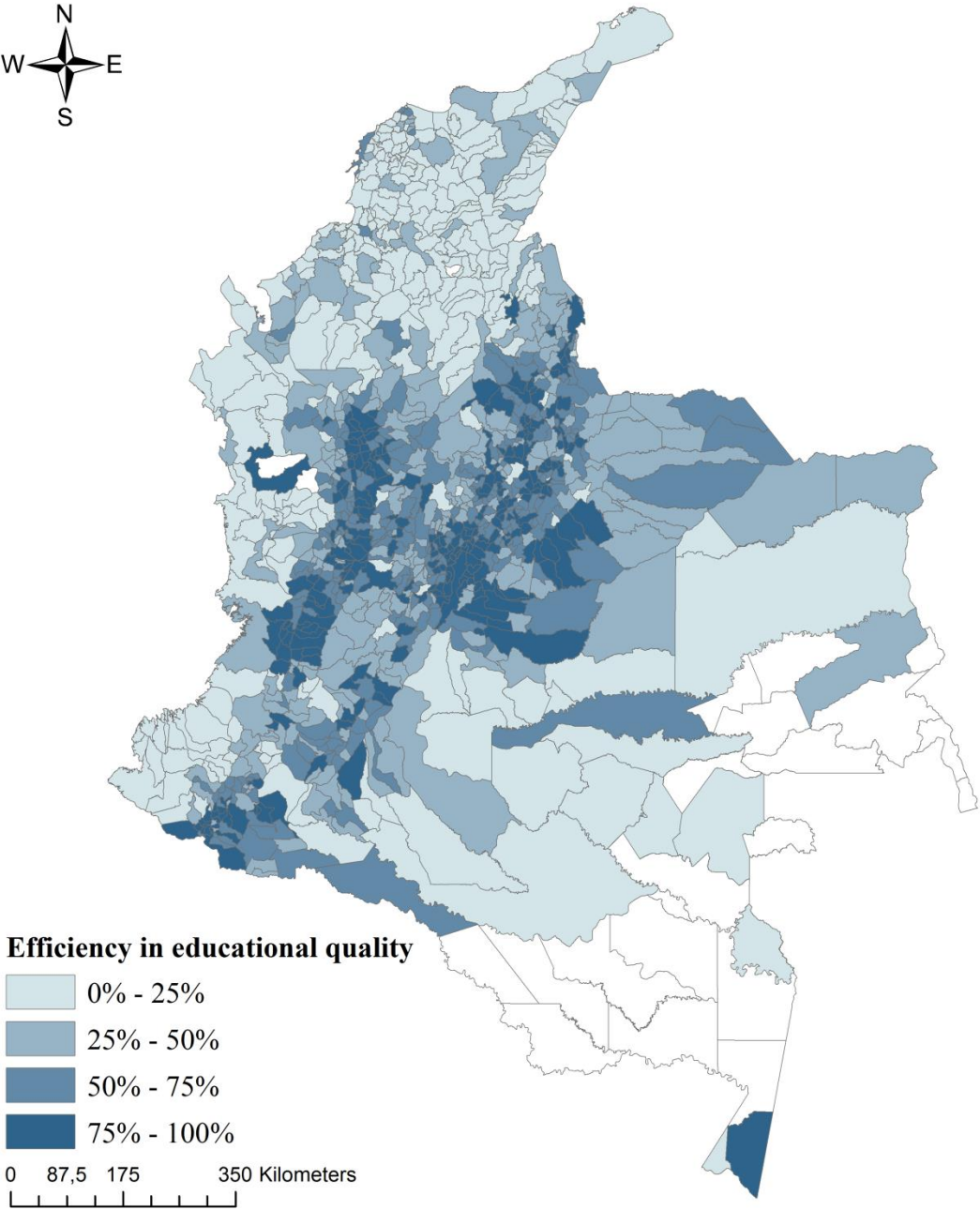


Source: Author's elaboration based on efficiency results.

Map 2. Local efficiency in the provision of educational enrolment, 2009 to 2014
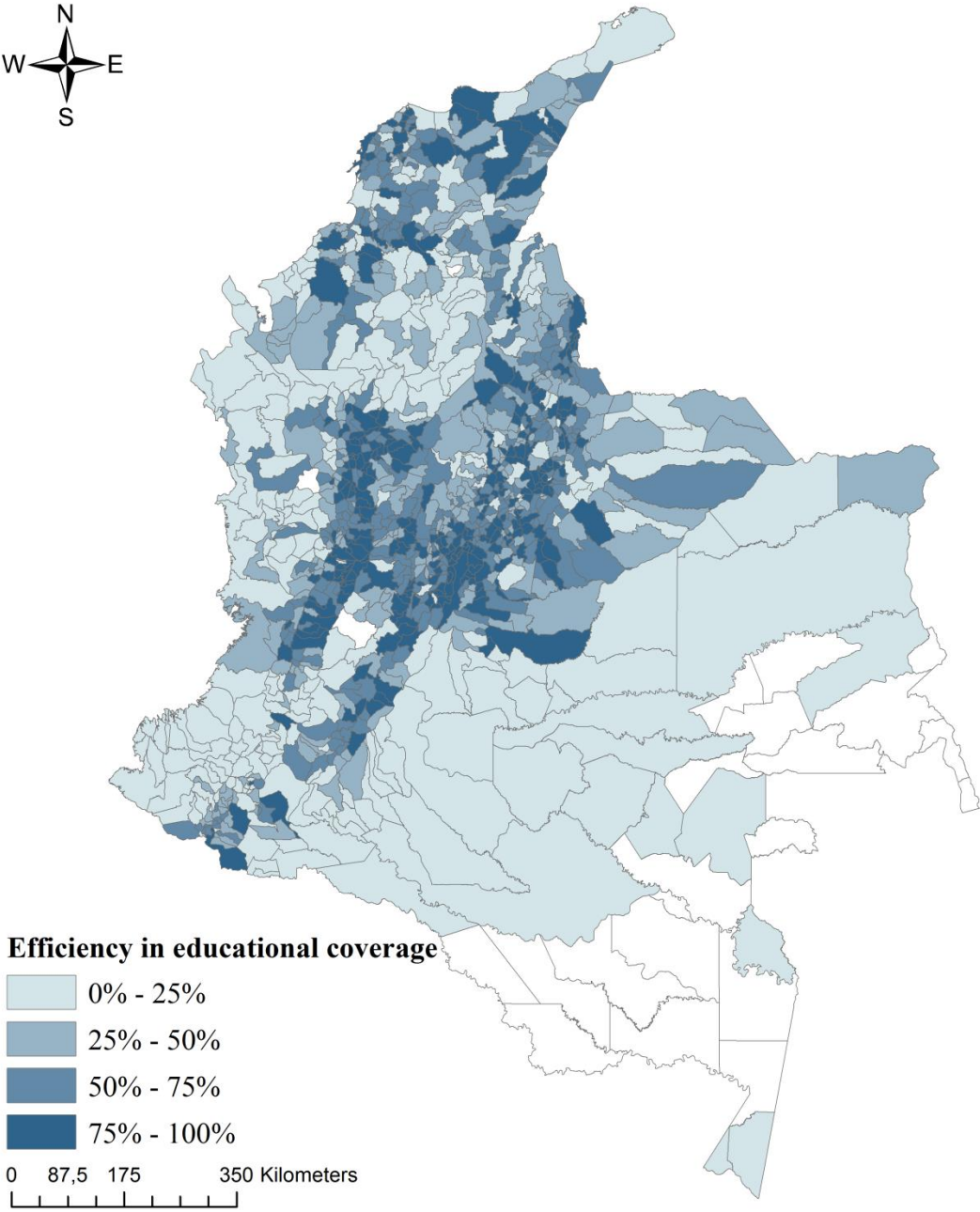


Source: Source: Author's elaboration based on efficiency results.

## 4.2. Certification

The decentralisation process in Colombia has been partial, given that only 50 to 60 municipalities each year have the fiscal autonomy to manage their educational resources directly. In order to obtain certification, the National Government demands that municipalities meet three conditions: local policies in education are consistent with the national model and are planned and evaluated on a regular basis; educational institutions are organised and registered according to the conditions established in Law 715 of 2001; and educational staff satisfy the requirements established by the same law and the institution is financially viable. Municipalities with a population of more than 100,000 are automatically certified. Figure 2 shows the efficiency mean for each version of the model by certification status. It is observed that certified municipalities have efficiencies that are statistically higher than uncertified municipalities in both quality and enrolment alternative models. Further research is necessary in order to establish a causal relationship between fiscal autonomy in Colombian municipalities and the public provision of education.

Figure 2. Local efficiency in public education by dependent variable and certification
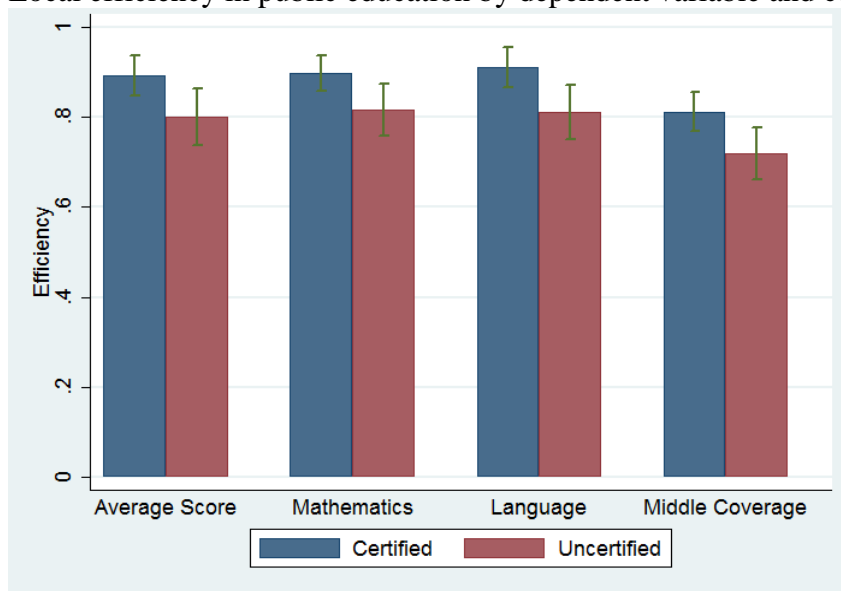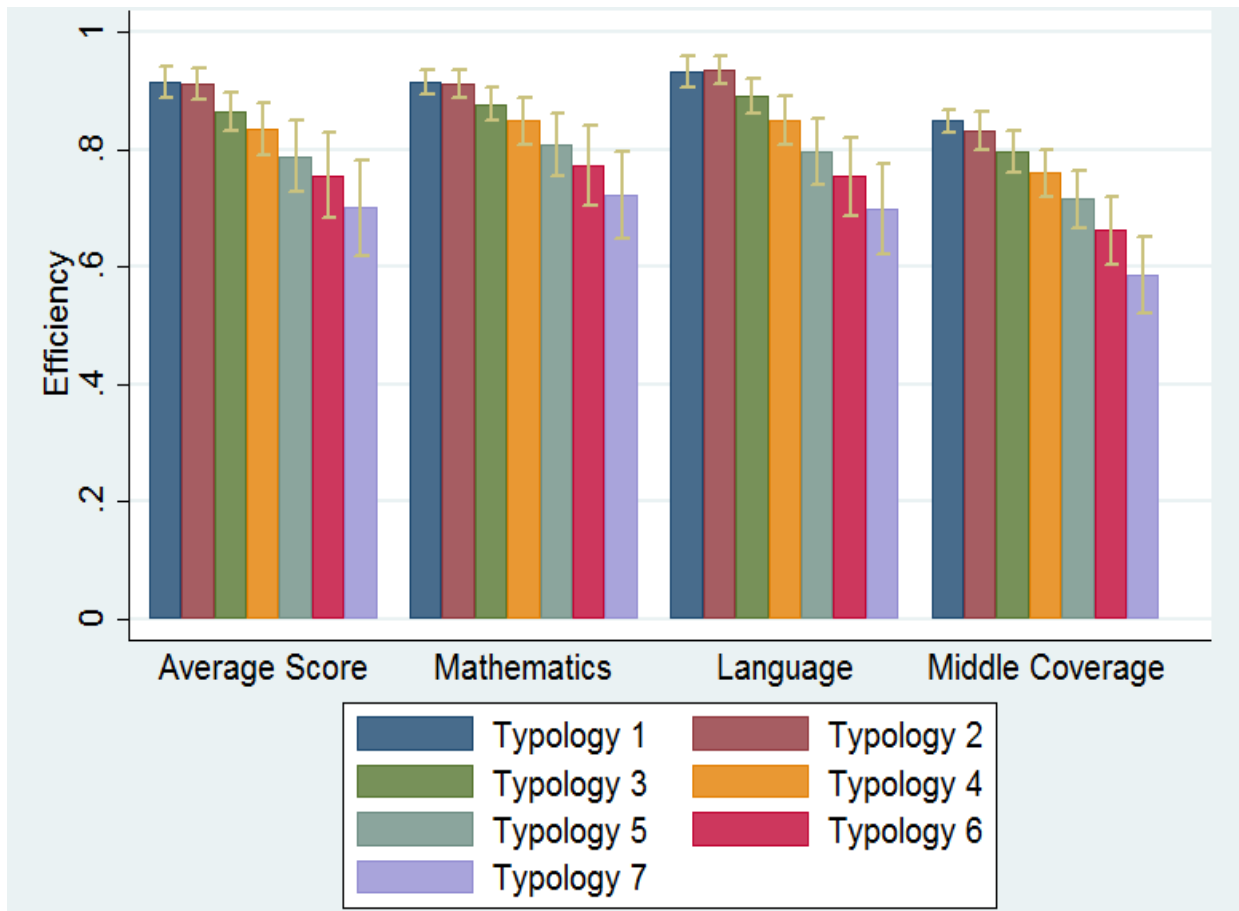


Source: Author's elaboration based on efficiency results.

## 4.3. Development context

When municipalities are grouped by their development context, it is observed that a higher level of development is related to higher efficiencies. Figure 3 shows the mean efficiency by development category (typology) for each model. Lower values of this variable indicate a better municipal context, measured according to socioeconomic, institutional, and environmental conditions, among others. As expected, the mean efficiency by category is statistically higher for municipalities with better conditions.

Figure 3. Local efficiency in public education by dependent variable and development conditions
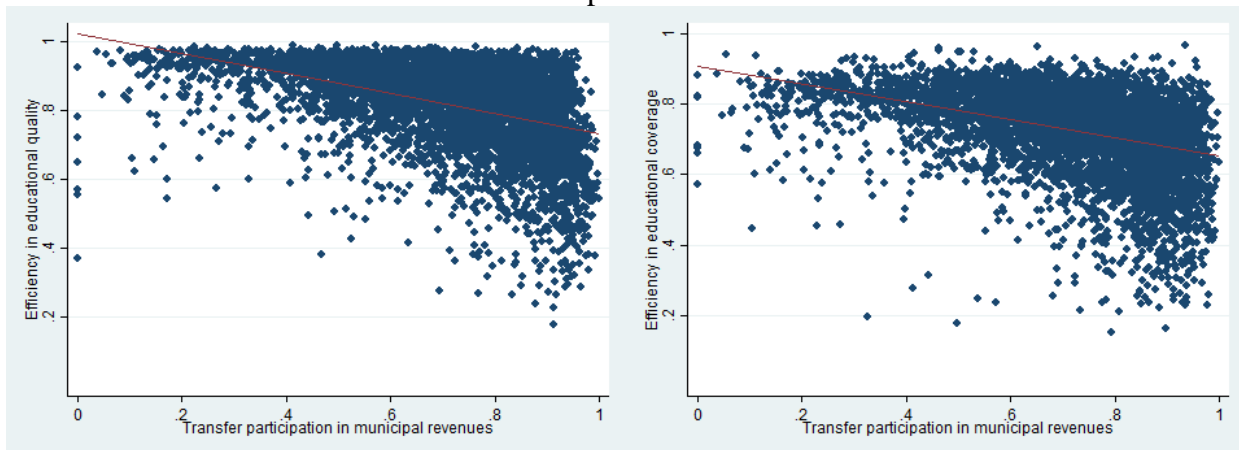


Source: author's elaboration based on efficiency results.

## 4.4. Fiscal dependence on National Transfers

A condition that may also affect municipal performance is fiscal dependence on national grants. Economic activity in Colombia is concentrated in a few regions located in the Andes Mountains (Royuela & García, 2013). The economic disparity between municipalities derives from a significant difference in their fiscal revenues. Municipalities with fewer resources require transfers from the National Government in order to cover the costs of the public provision of health and education. But national transfers usually have a specific destination. This means that those resources should not be used for other purposes, which are in some cases more urgent from the perspective of the local authority. For this reason, the difficulty to generate fiscal revenues may affect public municipal performance. In order to explore this possibility, Figure 4 shows the graphic relationship between efficiency and participation of national transfers in public revenues for each municipality. This last variable was obtained from "Panel CEDE," a public database created by the Universidad de Los Andes. For the case of educational quality, average score is the measure used to obtain efficiency. The correlation between fiscal dependence and efficiency obtained is negative. A causal relationship between both variables should be further investigated to establish if fiscal dependence reduces municipal efficiency.

Figure 4. Local efficiency in educational quality and enrolment vs. participation of national transfers in municipal revenues: 2009-2014



Source: Author's elaboration based on efficiency results.

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## 5. Concluding remarks

This paper estimates the efficiency of municipal performance in the provision of public education in Colombia between 2007 and 2014. The empirical analysis is performed using a multiproduct function, which allows for an estimation of efficiency scores given that local authorities are responsible for different objectives simultaneously. To provide more enrolment and better education quality, municipalities count on a set of resources that include national transfers and their own revenues. Even though the regions manage the administration of national transfers for the payment of staff in uncertified municipalities, the estimated production function uses the number of teachers per municipality.

Efficiency measures derived from both quality and enrolment models indicate that local authorities in Colombia may improve their educational outcomes significantly using the same resources. When efficiency measures are grouped by municipal characteristics, interesting patterns emerge. When considering municipal autonomy, those that are certified registered higher efficiencies than those that are uncertified. When exploring the municipal development context, those with more favourable conditions recorded higher scores, as expected. Regional patterns are also observed, which differ between the quality and enrolment alternative models. Colombian municipalities located in the periphery show relatively lower efficiencies than the central region. The causal relations behind these patterns should be the focus of further research.

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**Appendix 1.** Endogeneity and specifications tests for the first step estimation

| Variables | Average Score | Mathematics | Language | Middle enrolment rate |
|---|---|---|---|---|
| Endogeneity tests | | | | |
| Durbin, score | 22.96 | 22.98 | 8.38 | 21.54 |
| Durbin, p-value | 0.00 | 0.00 | 0.04 | 0.00 |
| Wu-Hausman, score | 7.65 | 7.66 | 2.79 | 7.18 |
| Wu-Hausman, p-value | 0.00 | 0.00 | 0.04 | 0.00 |
| | | | | |
| Specification test | | | | |
| Wald, score | 48.06 | 59.87 | 35.33 | 654.47 |
| Wald, p-value | 0.00 | 0.00 | 0.00 | 0.00 |

Source: Author's calculations