Universitat Autònoma de Barcelona

Efficiency of the Colombian educational system and social inequality

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por su apoyo y amor incondicional.

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Abstract

This thesis analyzes the efficiency of the educational system in a developing country with an emphasis on different sources of social inequality. Additionally, two phenomena of great importance are taken into account: the armed conflict, and the voluntary contributions of private organizations to education. The analysis is developed with innovative methods, taking a non-parametric approach using conditional *order-m* and the metafrontier Malmquist-Luenberger index. These models are applied in each chapter to schools throughout the country, different municipalities and students who are lagging behind and who belong to a specific program.

The introductory chapter motivates and presents the general context in which the analysis is carried out, presents specific aspects of the Colombian educational system and the two phenomena studied, sets out the objectives and specific contributions of the research, and finally, shows the databases and methodologies used to address the research questions.

This document contains three empirical chapters. In the first, the changes in productivity of 4,587 schools are measured considering the inequality between students and the differences between public[1] and private schools. To do this, we consider the students who participated in the Saber 11 standardized test between 2014 and 2017 in the subjects of mathematics, reading, sciences, social and citizen sciences and English. To calculate the change in productivity between these years, a metafrontier Malmquist-Luenberger index is used since it can take into account both outputs and bad outputs.

The second empirical chapter analyzes the relationship between homicides due to armed conflict and educational efficiency in 912 municipalities between 2014 and 2018. A conditional *order-m* is used to calculate the potential loss of efficiency of municipalities due to the armed conflict since it is ideal for including context variables in efficiency estimates. Finally, the third empirical chapter evaluates the causal impact on the educational efficiency of a tutoring program of 6,455 students who are lagging behind; a combination of experimental and

[1] The National Administrative Department of Statistics (DANE) of Colombia uses the terms 'official' and 'unofficial' to differentiate schools managed by the public administration from those that are not; however, in this article we refer to these schools as 'public' and 'private', respectively, as these terms will be more familiar to international readers.

efficiency evaluation methodologies is used. The conclusions, contributions, and implications for public and educational policy and future lines of research are presented in the final chapter.

Key Words: Armed Conflict ● Conditional Order-m Model ● Education ● Education and development ● Efficiency ● Inequality ● Metafrontier Malmquist-Luenberger Index ● Private contribution ● Private provision of public goods.

JEL codes: C61 ● D74 ● H52 ● I20 ● I21 ● I25 ● H44.

Acronyms

ANDI: *"Asociación Nacional De Industriales"* (National Association of Industrialists).

AUC: *"Autodefensas Unidas de Colombia"* (United Self-Defense Forces of Colombia).

BPC: Best Practices Change.

CCSPJP: *"Consejo Ciudadano para la Seguridad Pública y la Justicia Penal"* (Citizen Council for Public Safety and Criminal Justice).

CEDE: *"Centro de Estudios sobre Desarrollo Económico"* (Center for Economic Development Studies).

CLEI: *"Ciclos Lectivos Especiales Integrados"* (Special Integrated Lesson Cycle).

CNMH: *"Centro Nacional de Memoria Histórica"* (National Center for Historical Memory).

DANE: "*Departamento Administrativo Nacional de Estadística*" (National Administrative Department of Statistics).

DDF: Directional Distance Functions.

DEA: Data Envelopment Analysis.

DMU: Decision Making Unit.

DNP: *"Departamento Nacional de Planeación"* (National Planning Department).

EC: Efficiency Change.

EEO: Equal Educational Opportunity.

EGMA: Early Grade Mathematics Assessment.

EGRA: Early Grade Reading Assessment.

EIAIPI: *"Educación Infantil Atención Integral a la Primera Infancia"* (Early Childhood Education Care).

EXE: *"Empresarios por la Educación"* (Business people for Education).

FARC-EP: *"Fuerzas Armadas Revolucionarias de Colombia - Ejército del Pueblo"* (Revolutionary Armed Forces of Colombia).

FDH: Free Disposal Hull.

GDP: Gross Domestic Product.

GML: Global Malmquist Luenberger.

ICFES: *"Instituto Colombiano para la Evaluación de la Educación"* (Colombian Institute for the Evaluation of Education).

ICT: Information and Communication Technologies.

IGCE: *"Índice de Gestión de Calidad Educativa"* (Management Index for Educational Quality).

ISCE: *"Índice Sintético de Calidad Educativa"* (Synthetic Index of Educational Quality).

MEN: *"Ministerio de Educación Nacional"* (National Ministry of Education).

ML: Malmquist-Luenberger.

MML: Metafrontier Malmquist-Luenberger.

NGO: Non-Governmental Organizations.

OECD: Organization for Economic Cooperation and Development.

OST: Out of School Time.

PIMBN: *"Programa de Investigación sobre Medición del Bien-estar en la Niñez"* (Research Program on Measurement of Well-being in Childhood).

PISA: Program for International Student Assessment.

PPA: Public-Private Associations.

SDG: Sustainable Development Goal.

SIIPE: *"Sistema de Información de Iniciativas y Programas en Educación"* (Information System of Initiatives and Programs in Education).

TGC: Change in Technology Gap.

UNESCO: United Nations Educational, Scientific and Cultural Organization.

WOS: Web of Science.

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CHAPTER 1

INTRODUCTION

1. Introduction

1.1 General context and motivation

Education is a priority for everyone; it is a fundamental right that matters to the government, all public and private institutions, families, and society in general. Article 26 of the Universal Declaration of Human Rights adopted in 1948 recognizes education as a right, establishing that “everyone has the right to education”, thus becoming the first international legal instrument, which has led governments and the international community to promote various treaties that enhance each of the benefits of education.

In this context, education is and will continue to be one of the most significant concerns for society in general. Therefore, the fourth Sustainable Development Goal (SDG) aims to “Guarantee inclusive and equitable quality education and promote lifelong learning opportunities for all” within the framework of the United Nations 2030 agenda. Importantly, the strategic role of SDG 4 should be highlighted in terms of the effects brought about by its own fulfillment and in the way it works indirectly in bringing about the realization of other SDGs such as good health and well-being (SDG3), decent work and economic growth (SDG8), responsible consumption and production (SDG12) and climate action (SDG13) (UNDP & UNESCO, 2015).

The priorities of education in the framework of the 2030 agenda have focused changes on inclusion, equity, and giving the same opportunities to all. They must therefore align with the main governmental efforts to help the most vulnerable and marginalized population; governments must provide the same access to and quality of education to all, regardless of their sex, age, race, ethnicity, religion, political opinion, country of birth, disability, income, among others (UNDP & UNESCO, 2015). In this sense, the findings of the United Nations Educational, Scientific and Cultural Organization - UNESCO (2020) report “Inclusion and education: everyone without exception” highlight that, in low and middle income countries, adolescents from the wealthiest 20% households are three times more likely to complete lower secondary school than adolescents from the poorest families. This finding connects directly with the objectives, research questions,

and problems raised in this thesis, which analyzes educational efficiency related to inequality, students who are lagging behind, and the phenomena of armed conflict and private contributions from private organizations.

Education is a subject of intense political, social, and academic debate (De Witte & López-Torres, 2017) mainly because of its strategic role in society. Historically, the positive effects of education in society have been highlighted in different ways; some of the main reasons why academics, policymakers, and society, in general, prioritize improving education in terms of access and quality are as follows. First, it is essential to improve development and economic growth since it is the main source of capital accumulation in a country (Hanushek & Woessmann, 2008). Second, it is a determining factor in improving levels of knowledge and gaining access to competitive advantages, leading to increases in the well-being of a country's citizens (Hanushek & Kimko, 2000; Krueger & Lindahl, 2001). Third, it works as a tool to create social stability (Mir-Babayev, 2015). Fourth, it helps to redistribute the living conditions of society (Hanushek, 1986). Fifth, the differences in access to education compromise a country's levels of innovation and productivity (CEPAL, 2018). Finally, education budgets are high and growing (Eurostat, 2014).

Despite the strategic role of education for society and all the efforts made by individual countries and by the international community to improve access and quality levels, there are still significant gaps, mainly in developing countries. These countries must work effectively and efficiently to close them. According to UNESCO (2020), 258 million (17% of the total) of the world's children, adolescents, and young people are not in school, and although this trend is falling, 10% of them are in Latin America and the Caribbean.

In this region, according to the World Bank Group, spending on education as part of GDP decreased from 4.8% to 4% between 2013 and 2019. Likewise, in this period, education spending as a percentage of total government spending fell from 16.5% to 14.6% (UNESCO, 2020). However, although it is assumed that the responsibility for educational expenditure lies mainly with the government, private spending on education is growing (Gibson & Davies, 2008), mainly that of households; this phenomenon is more recurrent in developing countries (Aksoy,

2015; Kondakci et al., 2014; Morgan, 2017), affecting the disposable income of the most vulnerable households, and by extension, their well-being.

Those in charge of public policies in education must make decisions effectively and efficiently to meet their objectives in challenging contexts; however, it is notable that in times of budget restrictions, how public spending is executed is subject to debate (López-Torres & Prior, 2016). The Covid 19 pandemic has added a further problem[2], since more than 1.5 billion students worldwide have been affected due to the closure of schools and universities, representing 91% of the total school-age population. This problem has put additional pressure on the educational crisis caused by the multiple inequalities in society. Although these inequalities have existed for a long time, the confinements and school closures have brought them to light (United Nations, 2021).

The priority of academics and policymakers is for governments to guarantee global access to education without neglecting quality. However, this is a challenging task in a developing country that, on average, has low public spending, high levels of inequality, and is struggling with the effects of the Covid 19 pandemic. Therefore, it is necessary to ensure the effectiveness of the process, but to do so in the most efficient way possible, taking into account general inequalities and differences in contexts, to provide more and better education to close social gaps (Arbona, 2018).

This thesis aims to study the efficiency of schools taking into account educational inequality, environmental inequalities, armed conflict, and the voluntary contributions of private organizations. In addition, it compares the public and private sectors, considering the complexity of measuring the education sector, including the good and bad outputs of the process. This will provide evidence to evaluate and improve the efficiency of the education sector (Tran & Villano, 2018), both public and private, since in difficult times any action that helps to improve productivity is a priority (López-Torres & Prior, 2016).

Improving the understanding of how social inequalities affect or are related to educational efficiency helps public and private organizations to make better

[2] Evaluations are not carried out in pandemic years, mainly due to structural changes in conditions and the availability of disaggregated data.

decisions based on evidence, in pursuit of the objective to improve the well-being of society (Tran & Villano, 2018). Likewise, understanding how armed conflict and voluntary contributions of private organizations affect education helps to enhance public policies and stimulate private sector financing by improving allocation criteria (Kondakci et al., 2014).

Although the difficulty of the context in developing countries is huge relative to developed ones, the gaps may be even more significant within countries. Therefore, the analysis of this thesis focuses on the educational system of Colombia due to its characteristics as a developing country, its high social inequality, its information systems in education, its educational policies, the efforts of policymakers to make changes in the processes, and additionally, due to the presence of strong economic and social phenomena across the entire territory, namely the armed conflict and the voluntary contributions of private organizations.

Colombia aims to be the best-educated country in Latin America by 2025. In pursuit of this goal, the Colombian educational system has undergone significant changes. The following four achievements are highlighted (Ministerio de Educacion, 2016): first, it has increased the time children spend in schools; second, the early admission of children to early childhood education centers has been improved; third, mechanisms have been introduced based on the assurance of learning; fourth, significant efforts are underway to improve the teaching profession. Additionally, in the last decade, school life expectancy has increased by two years, and participation in *Atención Integral y Educación Infantil (EIAIPI)* and higher education has more than doubled: up to 40% and 50%, respectively (Ministerio de Educacion, 2016).

Despite the achievements made in the educational system in the last two decades, the Ministry of National Education of Colombia - MEN (2016) identified multiple challenges in the evaluation of its policies and practices in education during the process of joining the Organization for Economic Cooperation and Development (OECD). Therefore, the MEN report for OECD was produced following five principles: a strong focus on improving learning outcomes, equity of educational opportunities, ability to collect and use data to document policy,

effective use of funding to guide reforms, and greater participation of multiple stakeholders in the design and implementation of policies.

In this context, the MEN has concluded that the two main challenges facing the education system today are closing the gaps in participation and improving education for all. Historically, Colombia has had significant differences in socioeconomic terms, which affects school life expectancy, leading students in the worst conditions of poverty to have six years less education than the richest (12 years). Likewise, abysmal differences are found in access to higher education; the enrollment rate for students from families in the worst conditions is 9%, whereas this percentage rises to 53% for those from higher socioeconomic levels (Ministerio de Educacion, 2016).

Similarly, students who take the Program for International Student Assessment (PISA) test in Colombia show much lower performance than their peers in OECD countries; these students have an average of 376 points while the OECD average in 2012 was 494 (Ministerio de Educacion, 2016). Likewise, a more worrying statistic is that only 49% of students reach the minimum standards. This is a major challenge for the country and for society, as it must take advantage of its demographic bonus.

This thesis represents an advance in the line of research since it addresses multiple problems that have not been sufficiently developed previously. It also covers numerous limitations identified in the research line, thereby providing public and private institutions with evidence to help them improve their performance. In this thesis, three empirical chapters are developed to address problems that follow objectives in the same line to evaluate educational efficiency or productivity, taking into account inequality in contexts and educational inequality, and controlling for the phenomena of armed conflict and voluntary contributions from private organizations.

The second chapter evaluates the changes in productivity of 4587 schools using the metafrontier Malmquist-Luenberger index (MML); to this end, the results of Saber 11 from both public and private schools between the years 2014 and 2017 are taken into account. This methodology is used for two main reasons: first, it is ideal for measuring changes in efficiency over time; second, due to the index

approach, both good and bad outputs in the educational process are considered. The main results provide measurements and show the significant disparities between the different departments around the country. In addition, there is evidence of a deterioration in terms of productivity in both educational sectors; however, the behavior of the public sector shows fewer inefficiencies.

The third chapter studies the relationship between the armed conflict and the educational efficiency of 912 municipalities in Colombia. In this chapter, the loss of efficiency between 2014 and 2018 due to the armed conflict is calculated using a robust conditional non-parametric approach, which is an ideal methodology to control for environmental variables. This efficiency estimation is done using the Saber 11 standardized tests, specifically, the global score, which contains the results of mathematics, critical reading, social studies, science and English. In addition, school approval is taken into account since in environments of high intensity in the armed conflict, a balance is needed between variables related to educational quality and approval. The second chapter offers three main results: the first, homicides related to the armed conflict negatively impact educational efficiency, as expected; however, this is the first study to provide evidence of the relationship. Second, the effect of the armed conflict in the municipalities and in their neighbors is heterogeneous. Finally, the inefficiencies derived from the armed conflict are calculated to reach 33% in the most affected municipalities.

The fourth chapter assesses the causal impact of a tutoring program for 6,455 students who are lagging behind using data from the Carvajal Foundation, which is involved in various schools in the city of Cali, Colombia. The approach taken in this chapter is innovative in this line of research in that it combines experimental and efficiency evaluation methodologies (De Witte & Smet, 2018). Two main results are found. First, there is an improvement effect in educational efficiency of 9.6% on average. Second, a positive impact is found in at least 62.5% of schools in each academic grade.

The first subsection of the introductory chapter presents the motivation for this thesis and the structure of the three empirical chapters. In the following sub-sections, the methodologies used. After, the educational context of Colombia and the two phenomena under study (armed conflict and voluntary contributions from private organizations) are broadly explained. The general and specific objectives

of each of the empirical chapters are then presented in detail; the databases used are explained, together with their respective sources. The main results and contributions are presented, followed by a synthesis of the roadmap of the investigation.

1.2 Brief literature review

This subsection provides a brief introduction to the literature framework on educational efficiency that is used for the development of the thesis. It is so important to carry out both theoretical and empirical studies on education, multiple approaches have been taken in different lines of research, with the most significant empirical efforts developed in studying effectiveness and efficiency (Thieme et al., 2011). Furthermore, in recent decades, the line of research in educational efficiency has gained relevance due to its interaction with other problems, thus increasing interest from academics and educational providers (Goldstein & Woodhouse, 2000).

In this line, the importance of educational efficiency studies has been highlighted. Empirical evidence can contribute to making decisions that help to improve the functioning of the process (Tran & Villano, 2018). In addition, when there is low productivity or inefficiencies, empirical studies help identify the origin of the problem (Essid et al., 2014). Research on educational efficiency has increased exponentially in terms of publications and citations due to the relevance of its contributions. The dynamics of the research line have significantly improved the discipline, both in the theoretical and methodological approach; as a result, improvement of school efficiency has emerged as a now consolidated research line, thus responding to economic and social changes that are increasingly rapid and of greater magnitude (De Witte & López-Torres, 2017).

In general, efficiency studies consist of empirical approximations, in which relative and absolute measures are estimated considering the outputs, inputs, and environmental variables to characterize an efficient Decision-Making Unit (DMU). Since the pioneering works in the field (Bessent et al., 1982; Bessent & Bessent, 1980; Charnes et al., 1978), approaches have been made in different countries, with greater methodological advances continuously being developed. However, the concept of an efficient unit continues to be one that makes the best

use of its available resources; that is, when the level of outputs cannot be improved given specific inputs or when, given a level of outputs, the inputs cannot decrease (Bessent & Bessent, 1980).

The methodological approach of the research line in terms of technical efficiency in education has changed in recent years. In general, the efficiency of schools has been measured through different methodologies, which involve the fields of education, economics, and management (López-Torres & Prior, 2016). Until a few years ago, one of the most commonly used techniques was linear regression models; however, the variations in students' results are hidden within the averages (Silva Portela & Thanassoulis, 2001). In addition, the estimates through ordinary least squares are complicated when there is more than one outcome variable (Thieme et al., 2013).

On the other hand, some methodologies in this area of research offer the possibility of using more than one output variable, and are therefore a better approach to analyze the problems of education. For example, data envelopment analysis (DEA) is a linear programming technique, initially developed by Charnes, Cooper, and Rhodes (1978), widely used in different contexts, particularly the educational sector where it has been applied at the school (Johnes, Bradley, & Little, 2012; López-Torres & Prior, 2016; Naper, 2010; Sarrico, Rosa, & Coelho, 2010), student (De Witte & Kortelainen, 2013; Cordero, Prior, & Simancas, 2016; Thieme, Prior, & Tortosa-Ausina, 2013), classroom (De Witte & Rogge, 2011), municipality (Johnson & Ruggiero, 2014; Ouellette & Vierstraete, 2010) and educational system (Giménez et al., 2019; Thieme, Giménez, & Prior, 2012) levels. Further information on these applications can be found in the exhaustive literature review by De Witte & López-Torres (2017).

Another of the models used is the free disposal hull (FDH), initially proposed by Deprins, Simar, and Tulkens (2006) by relaxing the convexity assumption with which the DEA works. This intuitively implies that DMUs are only compared with other existing DMUs (Thieme et al., 2013) and not with a convex combination of them. Accordingly it has gained prominence, and its applications at different levels have increased in recent years (Cherchye et al., 2010; De Witte et al., 2010; De Witte & Kortelainen, 2013; Cordero et al., 2016).

Although the DEA and the FDH are two of the main non-parametric methods used in the educational efficiency literature, other methodological variants provide more robustness or greater scope to the estimates. For example, bootstrapping methods (Thieme et al., 2011; 2013) make it possible to have confidence intervals in their estimates. Another variant is the *order-m* (Cherchye et al., 2010; De Witte et al., 2010; Thieme et al., 2011; 2013), where the convexity assumption is relaxed, and estimates obtained by resampling are not very sensitive to the existence of extreme and atypical values.

To analyze the temporal change in productivity, the Malmquist index has been used (Agasisti & Dal Bianco, 2008; Camanho & Dyson, 2006; Giménez et al., 2017; Ouellette & Vierstraete, 2010; Portela et al., 2013; Thanassoulis et al., 2011). This index explains the change in productivity in a certain period from technological change and the change in efficiency. Finally, another methodological variant that has gained importance in recent years is metafrontiers (Cordero et al., 2015; 2016; Thieme et al., 2013), which, based on the approach of Battese et al. (2004), allow decompositions of various categories (Thieme et., 2013) and analysis of different groups or technologies (De la Torre et al., 2017) in the same context. In addition, the Hicks-Moorsteen index (Aparicio et al., 2018) and an approach based on performance and productivity ratios have been used in applications in the education sector (Cherchye et al., 2019).

In methodological terms it is also important to note that the characteristics of the environment being analyzed must be taken into account since they explain an essential part of the efficiency (Levin & Kelley, 1994). In the literature, multiple applications attempt to find the environmental determinants that influence the achievement of individuals (Mayston & Jesson, 1988; Sammons et al., 1993), increasingly requiring the consideration of environmental variables (Thanassoulis et al., 2016).

Giménez et al. (2007) identify four alternatives to control for the influence of environmental variables, although they point out that there is no consensus in the literature (Bifulco & Bretschneider, 2001). First, DMUs are separated based on their main environmental factors and estimated partial frontiers (Charnes et al., 1981). Second, the variables are directly included as inputs in the model to be estimated (Banker & Morey, 1986; Cordero et al., 2017; Crespo-Cebada,

Pedraja-Chaparro, & Santín, 2014; Giménez et al., 2017; Mancebon & Muñiz, 2008; Thieme et al., 2013). The third and fourth cases use two-stage models where estimations are made through econometric techniques to calculate the effect of environmental variables after estimating efficiency (López-Torres & Prior, 2016; Ray, 1991). In addition, Cazals et al. (2002) suggest using conditional models since they consider the heterogeneity of the sample and incorporate the effect of the environmental variables in a single stage.

Because of the importance of the education sector in society and its strategic role in the development agenda, both for academics and policymakers, it is necessary and relevant to have studies in the field of educational efficiency that help to make decisions. Based on the above and the different empirical approaches in the literature, this thesis uses two different methodological approaches for the three empirical chapters. The models used are the metafrontier Malmquist-Luenberger index (chapter 1) and the conditional *order-m* (chapters 2 and 3); these models are explained in depth in their respective chapters.

1.3 Specific aspects of the Colombian context

Colombia is a middle-income country with a population of approximately 50 million inhabitants in 2021, only surpassed by Brazil and Mexico in Latin America. In addition, 22.6% of people are between 0 and 14 years old, and 51.2% are women. The 2018 National Population and Housing Census found that 9.34% of people self-recognized as Black, Afro-Colombian, Raizal or Palanquero; in addition, 77.1% of the population lives in municipal capitals (urban areas).

As mentioned above, the levels of inequality in Latin America are high; however, they can sometimes be higher within countries. For political-administrative purposes, Colombia is divided into 32 departments and the capital district of Bogotá, which have administrative and financial autonomy; each department is divided into municipalities, of which there are a total of 1,122. Approximately 19 million people live in the three main departments of the country (Bogotá, Antioquia, and Valle del Cauca); however, there are 982 municipalities with a population of fewer than 50,000 people.

Economic activity is also concentrated in the three main departments of the country, since their combined GDP totals 51% (Bogotá 26.1%; Antioquia 14.9%; Valle del Cauca 10%). Likewise, the majority (824) of the 1000 most prominent companies in Colombia are located in these departments: 535 in Bogotá, 199 in Medellin, and 90 in Valle del Cauca. Moreover, Colombia has other considerable problems, such as criminality, low institutionality, armed conflict and the struggle to maintain the stability of the agreements reached with the Revolutionary Armed Forces of Colombia - People's Army (FARC-EP). These problems are highlighted by their relevance to society. Therefore, studying educational efficiency is one of the solutions that may have the greatest effectiveness and could be the most efficient way forward in the long term. Table 1.1 and Figure 1.1 present the GDP for each department, showing the concentration of economic activity across the country.

Two of the main challenges Colombia has faced historically are poverty and inequality. Moreover, Colombia has other considerable problems, such as criminality, low institutionality, armed conflict and the struggle to maintain the stability of the agreements reached with the Revolutionary Armed Forces of Colombia - People's Army (FARC-EP). These problems are highlighted by their relevance to society. Therefore, studying educational efficiency is one of the solutions that may have the greatest effectiveness and could be the most efficient way forward in the long term.

Table 1.1 shows the figures corresponding to monetary poverty[3] based on the DANE survey *Gran Encuesta Integrada de Hogares (2020)*[4]. This table clearly reflects the high poverty rates, with departments such as La Guajira reporting figures of 66%, in contrast to others such as Cundinamarca with 27%. These figures help to highlight three points. First, the department with the lowest percentage of monetary poverty in Colombia is 16% higher than the OECD average (2016)[5].

[3] The monetary poverty measure is the value in money that a person needs per month to acquire a basic basket of food, services, and other minimum goods to live. https://www.dane.gov.co/files/lineas-de-tiempo/boletin-poblacion-ocupada-pobreza-monetaria/index.html

[4] https://www.dane.gov.co/index.php/estadisticas-por-tema/pobreza-y-condiciones-de-vida/pobreza-monetaria

[5] *OECD Income Distribution Database*, http://oe.cd/idd.

Table 1.1. GDP and monetary poverty by department for the year 2020. GDP in billions of Colombian Pesos.

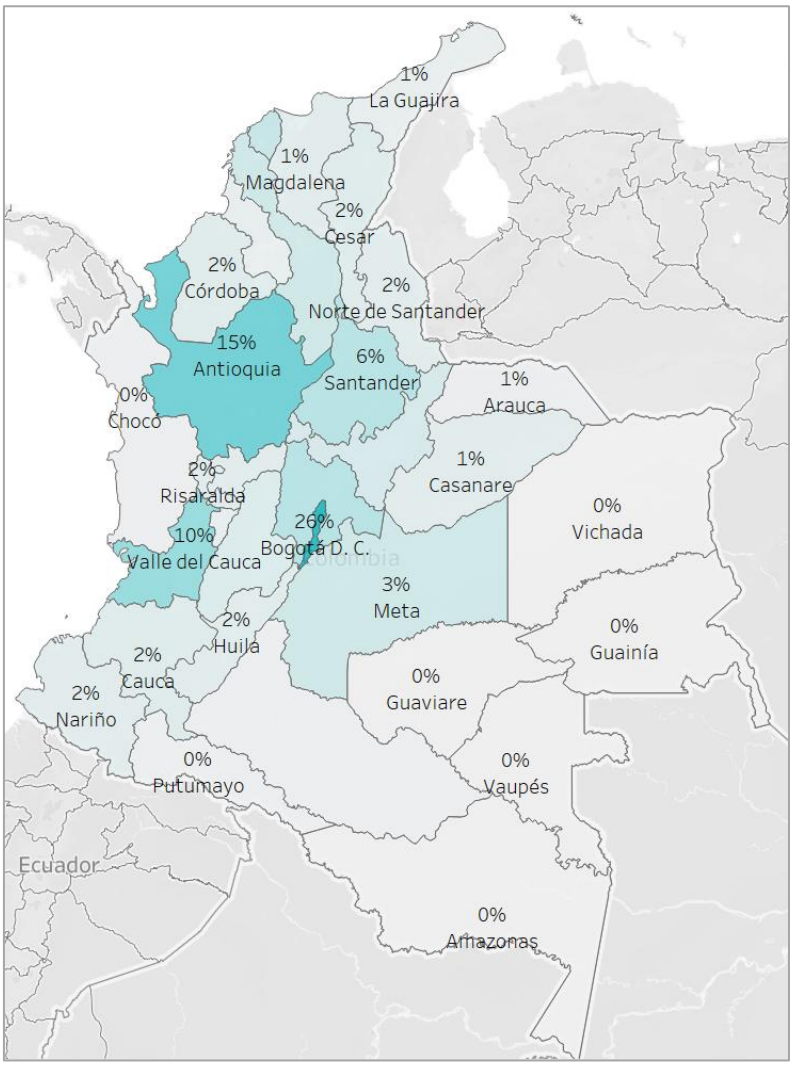
Department	GDP 2020	% GDP	% GDP aggregate	% Monetary poverty
Bogotá D. C.	214,905	26%	26%	40%
Antioquia	122,644	15%	41%	34%
Valle del Cauca	82,495	10%	51%	35%
Santander	51,882	6%	57%	39%
Cundinamarca	50,067	6%	63%	27%
Atlántico	36,557	4%	68%	40%
Bolívar	28,542	3%	71%	53%
Meta	28,255	3%	75%	40%
Boyacá	22,046	3%	78%	40%
Tolima	17,361	2%	80%	46%
Cauca	14,609	2%	81%	56%
Córdoba	13,974	2%	83%	59%
Cesar	13,836	2%	85%	58%
Risaralda	13,230	2%	86%	36%
Caldas	13,187	2%	88%	31%
Huila	13,087	2%	90%	56%
Norte de Santander	12,814	2%	91%	56%
Nariño	12,472	2%	93%	50%
Casanare	12,098	1%	94%	na
Magdalena	10,828	1%	95%	60%
Sucre	6,930	1%	96%	51%
Quindío	6,552	1%	97%	38%
La Guajira	6,471	1%	98%	66%
Arauca	4,577	1%	98%	na
Caquetá	3,393	0%	99%	44%
Chocó	3,291	0%	99%	65%
Putumayo	2,822	0%	100%	na
San Andrés, Providencia y Santa Catalina	1,101	0%	100%	na
Guaviare	675	0%	100%	na
Amazonas	609	0%	100%	na
Vichada	552	0%	100%	na
Guainía	287	0%	100%	na
Vaupés	236	0%	100%	na
Total	822,384	100%	100%	43%

Source: DANE - Gran Encuesta Integrada de Hogares (2020).
*na: the DANE study on monetary poverty does not have results for nine departments.

Second, the difference between departments reaches values of 39%. Third, nine departments do not have figures due to the scope of the study, which shows the significant differences in the development of the departments and the institutional presence. Additionally, the average Gini index in Colombia for the year 2020 is 0.544, which is extremely high compared to OECD countries and has an

increasing trend (Ministerio de Educacion, 2016). Finally, all these data may be even more significant in rural areas, for which evidence is more limited.

Figure 1.1 Percentage of GDP by department for the year 2020



Source: DANE – Censo Nacional de Población y Vivienda (2018).

Moreover, Colombia has other considerable problems, such as criminality, low institutionality, armed conflict and the struggle to maintain the stability of the agreements reached with the Revolutionary Armed Forces of Colombia - People's Army (FARC-EP). These problems are highlighted by their relevance to society. Therefore, studying educational efficiency is one of the solutions that may have the greatest effectiveness and could be the most efficient way forward in the long term.

Table 1.2. Educational enrollment by level and educational sector for the year 2020

Department	Preschool				Primary			
	Total	Public	Schools with contracted enrollment[6]	Private	Total	Public	Schools with contracted enrollment	Private
Total	922,945	592,665	18,640	311,640	3,587,025	2,780,083	97,748	709,194
Amazonas	1,860	1,667	0	193	8,608	8,264	0	344
Antioquia	101,086	65,117	1,785	34,184	404,233	334,525	9,814	59,894
Arauca	5,859	5,210	35	614	24,910	23,391	69	1,450
Archipiélago de San Andrés, Providencia y Santa Catalina	1,381	714	0	667	4,779	3,734	0	1,045
Atlántico	60,229	28,510	3,695	28,024	230,717	157,356	26,803	46,558
Bogotá, D.C.	145,575	82,978	1,159	61,438	498,699	311,460	3,804	183,435
Bolívar	49,132	33,925	1,649	13,558	210,215	167,516	9,421	33,278
Boyacá	21,173	13,140	302	7,731	71,811	53,546	471	17,794
Caldas	12,834	8,587	0	4,247	44,124	36,874	0	7,250
Caquetá	7,706	6,521	0	1,185	27,044	24,447	89	2,508
Casanare	8,434	6,531	100	1,803	38,147	34,713	163	3,271
Cauca	22,393	18,827	105	3,461	100,745	92,300	474	7,971
Cesar	30,382	19,926	364	10,092	118,255	97,575	527	20,153
Chocó	11,324	10,578	34	712	49,272	48,024	0	1,248
Córdoba	37,945	28,465	274	9,206	148,841	132,217	575	16,049
Cundinamarca	56,177	27,282	2,489	26,406	234,700	152,195	12,099	70,406
Guainía	1,310	1,235	0	75	6,352	6,258	0	94
Guaviare	1,597	1,335	0	262	4,796	4,322	0	474
Huila	21,153	15,837	208	5,108	68,925	55,857	76	12,992
La Guajira	28,835	23,775	524	4,536	124,318	114,053	1,061	9,204
Magdalena	36,689	25,517	169	11,003	141,649	118,962	408	22,279
Meta	20,877	13,267	280	7,330	78,275	63,743	1,639	12,893
Nariño	22,801	17,606	182	5,013	101,595	91,993	777	8,825
Norte de Santander	30,788	21,443	290	9,055	112,174	95,159	508	16,507
Putumayo	5,806	5,189	0	617	20,683	20,106	0	577
Quindío	7,452	5,180	132	2,140	31,020	26,598	0	4,422
Risaralda	15,247	9,877	435	4,935	56,345	47,000	727	8,618
Santander	40,221	24,147	400	15,674	147,874	114,220	701	32,953
Sucre	24,508	18,330	125	6,053	87,576	76,371	266	10,939
Tolima	23,223	15,686	80	7,457	83,238	65,308	305	17,625
Valle del Cauca	66,637	34,123	3,810	28,704	290,550	185,638	26,971	77,941
Vaupés	513	443	0	70	4,393	4,386	0	7
Vichada	1,798	1,697	14	87	12,162	11,972	0	190

Source: DANE. Educación formal - EDUC

[6] These schools are private organizations, partially or fully funded by public monies under a contract with a government agency.

Table 1.2 Educational enrollment by level and educational sector for the year 2020 – continuation

Department	Secondary				Middle education			
	Total	Public	Schools with contracted enrollment	Private	Total	Public	Schools with contracted enrollment	Private
Total	3,017,236	2,473,708	72,532	470,996	1,076,939	862,396	21,818	192,725
Amazonas	6,305	6,055	0	250	1,932	1,880	0	52
Antioquia	367,338	312,897	8,590	45,851	127,157	106,204	2,495	18,458
Arauca	18,637	17,847	9	781	5,444	5,184	0	260
Archipiélago de San Andrés, Providencia y Santa Catalina	3,725	2,987	0	738	1,255	947	0	308
Atlántico	173,656	130,387	17,445	25,824	63,983	48,800	3,819	11,364
Bogotá, D.C.	417,142	270,177	4,526	142,439	162,435	98,824	2,515	61,096
Bolívar	159,118	132,488	6,225	20,405	54,309	44,799	1,471	8,039
Boyacá	82,851	71,060	486	11,305	33,125	28,399	327	4,399
Caldas	43,512	38,616	0	4,896	19,188	16,897	0	2,291
Caquetá	22,520	21,208	43	1,269	7,970	7,566	0	404
Casanare	31,368	29,721	0	1,647	10,470	9,885	0	585
Cauca	88,068	81,612	429	6,027	31,554	29,044	122	2,388
Cesar	85,887	77,521	96	8,270	27,319	24,109	19	3,191
Chocó	32,122	31,407	0	715	9,944	9,634	0	310
Córdoba	129,910	120,124	177	9,609	44,971	41,067	48	3,856
Cundinamarca	201,399	141,255	9,297	50,847	71,075	48,241	3,022	19,812
Guainía	3,286	3,278	0	8	839	839	0	0
Guaviare	4,414	4,129	0	285	1,354	1,239	0	115
Huila	66,576	59,617	0	6,959	24,713	22,223	0	2,490
La Guajira	68,843	64,709	644	3,490	18,246	16,627	201	1,418
Magdalena	106,655	97,349	295	9,011	35,689	31,852	177	3,660
Meta	68,408	60,681	1,214	6,513	23,426	20,854	137	2,435
Nariño	94,562	87,713	586	6,263	35,895	33,049	214	2,632
Norte de Santander	94,050	83,916	219	9,915	30,899	26,747	53	4,099
Putumayo	19,267	19,152	0	115	6,899	6,845	0	54
Quindío	28,849	25,760	0	3,089	11,343	10,145	0	1,198
Risaralda	53,453	47,644	325	5,484	19,225	16,918	110	2,197
Santander	132,552	113,298	389	18,865	47,090	39,249	188	7,653
Sucre	67,060	62,223	39	4,798	23,754	21,877	0	1,877
Tolima	83,962	73,713	112	10,137	30,483	26,636	53	3,794
Valle del Cauca	254,741	178,164	21,386	55,191	93,008	63,871	6,847	22,290
Vaupés	2,579	2,579	0	0	746	746	0	0
Vichada	4,421	4,421	0	0	1,199	1,199	0	0

Source: DANE. Educación formal - EDUC

In this context, studies on topics such as the ones in this thesis are even more relevant. In what follows, the Colombian educational system is briefly contextualized to allow a proper understanding of the study's scope, relevance, and results. According to the 1991 constitution and the 1994 Education Law, education is a right to which all people in Colombia have access. The Colombian

educational system before higher education is divided into four stages: preschool (EIAIPI), primary education (5 years), basic secondary education (4 years) and secondary education (2 years). Higher education is more complex since there are different programs of varying length and with multiple providers.

Table 1.3. Total enrollment by department and academic sector

Department	Total	Public	%	Schools with contracted enrollment	%	Private	%
Total	8,604,145	6,708,852	78.0%	210,738	2.4%	1,684,555	19.6%
Amazonas	18,705	17,866	95.5%	0	0.0%	839	4.5%
Antioquia	999,814	818,743	81.9%	22,684	2.3%	158,387	15.8%
Arauca	54,850	51,632	94.1%	113	0.2%	3,105	5.7%
Archipiélago de San Andrés, Providencia y Santa Catalina	11,140	8,382	75.2%	0	0.0%	2,758	24.8%
Atlántico	528,585	365,053	69.1%	51,762	9.8%	111,770	21.1%
Bogotá, D.C.	1,223,851	763,439	62.4%	12,004	1.0%	448,408	36.6%
Bolívar	472,774	378,728	80.1%	18,766	4.0%	75,280	15.9%
Boyacá	208,960	166,145	79.5%	1,586	0.8%	41,229	19.7%
Caldas	119,658	100,974	84.4%	0	0.0%	18,684	15.6%
Caquetá	65,240	59,742	91.6%	132	0.2%	5,366	8.2%
Casanare	88,419	80,850	91.4%	263	0.3%	7,306	8.3%
Cauca	242,760	221,783	91.4%	1,130	0.5%	19,847	8.2%
Cesar	261,843	219,131	83.7%	1,006	0.4%	41,706	15.9%
Chocó	102,662	99,643	97.1%	34	0.0%	2,985	2.9%
Córdoba	361,667	321,873	89.0%	1,074	0.3%	38,720	10.7%
Cundinamarca	563,351	368,973	65.5%	26,907	4.8%	167,471	29.7%
Guainía	11,787	11,610	98.5%	0	0.0%	177	1.5%
Guaviare	12,161	11,025	90.7%	0	0.0%	1,136	9.3%
Huila	181,367	153,534	84.7%	284	0.2%	27,549	15.2%
La Guajira	240,242	219,164	91.2%	2,430	1.0%	18,648	7.8%
Magdalena	320,682	273,680	85.3%	1,049	0.3%	45,953	14.3%
Meta	190,986	158,545	83.0%	3,270	1.7%	29,171	15.3%
Nariño	254,853	230,361	90.4%	1,759	0.7%	22,733	8.9%
Norte de Santander	267,911	227,265	84.8%	1,070	0.4%	39,576	14.8%
Putumayo	52,655	51,292	97.4%	0	0.0%	1,363	2.6%
Quindío	78,664	67,683	86.0%	132	0.2%	10,849	13.8%
Risaralda	144,270	121,439	84.2%	1,597	1.1%	21,234	14.7%
Santander	367,737	290,914	79.1%	1,678	0.5%	75,145	20.4%
Sucre	202,898	178,801	88.1%	430	0.2%	23,667	11.7%
Tolima	220,906	181,343	82.1%	550	0.2%	39,013	17.7%
Valle del Cauca	704,936	461,796	65.5%	59,014	8.4%	184,126	26.1%
Vaupés	8,231	8,154	99.1%	0	0.0%	77	0.9%
Vichada	19,580	19,289	98.5%	14	0.1%	277	1.4%

Source: DANE. Educación formal – EDUC

Table 1.2 shows enrollment by department, academic level, and sector. The preschool level contains the pre-kindergarten, kindergarten and transition grades, of which the latter represents 76.8% since it is the only one that is mandatory according to Law 115 of 1994. In all academic levels, there is a high concentration in the main departments of the country: together, Bogotá (16%), Antioquia (11%), and Valle del Cauca (7%) account for 34% (313,298 students) of the total enrollment (922,945 students) at the preschool level for the year 2020. The public sector represents 64.2% of this total and the private 33.8%. In the private sector, there is a greater concentration in urban areas; for example, Bogotá accounts for 61,438 students, which is equivalent to 20% of the sector's enrollment.

In primary basic education (ranging from first to fifth grade), there are 3,587,025 students enrolled in the country; 77.5% are enrolled in the public sector and 19.8% in the private sector. In general, the levels of educational quality the Colombian public sector are lower than those of the private sector (Guarín et al., 2018); from this point on, inequalities in the training and capacities of children begin to be generated. Again, the main cities account for a large part of the private educational demand and supply. In this case, 26% is concentrated in Bogotá (183,435 students), while 13 departments each contain less than 1% of the students in this educational sector.

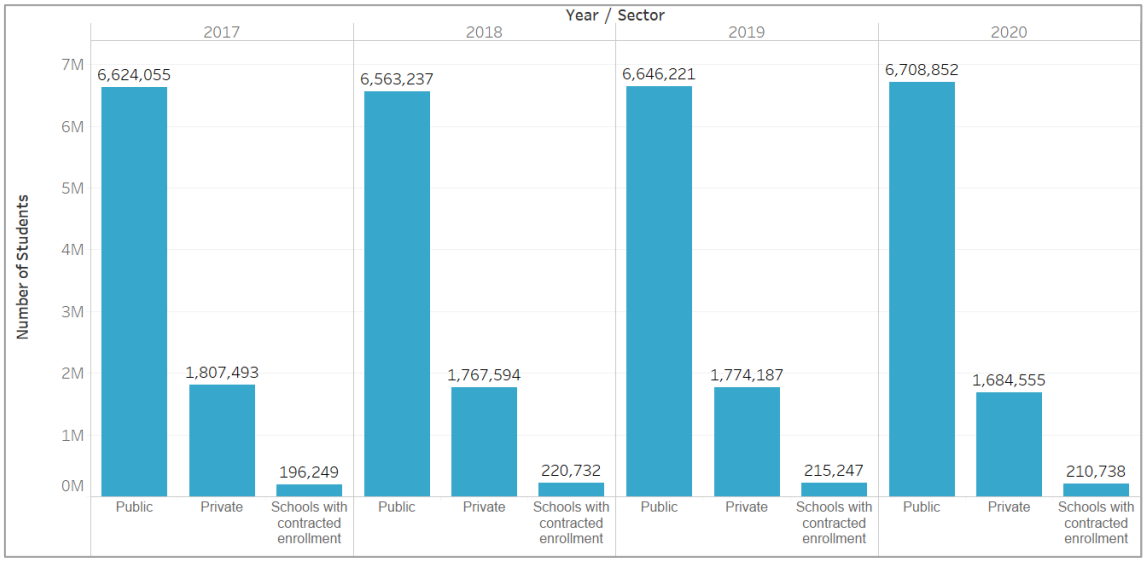
Basic secondary education (ranging from sixth to ninth grade) represents 35.1% of the country's educational enrollment[7]. The public sector has 80.1% of the students, and the private sector, 17.9% at this academic level. In the public sector, Bogotá represents 14% and in the private sector, 30%. Likewise, middle education (grades ten and eleven) represents 12.5% of the total enrollment with 1,076,939 students; 382,600 are in Bogotá, Antioquia and Valle del Cauca. In this context, studies on topics such as the ones in this thesis are even more relevant. In what follows, the Colombian educational system is briefly contextualized to allow a proper understanding of the study's scope, relevance, and results. According to the 1991 constitution and the 1994 Education Law, education is a right to which all people in Colombia have access. The Colombian educational system before higher education is divided into four stages: preschool

[7] Without taking into account the flexible models (742,639 students) and the Special Integrated Lesson Cycle - CLEI (536,059).

(EIAIPI), primary education (5 years), basic secondary education (4 years) and secondary education (2 years). Higher education is more complex since there are different programs of varying length and with multiple providers.

Table 1.3 shows the summary by department of students enrolled in the Colombian educational system. In total, 8,604,145 students are enrolled, without taking into account education in flexible models and CLEI (which total 1,278,698 students); however, due to the difference in the target ages of the people and the schemes in which the educational processes are carried out, these flexible models and CLEI are not included in the descriptive analysis. The public sector represents 78% and the private sector 19.6%.

Figure 1.2 Students enrolled between the years 2017 and 2020 by educational sector



Source: DANE. Educación formal – EDUC

In recent years, total enrollment has decreased by approximately 23,000 students: in 2017, total enrollment was 8,627,797 students, and by 2020, it had fallen to 8,604,145. However, sector behavior was not homogeneous; the public sector increased by 1.2% (84,797 students) while the private sector decreased by 6.8% (122,938 students). These changes are reflected in Figure 1.2, which clearly shows the predominance of the public sector and the migration from the private to the public sector; this shift is mainly due to the associated costs.

Table 1.4. Schools by department, level and education sector in 2020

Department	Public				Private			
	Preschool	**Primary**	**Secondary**	**Middle education**	**Preschool**	**Primary**	**Secondary**	**Middle education**
Total	34,131	41,261	10,682	7,850	8,171	6,678	3,495	3,039
Amazonas	107	114	21	18	5	4	3	2
Antioquia	3,995	4,887	1,826	1,175	628	339	265	246
Arauca	420	464	64	50	30	28	15	10
Archipiélago de San Andrés, Providencia y Santa Catalina	15	18	10	8	9	7	6	6
Atlántico	383	443	321	298	676	570	270	214
Bogotá, D.C.	549	648	424	401	1,389	1,153	761	708
Bolívar	1,247	1,384	456	370	349	337	150	116
Boyacá	1,581	1,993	363	309	286	229	92	79
Caldas	835	1,045	336	231	102	67	41	38
Caquetá	948	1,281	248	103	28	26	11	8
Casanare	461	568	113	93	61	40	19	16
Cauca	1,990	2,388	490	419	119	102	64	51
Cesar	969	1,128	338	193	256	214	65	49
Chocó	961	1,163	257	185	15	9	5	5
Córdoba	1,673	1,840	523	385	163	139	61	51
Cundinamarca	1,966	2,493	463	396	768	694	415	368
Guainía	88	90	19	12	2	2	1	0
Guaviare	176	226	47	26	10	8	3	3
Huila	1,391	1,694	301	231	174	154	51	44
La Guajira	1,358	1,454	212	131	115	111	37	30
Magdalena	937	1,051	382	278	326	314	93	73
Meta	889	1,038	228	152	189	159	68	55
Nariño	1,867	2,429	487	338	143	81	44	38
Norte de Santander	1,642	1,986	360	206	234	185	88	82
Putumayo	665	884	137	106	22	7	1	1
Quindío	261	319	104	87	48	34	23	23
Risaralda	644	761	199	164	200	111	48	41
Santander	1,981	2,540	551	412	427	344	147	129
Sucre	809	842	211	178	120	114	34	26
Tolima	1,616	1,926	438	348	245	213	91	75
Valle del Cauca	1,472	1,849	696	512	1,027	880	523	452
Vaupés	55	114	21	15	2	1	0	0
Vichada	180	201	36	20	3	2	0	0

Source: DANE. Educación formal – EDUC

Based on the above, it can be stated that, although educational policies have prioritized expanding participation, no significant increases have been achieved in recent years.

Table **1.4** displays the number of schools by department, sector and educational level, indirectly showing the inequality in the educational offer. Unlike educational enrollment, the sectors behave differently; for example, Bogotá represents only 2.2% of schools in the public sector. However, in the private sector, it represents 18.8%, helping to show that in the main cities, education sector behavior is assimilated to a market economy due to the availability to pay and the presence of private organizations. The three main departments account for 19.6% of the schools in the public sector, while this figure is 39.1% in the private sector.

One of the main problems in the Colombian educational system is the transition from high school to higher education. The Ministry of Education (2016) has estimated that only 30% of young people make the transition from school to higher education (university or technical/technological institutes); additionally, the dropout rate among those who reach higher education is 10.4% annually in universities and 22% in technical or technological institutes (Ministerio de Educacion, 2016). Notably, many of the problems in higher education are the lack of educational opportunities in terms of funding, poverty, inequality, pressure to start work and generate income, armed conflict and violence. However, since higher education is not the main objective of the present study, it has not been taken into account in the basic descriptions.

The Colombian Institute for the Evaluation of Education (ICFES) is responsible for evaluating education across the country. These evaluations are carried out with multiple standardized exams at the national level, although the most important are Saber 3, 5 and 9 and Saber 11 for secondary and middle education. In turn, the most important standardized exams for higher education are Saber PRO and Saber TyT (for the Technical and Technological level). Additionally, multiple standardized tests are carried out to make comparisons at an international level, the main one being the Program for International Student Assessment (PISA).

On average, private sector students (average 263) outperform public sector students (average 241) by 23 points. The departments with the best performance in the public sector are Boyacá and Norte de Santander, with 257 points. In the private sector, the departments with the best performance are Quindío and Boyacá, with scores of 295 (649 students taking the test) and 283, respectively.

Likewise, the department with the worst performance in the public sector is Choco with 201 points and in the private sector, Cauca with 224 points (considering only the departments with more than 500 students).

Table 1.5. Saber 11 average score, standard deviation and number of students by department and educational sector in the period 2019-2

Department/ Educational Sector	Public			Private		
	Average	Standard Deviation	Number of Students	Average	Standard Deviation	Number of Students
Total	241	48	415,775	263	58	129,926
Amazonas	210	42	797	296	38	28
Antioquia	239	49	57,417	253	62	16,811
Arauca	241	47	3,062	241	55	297
Atlántico	238	48	22,786	249	60	9,393
Bogotá	255	43	45,485	281	52	38,115
Bolivar	219	45	20,462	266	57	4,770
Boyacá	257	45	13,718	283	53	3,045
Caldas	243	48	9,065	270	57	1,368
Caquetá	235	44	3,813	227	53	820
Casanare	245	45	5,466	264	63	527
Cauca	229	47	12,072	224	51	1,908
Cesar	235	45	11,082	254	63	2,194
Choco	201	43	4,692	199	41	198
Cordoba	232	45	16,939	258	63	3,098
Cundinamarca	248	45	24,321	264	50	11,875
Guainía	223	49	267	195		1
Guaviare	224	44	883	222	52	134
Huila	249	48	11,384	253	62	2,704
La Guajira	213	43	7,925	259	55	915
Magdalena	217	42	14,532	253	56	2,095
Meta	249	45	10,030	245	56	2,432
Nariño	244	52	14,593	249	55	2,310
Norte Santander	257	46	11,599	251	58	4,169
Putumayo	238	46	3,833	218	45	198
Quindío	247	50	5,761	295	53	649
Risaralda	247	47	9,145	271	55	1,555
San Andrés	223	47	476	253	49	151
Santander	260	48	19,825	278	62	5,648
Sucre	233	47	9,530	257	65	1,403
Tolima	238	45	13,538	253	58	2,900
Valle	242	49	30,437	246	51	8,203
Vaupes	210	40	343	208	55	10
Vichada	225	46	497	168	10	2

Source: ICFES – Saber 11

Table 1.5 shows the average Saber 11 standardized test results, the standard deviation, and the number of students who took the test by department and education sector. A total of 545,701 students took the test in the second semester of 2019 across the country, 76% of whom did so through public sector institutions. The departments with the highest participation were Bogotá, Antioquia and Valle del Cauca, with 15%, 14% and 7%, respectively. Additionally, there is a significant difference between the sectors due to the institutional presence and market mechanisms; this is evidenced in the private sector since in seven departments fewer than 500 students took the test.

Additionally, Table 1.5 shows the standard deviation by department, which has been used to measure inequality in the academic literature (Arbona et al., 2021; Giménez et al., 2018; Tsai et al., 2017). On average, the private sector performs better but has a standard deviation 10 points higher (58 points) than the public sector (48 points). Likewise, there are significant differences between departments in terms of the educational sectors; for example, in the public sector there is a 10-point difference between the departments with the lowest (Magdalena and Amazonas with 42 points) and the highest (Nariño with 52 points) standard deviations[8].

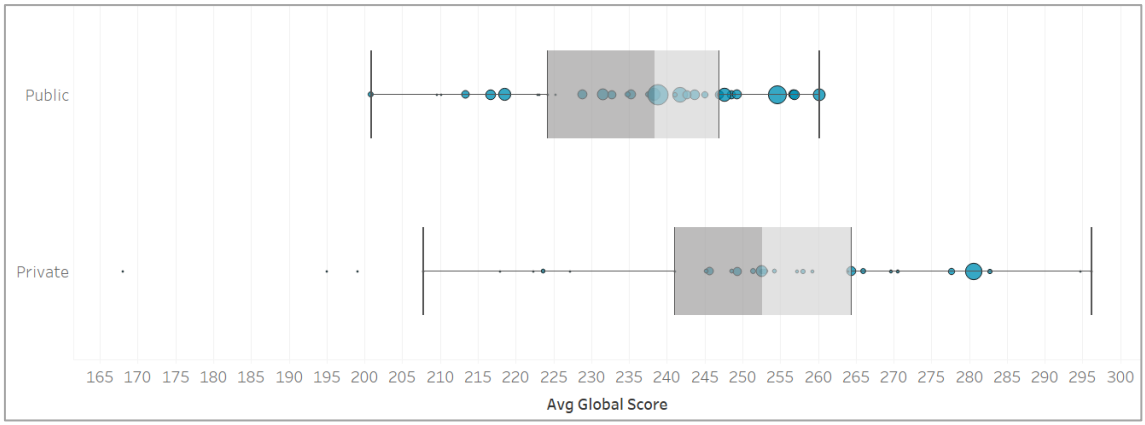
Figure 1.3 helps to illustrate two of the main results of the Saber 11 test for the second period of the year 2019. First, on average, the private sector performs better than the public sector. Second, there are significant differences between the average scores and the standard deviation of the departments in each of the educational sectors. Additionally, on average, the higher the average of the department, the higher the standard deviation; however, it depends on the number of students who take the test by department, municipality and school.

This subsection provides a general presentation of some social and economic activity indicators that allow us to understand the context in which this research is carried out. Access figures for the different educational levels of the country and the results in the Saber 11 exam are also shown descriptively, according to the department and educational sector. Additionally, due to the relevance for this thesis, two notable phenomena in the Colombian context are explained below:

[8] Only departments with more than 500 students in the test are considered.

first, the armed conflict, and second, the voluntary contributions of private organizations.

Figure 1.3 Saber 11 average score by department and sector in the period 2019-2



Source: ICFES – Saber 11

The academic literature reports that armed conflict has important economic, social and political repercussions which can affect educational achievement, highlighting that early exposure is much more persistent (Gianmarco, 2012). The armed conflict in Colombia has a history of more than 50 years. There have been multiple manifestations of conflict that affect the civilian population in the short and long term. In general, the armed conflict has varied significantly in intensity among municipalities, although it has been centered in the rural areas of the country. Multiple guerrilla and paramilitary groups led the armed conflict in Colombia between 1958 and 2021, resulting in more than 220,000 murders and more than six million displaced people, according to the National Center for Historical Memory (CNMH)[9].

The multiple financing strategies, the technological change in the Colombian armed forces and the peace process led by former president Andrés Pastrana (1998–2002) resulted in the most critical moments in the armed conflict in 2002. Following this peace process, the *Autodefensas Unidas de Colombia* (AUC) reached an agreement with the government to hand over their weapons in 2006. In this context, the FARC-EP became more powerful as it was the strongest outlawed group in the country until 2016 when it signed a peace agreement in negotiations led by former president Juan Manuel Santos.

[9] https://centrodememoriahistorica.gov.co/262-197-muertos-dejo-el-conflicto-armado/

The peace processes have resulted in a decrease in the main manifestations of the armed conflict (homicides, kidnappings, terrorist attacks). However, the conflict continues to be unevenly present in the country, the most affected municipalities being those with the least institutional presence. In terms of hard statistics, the United Nations verified 42 massacres and 224 murders in the first half of 2020. These killings make efforts to consolidate the peace agreements even more relevant since the armed conflict is a problem that continues to affect society, and directly impacts children, young people and the efficiency of the educational system.

The second phenomenon studied in this thesis is the voluntary contributions of private organizations; as mentioned above, rates of poverty and inequality are high in Colombia, and given a precarious public educational system, private organizations have chosen to become involved by lending support as part of their role in society. This support for the educational system takes shape through multiple strategies, including public-private associations (PPA) and vouchers (Patrinos et al., 2009). The survey of strategic social architecture carried out by the *Asociación Nacional De Industriales* (ANDI) concludes that of all the companies that make social investments, 46% do so in education, which is second only to environmental investments[10]

In Colombia, a group of companies created *Empresarios por la Educación (*EXE*)* in 2002 to influence the education sector. The objective of *EXE* is to contribute to closing educational gaps at the territorial and national levels, mainly through analysis, information production and monitoring of public policies. With the help of Proantioquia, the Ford Foundation, the Ministry of National Education and the Department of Social Prosperity, in 2013 EXE created the *Sistema de Información de Iniciativas y Programas en Educación* (SIIPE), which shows the significant contribution of private organizations to the country's education sector.

SIIPE[11] is a unique and robust database that systematically records the initiatives of private organizations. In 2020, 1,294 initiatives were registered, of which 903

[10] ANDI (2017). Overview of the social management of 500 companies in Colombia. Retrieved from http://www.andi.com.co/Uploads/Encuesta%20de%20Arquitectura%20Social%20Estrat%C3%A9gica%202017_636518022055690875.pdf

[11] Fundación EXE (2018). Sistema de Información de la Intervención Privada en Educación, SIIPE. Retrieved from https://siipe.fundacionexe.org.co/

are active. The initiatives are reported at all academic levels; however, most actions take place at the basic primary (371) and secondary (346) levels. These initiatives are divided into 11 categories, the main one being transversal training (457), followed by innovation and technology (219) and educational actors (205). The database provides evidence of initiatives in all the country's departments; however, these initiatives are associated with business activity so the departments with the highest number of initiatives are Antioquia (184), Valle del Cauca (181) and Bogotá (131).

From this subsection and the previous one, five main ideas can be highlighted: first, in Colombia, education is a right, and thanks to this and its importance in society, it has been classified as a priority for public policies and accordingly, the government has taken multiple actions to improve access and quality. Second, Colombia is a country with significant problems of poverty and inequality, both at a general level in society and in access to and quality of the educational system. Third, there are substantial differences between departments in economic activity, social characteristics, access to and quality of the educational system, especially when the three main departments (Bogotá, Antioquia and Valle del Cauca) are compared with the rest. Fourth, the armed conflict is a serious problem for Colombian society, especially for the full development of its educational systems. Fifth, private organizations in Colombia have taken great initiatives in education in their attempts to close the gaps across the territory.

1.4 Research objectives

To develop this thesis, a general objective and multiple specific objectives are set out in each empirical chapter. This approach follows the main objective that runs through all the chapters, namely to study the relationship between schools' educational efficiency or productivity, taking into account different sources of inequality and the context of students, schools, and municipalities.

Second chapter: the main objective of the second chapter is to evaluate the change in the productivity of 4,587 schools between 2014 and 2017, differentiating between the public and private sectors. In addition, there are two specific objectives: first, to propose a robust and integrating methodology of the concepts partially measured by the incentive system Stimuli for Quality; and

second, to analyze the change in the efficiency of the educational system by implementing the Synthetic Index of Educational Quality.

Third chapter: this chapter aims to evaluate the potential loss of educational efficiency of 912 municipalities in Colombia due to the armed conflict. To do this, an analysis is made of students' performance in the schools that took the Saber 11 standardized test between 2014 and 2018. Additionally, there are two specific objectives: first, to analyze how the intensity of the armed conflict is related to the results of educational efficiency. Second, to determine whether there is a significant relationship between the armed conflict of the residents of the municipalities analyzed and educational efficiency.

Fourth chapter: this chapter aims to evaluate the causal impact of the *Aula Global* program on school efficiency through an innovative procedure that combines literature on impact evaluation and the evaluation of social policies. Additionally, there are two specific objectives: first, to determine whether there are significant differences between the academic degrees where the *Aula Global* program has an impact. Second, to analyze whether the environmental variables significantly affect the program's effect on educational efficiency.

1.5 Datasets

A specific database is prepared for this thesis with secondary data taken from multiple sources since no one source contains all the variables necessary to achieve the different objectives. The main database is consolidated and complemented by two specific databases for the third and fourth chapters. The sources of information are the National Administrative Department of Statistics (DANE), the Colombian Institute for the Evaluation of Education (ICFES), the National Planning Department (DNP), the National Center for Historical Memory of Colombia and *Fundación Carvajal*.

The first source (DANE) offers information on the 62,758 schools in Colombia, related to the sector, area, school resources, number of teachers, number of students, electronic resources, teacher quality, enrollment costs, among others. This database is the result of public education research project C-600. The

database has multiple specialized components and unique codes for schools that allow it to be linked with the second source of information for this thesis.

ICFES, the second source of information, offers access to standardized tests that students take at different academic levels. For this thesis, the standardized test Saber 11 is mainly used; this contains information related to results in mathematics, critical reading, social studies and English. In addition, it includes socioeconomic information about the student, and information about the parents and the educational institution.

The third source of information, the DNP, offers context variables for all municipalities in Colombia. The variables are related to the city budget, education coverage, poverty, inequality, social programs, and health, among others. The database has more than 120 variables that help to characterize the level of development of the municipalities. The fourth source contains information related to the armed conflict in Colombia; this includes data on homicides, violent events, terrorist attacks, mines, anti-drug operations, forced migration, among others. Finally, the Carvajal Foundation offers privileged access to the database of its *Aula Global* program, which contains information on the results of the early grade mathematics assessment (EGMA) and the early grade reading assessment (EGRA) for students from the program and peers from their schools.

1.6 Principal results and contributions

This subsection summarizes the main results and contributions of each of the empirical chapters. In the second chapter, the results indicate a deterioration in the private and public sectors. This behavior is due to changes in best practices and change in efficiency. There are also significant gaps between departments. The results indicate better performance in the public than in the private sector, regardless of the orientation; in other words, the results of the metafrontier Malmquist-Luenberger index show an average deterioration for the private sector of 16.4% (good output), 3.20% (bad output) and 4.14% (good and bad output), depending on their orientation. On the other hand, for the public sector, there is a deterioration of 6.82% (good output), 0.91% (bad output) and 1.55% (good and bad output).

The second chapter offers two main contributions to the line of research. First, the methodology and the application to the specific problem open the way to multiple educational policies since they are proposed as a point of reference for the delivery of incentives in the public sector and act as a market signal in the private sector. And second, this chapter responds to various requests in the educational efficiency literature, specifically taking into account variables that consider all dimensions of the educational process (Hauser, 2009) and incorporating both performance and inequality in the educational process (Tsai et al., 2017).

Regarding the third chapter, the main results are as follows. First, as expected, homicides due to the armed conflict negatively impact educational efficiency. Second, both the conflict in the analyzed municipalities and that of their neighbors significantly affect the efficiency of educational institutions. Finally, inefficiencies due to the armed conflict are found to reach values of up to 33%. Additionally, high intensity of the armed conflict and the results of educational efficiency are closely related.

The third chapter makes three main contributions to the academic literature. First, it responds to calls in the literature to develop the intersection between the lines of research on education and armed conflict, mainly using quality variables in the form of standardized tests to measure the effect of the armed conflict (Gómez Soler, 2016, 2017; Kibris, 2015). Second, this chapter presents the first research to measure the relationship between armed conflict and educational efficiency. Finally, the armed conflict in neighboring municipalities is incorporated through spatial contagion models.

The fourth empirical chapter offers two main results. The first is the positive effect on the educational efficiency of the *Aula Global* program of up to 9.6%. Second, there is an average positive effect in at least 62.5% of schools by grade. The contributions of this chapter are twofold. First, it is the first empirical application to combine a randomized controlled trial with educational efficiency methodologies to evaluate a specific program. Second, the chapter responds to multiple calls in the literature for empirical evidence on the effect that contributions from private organizations have on educational quality (Rosati & Faria, 2019).

1.7 Synthesis and roadmap of the research

Table 1.6 summarizes the objectives, the methodology, the principal results and the contributions for each of the empirical chapters of this thesis.

Table 1.6. Synthesis of the thesis by chapter

	Chapter 2 **Efficiency and quality in Colombian education: An application of the metafrontier Malmquist-Luenberger productivity index**	**Chapter 3** **The effect of armed conflict on the efficiency of educational quality in Colombia**	**Chapter 4** **Alternative sources of funding and their effects on educational efficiency: the causal impact of the Aula Global program on performance**
Research Objective	To evaluate the change in the productivity of 4,587 schools between the years 2014 and 2017, differentiating between the public and private sectors.	To estimate the potential loss of educational efficiency of 912 municipalities in Colombia due to the armed conflict.	To evaluate the causal impact of the *Aula Global* program on school efficiency, through an innovative procedure that combines literature on impact evaluation and the evaluation of social policies.
Methodology	Metafrontier Malmquist-Luenberger index. This methodology is appropriate to measure productivity while using good and bad outputs in the educational context.	A conditional robust non-parametric approach is applied, incorporating armed conflict as an environmental variable.	First, a randomized control trial is performed; second, a robust non-parametric conditional model and decomposition are applied to separate the effect of the *Aula Global* program; third, a non-parametric regression is performed to determine the significance of the environmental variables.
Main Results	General deterioration of the educational system, both in the public sector (4.14%) and the private sector (16.4%). Productivity behavior is determined to be due to changes in best practices and changes in efficiency. There are significant differences in productivity between departments.	Homicides due to the armed conflict negatively affect educational efficiency. Both the conflict in the municipalities under analysis and that of their neighbors significantly affect the efficiency of educational institutions. Inefficiencies due to the armed conflict are calculated to reach values of up to 33%.	The *Aula Global* program has a positive effect on educational efficiency. An average positive effect is calculated in at least 68% of schools by academic grade.
Main Contributions	The application to the specific problem opens the way to multiple applications in educational policy since it is proposed as a reference point for the delivery of incentives in the public sector and acts as a market signal in the private sector. Responds to calls from the research. First, it considers variables that take into account all dimensions of the educational process. Second, it incorporates both performance and inequality into the educational process.	The intersection between the lines of research on education and armed conflict is developed, using quality variables in the form of standardized tests to measure the effect of the armed conflict. It is the first research that measures the relationship between armed conflict and educational efficiency. In addition, the armed conflict in neighboring municipalities is incorporated through spatial contagion models.	It is the first empirical application where a randomized controlled trial and educational efficiency methodologies are combined to evaluate a specific program. It responds to multiple calls in the literature for empirical evidence on the effect contributions from private organizations have on educational quality.

Source: self-devised

CHAPTER 2

EFFICIENCY AND QUALITY IN EDUCATIONAL ACTIVITY: AN APPLICATION OF THE METAFRONTIER MALMQUIST-LUENBERGER PRODUCTIVITY INDEX

2. Efficiency and quality in educational activity: an application of the metafrontier Malmquist-Luenberger productivity index

2.1. Introduction

Educational efficiency is a topic of intense political, social and academic debate (De Witte & López-Torres, 2017) for various reasons. First, education is considered as the main source of human capital accumulation of a country (Hanushek & Woessmann, 2008). Second, education plays a fundamental role in the redistribution of living conditions in society (Hanushek, 1986). Finally, because educational budgets are high and growing (Eurostat, 2014), it is important to ensure that educational spending is carried out with a high level of efficiency.

Different development plans around the world recognize education as a priority due to the social externalities it presents (McMahon, 2004). Colombia is no exception, as shown by its efforts to close inequality gaps through education. At the local level, the Ministry of National Education (MEN) of Colombia is the institution responsible for managing resources in education, one of the focuses of which is to reduce gaps in access and quality, thus improving the level of human capital and, in turn, promoting economic growth and development (Badunenko, Henderson & Russell, 2013).

The main objective of recent educational policies has been to close social gaps (Hanushek & Kimko, 2000); again, Colombia is no exception. To this end, the *Estimulos a la Calidad Educativa* (Incentives to Educational Quality) incentive system was designed under MEN Decree 501 of 2016, which uses the *Índice de*

Calidad (Quality Index) as a single measurement tool for the granting of stimuli. In turn, this index comprises the Synthetic Index of Educational Quality (ISCE) and the Management Index for Educational Quality (IGCE). The first focuses on the results of the educational process (progress, performance, efficiency and school environment), and the second, on the schools' resources (efficiency in the infrastructure). The application of this index reflects the importance that the government attributes to the efficient management of resources in education, showing that educational quality is being measured from different perspectives (Tsai et al., 2017). However, although the quality index aims to measure the efficiency in both components, it should be noted that there is no input-output logic in its construction.

The educational reform carried out with the implementation of the Quality Index is relevant for the context in which it is developed and for the objective it is intended to achieve; however, the methodology of the index is not robust. The main characteristics that can be improved and that motivate the present study are: first, the components should not have a priori weights within the indicators; second, the conceptualization of efficiency must be underpinned on production theory (Bessent & Bessent, 1980); and finally, there must be a global vision that can have multiple benchmarks for comparison, and not a partial vision through two weighted indexes. It is worth pointing out that estimation of models based on data envelopment analysis methods for the calculation of composite indicators has gained prominence (Greco et al., 2019), among other reasons, to avoid the subjectivity of choosing the weights of the components a priori (Ray, 2008) and to have the possibility of estimating different groups under the same approach (Battese et al., 2004).

The main objective of the study is to evaluate the change in the productivity of 4,587 schools over time, differentiating between public and private sectors. In addition, there are two specific objectives: first, to propose a robust and integrative methodology of the concepts measured partially by the incentive system *Estimulos a la Calidad*; and second, to analyze the change in the efficiency of the education system with the introduction of the ISCE. The analysis takes into account the political–administrative division of Colombia, which is divided into 32 departments and its capital district, to determine if there are differences. This methodology also allows the analysis to consider three different orientations in the results, towards performance, towards inequality, or both at the same time.

The education sector in Colombia is a representative case of a developing economy with high social inequity, where there are large gaps between public and private education (Celis et al., 2012). Therefore, rigorous analysis of the differences between the sectors is important for developing educational policies. The gaps between the public and private sectors are worrisome for two main reasons: first, there is high private spending by households that want to access a better education for their children, which generates strong pressure on their well-being (OECD, 2016). Second, there is evidence that the difference in resources between schools in the public and private sectors is one of the most relevant drivers of gaps (Castro Aristizabal, 2019), which depends mainly on the differences in their funding.

There is a wide gap between the public and private sectors in several regards. On financial grounds, schools in the public sector receive a budget allocation based on the population being served whilst in the private sector, it is purely

based on the demand and purchasing power of the people. On organizational grounds, public sector schools generally have a small workforce; the main reason for this is that the hiring process is handled by the State. Whereas in the private sector, the schools hire their employees directly, enabling them to have much bigger manpower than public schools. Finally, on institutional grounds, with public schools being established even in remote municipalities, ensuring a much wider reach, they suffer a lack of municipal facilities. With private schools being only in the bigger cities, they all, in general, boast a high standard of amenities, owing both to easier access to such resources and their own higher budgets.

One of the main motivations of this study is to use efficiency measures with an input-output logic, and in turn, incorporate inequality in the education system by using undesirable or bad outputs, thus improving the approach used by the government's quality index. Inequality and inequity in education are two problems of constant concern around the world and especially in developing countries. However, this study focuses on inequality as a bad output for various reasons. First, it is a relevant topic of constant debate that is attracting increasing interest in the literature (Josa & Aguado, 2020). Second, it is a problem in which schools play a fundamental role, for example, by running additional classes or by grouping students according to levels (Agasisti & Falzetti, 2017). And finally, the effects of inequality are not only localized, but are also externalized and affect the whole economic system (CEPAL, 2018).

Educational efficiency has gained relevance in the measurement of different problems (De Witte & López-Torres, 2017), among which the temporal evolution of educational productivity is highlighted (Aparicio et al., 2017; Essid et al., 2014). Three studies have focused on measuring changes in educational productivity by

incorporating desirable and undesirable outputs (Ben Yahia et al., 2018; Giménez, et al., 2017; 2019). Tsai et al. (2017) state that the correct evaluation of the productivity of an education system must consider both outputs (good and bad) while controlling the inputs and environmental variables. As far as we are aware, no evaluation has these characteristics, nor considers the differences between groups (public and private). As this paper offers an initial approach, it is therefore relevant to all contexts, but even more so for Colombia due to the large inequality gaps and the country's demonstrated interest in education policy.

To carry out this approach, we use the Metafrontier Malmquist Luenberger (MML) index developed by Oh (2010a) because it helps to incorporate a temporal dimension in the analysis while considering good and bad outputs in the process. Additionally, Directional Distance Functions (DDF) are applied since they allow efficiency to be measured by improving the academic average while reducing the variance of the results. This paper analyzes the changes in the productivity of 4,587 schools through the result in the standardized exams of senior high-school students who participated in 2014 and 2017. This period is relevant to analyze the evolution of productivity due to the change in the regulations related to the *Índice de Calidad*, which proposes incentives to schools in matters of management and budget, and acts as a market signal.

The contribution of this work is threefold. First, it opens the way for multiple applications in educational policy, since it is proposed as a benchmark for delivering incentives in the public sector, and it acts as a market signal in the private sector. Second, it responds to calls for research related to educational efficiency which applies variables that take into account all the dimensions of standardized tests (Hauser, 2009), and incorporates both performance and

inequality in the educational process (Tsai et al., 2017). Third, comparing the application employed in this study with other similar studies in the literature (Ben Yahia et al., 2018; Giménez, et al., 2017; 2019), the Saber11 database is used instead of TIMSS (Trends in International Mathematics and Science Study) to measure the outputs of the process, and the C600 (census of schools in Colombia) provided by the DANE is used for the inputs. It is the first application of the Metafrontier Malmquist Luenberger index for a specific education system that applies partial frontiers for different sectors.

The results show, on average, better performance change in the public than the private sector, although there is a general deterioration in the education system regardless of the orientation used. The public sector has a better performance change when there is an orientation towards equality (bad outputs), driven mainly by the change in efficiency. Additionally, departments show different approaches to working on educational performance, and present results that vary significantly.

The study is organized into five sections. This introduction is followed by the literature review (Section 2). The methodological aspects of the MML index and its decomposition are then described (Section 3), after which the databases used in the education system evaluation process are presented, the variables are explained, and the main results are reported (Section 4). Finally, the main conclusions are detailed (Section 5).

2.2. Literature review

The study of efficiency of schools was strongly motivated by the Coleman report, which highlighted the lack of participation of educational institutions in the

struggle for equal opportunities in the United States (Coleman et al., 1966). This research line has been approached from different perspectives (Thieme, Prior, Giménez & Tortosa-Ausina, 2011). In this study, we take the public economics perspective, where emphasis is placed on technical efficiency, generally through a non-parametric approach, and the units evaluated are compared with their peers according to the levels of inputs and outputs, mainly using non-parametric frontier models.

The non-parametric approach is highlighted for the major advantages it has over the other methods used in the literature. First, it is less vulnerable to specification problems that affect econometric models (Sinuany-Stern et al., 1994). Second, it is not necessary to define assumptions about the distribution of errors and the production function (Worthington, 2001). And third, multiple inputs and outputs can be used (Thieme et al., 2013), which for the objective of this study is fundamental, since it takes into account performance and inequality at the same time. In addition, in the field of educational efficiency, non-parametric methods have been the most frequently applied in the literature (De Witte & López-Torres, 2017).

Within the line of public economics, the Malmquist index has been used to analyze temporary changes in productivity (Giménez et al., 2017; Portela et al., 2013; Thanassoulis et al., 2011), which can be split in two components: technological change and change in efficiency. Alternatively, the Hicks-Moorsteen index (Aparicio et al., 2018) has also been used with an approach based on performance and total factor productivity ratios. Studies addressing the evolution of productivity using the Malmquist index (Caves et al., 1982) have applied methodological complements that enhance the scope; for example, by

using Directional Distance Functions (DDF) (Chung, Färe & Grosskopf, 1997) efficiency can be measured with multiple approaches and flexible orientations. Moreover, the use of metafrontiers (Cordero et al., 2016; Thieme et al., 2013), based on the approach of Battese et al. (2004), allows decompositions of different categories (Thieme et., 2013) and analyzes different groups or technologies (De la Torre et al., 2017) in the same context.

In this study, the Metafrontier Malmquist Luenberger (MML) index developed by Oh (2010a) is adopted, since it incorporates a temporal dimension in the analysis while considering the good and bad outputs of the process, and in turn, it focuses on metafrontiers. To date, only Ben Yahia et al. (2018) and Giménez, et al. (2017; 2019) have measured changes in educational productivity considering good and bad outputs, all of which prioritize the educational quality orientation. However, the authors are unaware of any other applications of the MML approach to the education sector, making this study an innovation in this field.

Although the MML has not been applied to the education sector, similar studies have been undertaken. In the first, Giménez et al. (2017) used a global (non-radial) Malmquist index to measure the change in the productivity of 29 education systems from 2003 to 2012, considering as variables the results of mathematics and reading and their standard deviation. Subsequently, Ben Yahia et al. (2018) conducted research using DDF to work with bad outputs and non-discretionary inputs, based on a sample of Tunisian schools in 2012. Finally, Giménez et al. (2019) used TIMSS data for 28 countries in an efficiency analysis from 2007 to 2011 with a global Malmquist-Luenberger model due to the presence of bad outputs. These authors conclude that although there are large differences

between countries, on average educational performance declined during those years.

The quality of an education system does not depend exclusively on academic performance. For this reason, the present study highlights not only educational achievement but also equality in the education process. Tsai et al. (2017) frame two objectives as a golden rule in educational policy: excellence (high performance) and equality (low variability in performance) in the results. The first objective has been thoroughly studied in the literature (Johnes & Johnes, 2004), for example, to find its determinants (Hauser, 2009), the role of environmental variables (López-Torres & Prior, 2016) and the differences between education systems (Parteka & Wolszczak-Derlacz, 2013). Additionally, most transnational studies that examine performance consider each area of interest separately (Hanushek & Woessmann, 2008). However, it is desirable to have composite measures of academic performance to produce more reliable studies (Hauser, 2009).

The second objective, equality, has been analyzed in terms of the role of education systems in the standardization of opportunities (Jackson et al., 2012). Equality in educational processes has often been measured through the total variance of academic performance (Huang, 2009). However, how to measure and treat inequality among students within an educational system is a topic discussed in the literature (Betts & Shkolnik, 2000), which has been debated in many countries, with positions between a selective system (for example, Germany, Hungary, Austria) or a comprehensive system (for example, Japan, Canada, Norway) (Hanushek & Ludger, 2006). The main policies have focused on early follow-up of students (Dupriez et al., 2008; Hanushek & Woessmann,

2008), grouping of skills and/or Gperformance in the classroom (Hindriks et al. 2010) and individualized support (Ferrer-Esteban, 2016). In general, those in favor of homogenizing classes affirm an increase in efficiency, and those who are not in favor affirm that the level of low ability students is affected because of lowered expectations and self-esteem due, among other reasons, to the peer group effect (Betts & Shkolnik, 2000).

Based on the above, although there are different positions in the literature regarding student inequality, the present study takes it into account in terms of the standard deviation of students, mainly because it is a measure that can be used for different types of standardized tests (Phillips & Chin, 2004), and because it is a proxy of other measures used in previous studies (Huang, 2009). Also, the model jointly evaluates excellence and inequality, in pursuit of aspects of improvement based on the available inputs, following the quality education goal in the 2030 Agenda for Sustainable Development, which commits to “providing inclusive and equitable quality education and promoting lifelong learning opportunities for all” (UNDP & UNESCO, 2015)”

This paper proposes an approximation through the MML index, which responds to calls in the literature by prioritizing both the performance and the equality of the process, taking into account the differences between the types of schools, and considering composite measures that integrate all areas evaluated and their standard deviation. The present study is therefore the first approach of this type in this research field.

2.3. Methodology

The first part of this section explains the DDF, which are necessary to estimate the MML index. The second part presents the evolution of productivity measurement indices in general and explains the MML index model.

2.3.1. Directional distance functions

The technology that models the set of production possibilities assumes *K* groups *(k = 1,2..., K)* for *T* periods of time *(t = 1, 2...., T)*. A set of inputs and outputs is used in the process: the vector of inputs is $x = (x_1, \ldots, x_N) \in R_+^N$ and the outputs are distinguished between desirable $y = (y_1, \ldots, y_M) \in R_+^M$ and undesirable $b = (b_1, \ldots, b_J) \in R_+^J$. The set of production possibilities meets the following axioms (Färe et al., 2005):

$$P(X) = \{y, b \mid x\ can\ produce\ (y, b), x \in R_+^N\} \quad \textbf{(1)}$$

$$if\ (y, b) \in P(x) \mid y' < y, then\ (y', b) \in P(x) \quad \textbf{(2)}$$

$$if\ (y, b) \in P(x) \mid b = 0, then\ y = 0 \quad \textbf{(3)}$$

$$if\ (y, b) \in P(x) \mid 0 \leq \emptyset \leq 1, then\ (\tfrac{1}{\emptyset} y, \emptyset b) \in P(x) \quad \textbf{(4)}$$

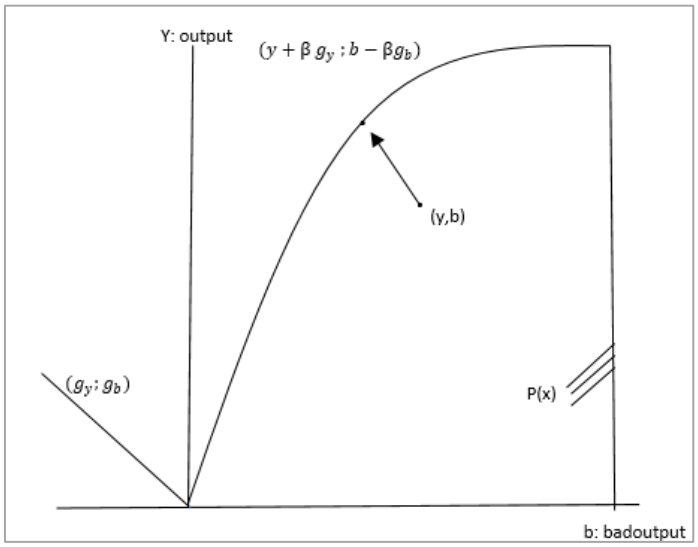
$$if\ (y, b) \in P(x) \mid (y', b') \leq (y, b), then\ (y', b') \in P(x) \quad \textbf{(4.1)}$$

The first axiom suggests that the set of outputs is strongly disposable, while the set of bad outputs is only weakly disposable; this means that there are no additional costs to reduce the production of desirable outputs, but the reduction of undesirable outputs can require more input consumption or, alternatively, the reduction of good outputs. The second, known as 'null-jointness', indicates that Decision Making Units (DMUs) cannot produce the desirable output without producing the undesirable output. The third axiom shows that bad outputs are

weakly disposable, indicating that minimizing this type of output is expensive. The fourth states that it is feasible to reduce the set of good outputs while increasing the bad outputs proportionally by Ø; note that this axiom must be contrasted with equation (4.1) since it allows a non-proportional reduction of good and bad outputs.

To estimate the DDF used by the MML index, parametric and non-parametric frontier models can be applied. In this study we chose the non-parametric approach because it does not require the assumption of a functional form, nor a specific distribution of the error term (Thieme et al., 2013). It also allows us to work with multiple sets of inputs and outputs without having to assume factor prices, which is appropriate and applicable to the education sector, since they are unknown or difficult to estimate (De Witte & López-Torres, 2017).

Figure 2.1 Directional Distance Function



Source: (Picazo-Tadeo & Prior, 2009; Choi et al., 2015).

The main idea of the DDF, as can be seen in Figure 2.1, is to maximize the desirable outputs while minimizing the undesirable ones by maintaining or

reducing the level of inputs used. The mathematical expression of the DDF is as follows:

$$D(x, y, b; g) = \max\left\{\beta \mid \left(y + \beta g_y, b - \beta g_b\right) \in P(x)\right\} \quad \textbf{(5)}$$

where $g = (g_y, g_b)$ is a directional vector, which indicates the direction of approach to the frontier. Following Chung, Färe and Grosskopf (1997), and if $g = (y, b)$, the DDF can be rewritten as follows:

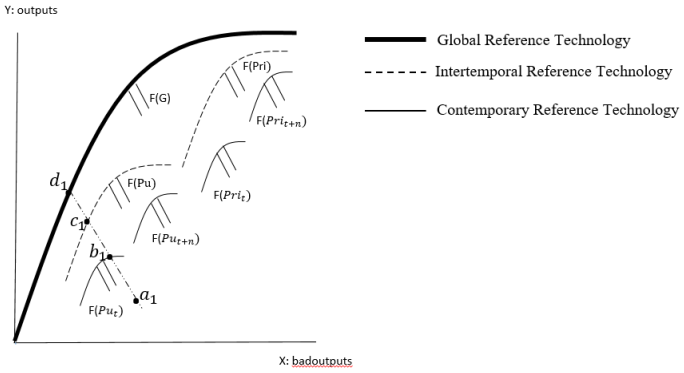
$$D(x, y, b; g) = \max\{\beta : \left((1 + \beta)y, (1 - \beta)b\right) \in P(x)\} \quad \textbf{(6)}$$

In the previous expression, the utility of the DDF can be analyzed, where the objective is to increase the desirable outputs *(y)* in a *β* proportion while reducing the undesirable outputs *(b)* in the same proportion.

2.3.2. Temporary productivity analysis

Changes in productivity have been quantified in the literature using the Malmquist Index, introduced by Caves et al. (1982), in a parametric framework. This index attributes the changes in productivity to two components: the change in efficiency (or catching up) and the technological change. The first refers to how the units have approached or moved away from the contemporary production frontier during the analyzed period, while the second quantifies how it has moved. Thus, the first of the components is the effect attributable to the capacity for management, organization, and coordination, and the second is related to the capacity for innovation (Luo et al., 2017).

Figure 2.2 MML productivity index diagram



Source: Han et al. (2018)

Source: Han et al. (2018)

The MML index arose from the Malmquist Luenberger (ML) index (Chung et al., 1997) and Oh's developments (2010a, 2010b). The ML evaluates changes in productivity when bad outputs are incorporated into the production function (Färe et al., 2005). Later, based on the ML, Oh (2010b) proposed the Global Malmquist Luenberger (GML), which focuses on comparing observations against a single global frontier, and finally, Oh (2010a) adapted the GML to the use of metafrontiers (Battese et al., 2004).

Figure 2.2 shows the MML index and its components with two years and two groups. The intertemporal reference technology is the envelope (metafrontiers) of contemporary technology and the global reference technology is the envelope of the intertemporal reference technology. In an intuitive way, the relationship between the distances of the figure for the public sector is explained as an example. For the present study, the contemporary reference (*F (Put)*) is the closest reference against which each school in a specific group and year is compared (public schools in period *t*). The intertemporal reference technology (*F (Pu)*) is the metafrontier that considers all the contemporary boundaries of a

specific group (for example, public schools). Finally, the global reference technology (*F(G)*) is the metafrontier that includes all the groups and years under study (public and private schools in periods *t* and *t* + *4*).

In other words, figure 2.2 shows the distances between frontiers. The distance between points a_1 and b_1 shows the inefficiencies (change in efficiency) of a public school with respect to similar ones in the same sector in year t (contemporary frontier). In this sense, the distance between points a_1 and c_1 shows the inefficiencies (Best Practice Change) of a public school with respect to similar ones in the same sector in all available years (intertemporal frontier). Finally, the distance between points a_1 and d_1 shows the inefficiency (Change in Technology Gap) between a public school and all schools (public and private sector) in all available years (global frontier).

To define the index and its decomposition, it must be considered that there are three types of possible references: technological, intertemporal and global (Tulkens & Vanden Eeckaut, 1995). Oh (2010a) defines the MML productivity index as follows:

$$MML^{t;t+1}(x^t, y^t, b^t, x^{t+1}, y^{t+1}, b^{t+1}) = \frac{1 + D^G(x^t, y^t, b^t)}{1 + D^G(x^{t+1}, y^{t+1}, b^{t+1})} \qquad (7)$$

$$= \frac{1 + D^t(x^t, y^t, b^t)}{1 + D^{t+1}(x^{t+1}, y^{t+1}, b^{t+1})}$$

$$\times \frac{(1 + D^I(x^t, y^t, b^t))/(1 + D^t(x^t, y^t, b^t))}{(1 + D^I(x^{t+1}, y^{t+1}, b^{t+1}))/(1 + D^{t+1}(x^{t+1}, y^{t+1}, b^{t+1}))}$$

$$\times \frac{(1 + D^G(x^t, y^t, b^t))/(1 + D^I(x^t, y^t, b^t))}{(1 + D^G(x^{t+1}, y^{t+1}, b^{t+1}))/(1 + D^I(x^{t+1}, y^{t+1}, b^{t+1}))} \qquad (8)$$

$$MML^{t;t+1}(x^t, y^t, b^t, x^{t+1}, y^{t+1}, b^{t+1}) = \frac{TE^{t+1}}{TE^t} \times \frac{BPR^{t+1}}{BPR^t} \times \frac{TGR^{t+1}}{TGR^t} \qquad (9)$$

$$MML^{t;t+1}(x^t, y^t, b^t, x^{t+1}, y^{t+1}, b^{t+1}) = EC \times BPC \times TGC \quad (\mathbf{10})$$

Following Oh's (2010a) proposal, it should be taken into account that the distances (D) shown in the previous equations (7, 8) are the DDF explained in the previous section, where a comparison is made with a global (D^G), an intertemporal (D^I) and a contemporary (D^t) frontier. Additionally, Oh (2010b) proposes decomposing the MML index into three components: the first is the Change in Efficiency (EC), the second is the Change in the Best Practices gap (BPC) and the third, the Change in Technology Gap (TGC). If the MML index is greater than unity, it indicates a positive change in productivity between periods *t* and *t + 1*; in other words, the distance to the global frontier is less in the period *t + 1* than in the period *t*. An MML index value less than unity is a deterioration in the productivity of the units evaluated.

If EC is greater than unity, it shows an improvement in efficiency, which is the measure of recovery of technical efficiency within a group during the added period, indicating how fast a DMU moves towards the reference technology. Referring to the second component, BPC measures the change between the best contemporary reference technology and intertemporal technology: when BPC is greater than unity, it indicates that the contemporary approaches the intertemporal frontier. Finally, TGC is the technical gap between the frontier of intertemporal reference technology in moment *t* and the global frontier reference in moment *t +1*. When TGC is greater than unity, it indicates a narrowing of the global technology gap from the frontier of a specific group.

The DDF can be calculated from different types of frontier models, following different programming systems $D^{\rightarrow G}(x^w, y^w, b^w)$, $D^{\rightarrow I}(x^w, y^w, b^w)$,

$D^{\rightarrow w}(x^w, y^w, b^w)$ where *w = t* and *t+1*. We chose to calculate the DDF with DEA type models because it avoids the need to assume a functional form for the production function a priori and it is possible to work with a combination of multiple inputs and outputs. To calculate these distance functions using DEA type models, the following optimization program must be solved (Choi et al., 2015; Oh, 2010b):

$$D^d\left(x^{k'w}, y^{k'w}, b^{k'w}\right) = \max \beta \quad \textbf{(11)}$$

s.t.

$$\sum \lambda^{k,w} y_m^{k,w} \geq (1 + \beta) y_m^{k',w}, \quad m = 1, \ldots M. \quad \textbf{(12)}$$

$$\sum \lambda^{k,w} b_j^{k,w} \leq (1 - \beta) b_j^{k',w}, \quad j = 1, \ldots J. \quad \textbf{(13)}$$

$$\sum \lambda^{k,w} x_n^{k,w} \leq x_n^{k',w}, \quad n = 1, \ldots N. \quad \textbf{(14)}$$

$$\lambda^{k,w} \geq 0 \quad \textbf{(15)}$$

The superscript *d* in the objective function is intended to identify the type of directional function since it can be contemporary, intertemporal or global. A vector $\lambda^{k,w}$ appears in the restrictions; this vector shows the intensity to construct the restriction, where *k* indicates the education sector. The estimation of the DDF through a DEA is an optimal solution for the calculation and decomposition of the index, where a *β* coefficient is obtained, which is interpreted as the simultaneous increase (decrease) that can be achieved in the good (bad) outputs, given the input consumption.

The next section presents the empirical study, and describes the variables and sources used in the analysis. The main results and decomposition are also shown according to the multiple directions offered by the index.

2.4. Empirical study: data and results

This section describes the data used in the model. It is focus on the variables and sources used for the analysis.

2.4.1. Sample and variables

To calculate the efficiency of the schools, a database was built from two sources. The first is the National Administrative Department of Statistics (DANE), which conducts the official census of all the country's schools. The second is the Colombian Institute for the Promotion of Higher Education (ICFES), responsible for conducting standardized tests. DANE, through the C600 census, offers information on the resources (teachers, principals, electronic) of all schools in the country, along with sector and educational level categorization.

The ICFES offers information based on multiple standardized tests, including Saber 3 and 5 (primary), Saber 9 (secondary), Saber 11 (high school), Saber TyT (technical and technological education – intermediate careers), and Saber Pro (university). The data here is categorized based on the level of education and competencies achieved. In this study, we use Saber 11 as it offers information from the standardized tests, the socio-economic context of the students and their families, and also some general variables of the school. University admissions are also determined based on Saber 11 scores, and hence this is one of the principals in the educational process.

The study considers 4,587 schools participating in Saber 11[12] (standardized test) in the years 2014 and 2017.These are the schools for which complete information

[12] Students who drop out in the educational process have not been taken into account in the estimation of efficiency.

is available in all the variables during the years of study. The sample is 75.5% from the public sector and 24.5% from the private sector.

Based on the literature review, and in accordance with the proposal in the methodological section, this study uses seven variables: one good output, one bad output, and five inputs. The good output is the sum of the generalized global score for the school (Thieme et al., 2013; Cordero et al., 2016; Giménez, et al., 2017; 2019; Ben Yahia et al., 2018; Tavana et al., 2018). The global score is the weighted average[13] of the individual scores of each of the tests that students take in the exam, divided into the total weighting (13) and multiplied by the number of tests (5). To generalize the variable at the school level, since the inputs are at this level, the sum of the global score is divided into the number of students who took the exam and multiplied by the total enrollment of the school.

The bad output, following the scale with which the global score is built, is the standard deviation of the generalized global score for schools. To date, equality in educational processes has been measured through the total variance of academic performance (Huang, 2009), whereas other approaches have used the percentage of students who do not reach minimum scores on standardized tests (Giménez et al., 2017, 2019). However, standard deviation is used because it is a measure that can be applied for different types of standardized tests (Phillips & Chin, 2004), and according to the literature, having homogeneous groups

[13] A weighted average is used (three points each for mathematics, reading, social studies and natural sciences and one for English language) for two reasons: first, the literature recommends using multiple areas of study (Hauser, 2009) and not just math and/or language, as is common; and second, because it is the measure used for admission to higher education and for the design of educational policies in Colombia. In addition, the weights of the areas are defined by the ICFES and are therefore maintained, mainly because one of the largest gaps between public and private education in Colombia is in the area of English and the global score smooths it out.

improves efficiency, which is the objective of the analysis of this study (Betts & Shkolnik, 2000).

The five inputs used are frequent in the literature (De Witte & López-Torres, 2017): the amount of electronic equipment, number of teachers working as managers, number of teachers in classrooms, number of students enrolled, and the average socioeconomic and cultural level of the school as an environmental variable. Electronic equipment is quantified as all desktops or laptops and tablets available and in use (Agasisti, 2011; Mancebón et al., 2012).

The next two inputs are the number of teachers in managerial roles and teachers in classrooms. The first one is used as a proxy for variables commonly used in the literature such as managers or administrative staff (Brennan et al., 2014; Grosskopf & Moutray, 2001; Haelermans & Ruggiero, 2013), and the second is teachers in classrooms (Aparicio et al., 2017; Cordero et al., 2017; López-Torres et al., 2017; Tran & Villano, 2018), whose main function is teaching. These two variables are included to represent the human capital of the school, mainly due to the different functions of the two roles. The fourth input refers to the number of students enrolled in the school (Crespo-Cebada et al., 2014; Podinovski et al., 2014).

Finally, there is a debate in the literature about how to include the socioeconomic index of the students in the estimations, where some authors use it as an input and others as an environmental variable. However, despite this debate, most scholars use it as input (Cordero et al., 2018; Cordero et al., 2017; Giménez et al., 2017; Thieme et al., 2013). On the other hand, the methodological relevance of the conditional models is recognized as having opened up the possibility of adopting the socioeconomic index as an environmental variable; however, even

so, some authors treat this variable as an input when using conditional models (Cordero et al., 2018). In this article, as in other research, the socioeconomic index is included as an input, since the evaluation is focused on the capacity of schools to make the most of the inputs (Bradley et al., 2001; Camanho et al., 2009; Cordero et al., 2017). In addition, because the databases do not offer the index, following Thieme et al. (2013), this is defined as an estimated latent variable through a multiple correspondence analysis, considering the educational level of parents and the socioeconomic level of the household. All the goodness of fit statistics yield results according to the calculation of the indicator.

Table 2.1 reports a summary of descriptive statistics for the variables used. The overall score shows an average decrease of 1.16%, and its standard deviation reflects a growth of 5.41%. It should be noted that statistics show an inverse behavior to the ideal in the educational process. The inputs have the following behavior: electronic equipment and teachers in classrooms increase on an average by 97.27% and 0.51%, respectively. The total enrollment of students, the number of teachers in management roles and the socioeconomic and cultural index show respective average decreases of 3.72%, 1.71%, and 1.59%. Looking at the growth rate of the socioeconomic and cultural index, the wide gap between the public (48.61%) and private (-13.5%) sectors stands out. This might be a result of the ever-growing social inequalities between the regions as well as with them, along with mobility differences between educational sectors.

Due to the considerable heterogeneities in access to and quality of education among Columbia's 33 departments and educational sectors (public/private), as discussed in the previous chapter, the results are presented with this disaggregation. The average global score for the private sector shows a growth

rate of 1.28%. Bad output shows positive behavior in the private sector and negative behavior in the private one.

Table 2.1. Descriptive statistics of inputs and outputs

Variables	Year	Average	Standard deviation	Private	Public
Output					
y_1: global score	2014	202,410	174,972	157,323	217,182
	2017	200,059	172,283	159,337	213,277
y_2: standard deviation of the global score	2014	474.28	304.14	557	447
	2017	499.95	275.68	552	483
Input					
x_1: electronic equipment	2014	79.88	78.65	53.62	88.49
	2017	157.58	185.06	58.32	189.8
x_2: enrollment of school	2014	798.19	670.16	553.14	878.48
	2017	768.46	639.71	540.83	842.34
x_3: teachers in management roles	2014	2.93	1.95	3.33	2.8
	2017	2.88	1.72	3.11	2.81
x_4: teachers	2014	31.64	22.90	27.57	32.97
	2017	31.8	22.63	27.84	33.08
x_5: socio-economic and cultural index	2014	5.04	0.85	3.97	5.39
	2017	4.96	0.73	5.9	4.66

Source: self-devised.

The inputs show different behaviors according to education sector. For example, electronic equipment had a growth rate of 114% in the public sector and 8.77% in the private. The teaching staff presented a relatively stable trend in both sectors, except for teachers in management roles in the private sector (-6.61%). Overall, the socioeconomic and cultural conditions of the students improved significantly: average growth for private schools was 48.61%, whereas these conditions deteriorated by 13.54% in the public schools. In next section, the inputs and outputs are used to estimate the Metafrontier Malmquist Luenberger index. The results are presented by component and educational sector.

2.5. Results

The results section presents the analysis of educational efficiency[14] for Colombia at the departmental level and by education sector from two points of view: first, a static analysis through a DEA to provide an initial reference point. And second, a temporary analysis of productivity, which focuses on the evolution over time.

2.5.1. Static efficiency analysis

The static analysis was carried out through a DDF and DEA described in the methodological section for the years 2014 and 2017, disaggregated by education sector and type of orientation. The analysis was performed for all departments of Colombia according to education sector and considering alternative orientations (good and bad output, bad output and, finally, good output). Evaluating different orientations enables us to contrast traditional policy approaches (performance) against some alternative ones based on inequality (good and bad outputs simultaneously). The foregoing is to disaggregate the departments of Colombia and achieve more relevant policy recommendations based on the territory and its current scenario.

The DEA estimation in the static analysis shows high variability in the results among the education sectors, types of orientation, and departments at different times. For example, in 2014 Casanare is the most efficient department when it has an orientation towards good and bad outputs simultaneously, with a coefficient of 0.1026, which means that good outputs can be increased by 10.26%

[14] Before the estimation, a procedure was carried out to detect the extreme values and outliers using, among other methods, super efficiency (Wilson, 1993) and a multivariate method, bacon (Weber, 2010), after which the estimation was performed without these extreme values.

while bad outputs are decreased in the same proportion while maintaining the level of inputs.

As we see in Table 2.2, the static analysis on average shows higher levels of inefficiency in the public than in the private sector. Following the orientation towards good and bad output simultaneously, the public sector presents potential improvements of 0.2101 and 0.2079 in 2014 and 2017, respectively, and the private sector presents values of 0.1969 and 0.1562, showing better performance at 1.32% and 5.16%. The estimate towards bad output shows inefficiencies of 0.6549 and 0.5715 in the private sector and 0.6754 and 0.6613 in the public sector for the years 2014 and 2017, respectively; these results reveal gaps of 2.06% and 8.98%, respectively. Finally, the estimate with a good output orientation shows inefficiencies of 0.2121 and 0.1618 for the private sector and 0.2227 and 0.2169 for the public sector, highlighting gaps of 1.05% and 5.51%. In summary, three results are evident in the education system. First, the private sector is more efficient in both 2014 and 2017. Second, the gaps between sectors widen in this period. And third when the focus is on performance (good output) and equality (bad output) simultaneously, inefficiency values are lower.

Table 2.2. Static analysis of educational (in)efficiency with different orientations between 2014 and 2017

Orientation	Year	Private	Public
Good and bad outputs	**2014**	0.1969***	0.2101***
	2017	0.1562***	0.2079***
Bad outputs	**2014**	0.6549***	0.6754***
	2017	0.5715***	0.6613***
Good outputs	**2014**	0.2121***	0.2227***
	2017	0.1618***	0.2169***

* 10%
** 5%
*** 1%
Source: self-devised

Table 2.3 shows the results at the departmental level, there are considerable differences in the results. In the private sector with simultaneous orientation towards good and bad outputs, the most efficient department (Casanare) has a value of 0.1026 and the least efficient (Putumayo), a value of 0.4514, showing a 35% gap in 2014 compared to the 23% gap for 2017 in the public sector. Following the orientation towards bad outputs and good outputs, the gaps in 2014 and 2017 are 39% and 41%, and 38% and 24%, respectively. Finally, the Li test (1996) is used to check whether there is a significant difference between the general distributions of the results (it is used to compare all the results calculated in this thesis). This nonparametric statistical test compares two unknown distributions using kernel densities. Its main advantage is that unlike most statistical tests, the Li test is not based on comparisons of means or medians, but compares two complete distributions against each other.

The results of this static analysis provide an initial overview of the efficiency of the Colombian education system in two moments, and show the heterogeneity and the diverse patterns between the departments and types of orientation. In general, the sensitivity analysis carried out when considering the multiple orientations helps to conclude that the differences between the first (good and bad outputs) and third (good outputs) orientations are marginal; when compared to the differences between the first (good and bad outputs) and the second (bad outputs) orientation. This may be due, to the fact that educational systems do not include a focus on reducing inequality (second orientation) directly as an educational policy, or alternatively, it is something that is just beginning to take on relevance.

Table 2.3. Static analysis through a DDF and DEA for the years 2014 and 2017, disaggregated by sector and type of orientation.

Sector	**Private**						**Public**					
Orientation	***Good and bad outputs***		***Bad outputs***		***Good outputs***		***Good and bad outputs***		***Bad outputs***		***Good outputs***	
Departments/year	**2014**	**2017**	**2014**	**2017**	**2014**	**2017**	**2014**	**2017**	**2014**	**2017**	**2014**	**2017**
Amazonas	0.1876	0.0438	0.7898	0.5743	0.1876	0.0440	0.3277	0.2448	0.8186	0.7804	0.3393	0.2497
Antioquia	0.1546	0.1426	0.6323	0.5013	0.1989	0.1428	0.2049	0.2025	0.7095	0.6737	0.2222	0.2031
Arauca	0.2208	0.1661	0.8154	0.8250	0.2238	0.1669	0.2182	0.1817	0.7735	0.7690	0.2247	0.1850
Archipiélago de San Andrés	0.2505	0.2632	0.7965	0.6923	0.2710	0.2680	0.2629	0.3717	0.6845	0.8024	0.2833	0.3813
Atlántico	0.2015	0.1428	0.6299	0.5769	0.2135	0.1333	0.2162	0.1922	0.6329	0.6190	0.2117	0.1916
Bogotá, D.C	0.1711	0.1434	0.6034	0.4615	0.1822	0.1526	0.1656	0.1549	0.5507	0.5703	0.1758	0.1681
Bolívar	0.1920	0.1974	0.6645	0.6651	0.1997	0.2100	0.2563	0.2697	0.6984	0.6925	0.2716	0.2893
Boyacá	0.1821	0.1365	0.6389	0.5834	0.1891	0.1442	0.2083	0.1774	0.7004	0.6798	0.2166	0.1872
Caldas	0.1980	0.1545	0.6257	0.5519	0.2107	0.1651	0.2199	0.2285	0.6491	0.6677	0.2393	0.2427
Caquetá	0.1599	0.1413	0.8149	0.7483	0.1622	0.1413	0.2503	0.2515	0.7539	0.7084	0.2609	0.2669
Casanare	0.1026	0.0810	0.6506	0.6678	0.1032	0.0830	0.2186	0.2146	0.7478	0.7455	0.2266	0.2211
Cauca	0.2606	0.2435	0.5275	0.6826	0.2817	0.2548	0.2197	0.3112	0.6322	0.7620	0.2309	0.3236
Cesar	0.3074	0.2517	0.6646	0.6713	0.3490	0.2706	0.2671	0.2433	0.7039	0.5719	0.2905	0.2562
Chocó							0.3390	0.3420	0.7370	0.6648	0.3633	0.3766
Córdoba	0.1659	0.1455	0.5058	0.6847	0.1879	0.1503	0.2615	0.2856	0.7415	0.7891	0.2760	0.2946
Cundinamarca	0.2034	0.1628	0.6648	0.6137	0.2165	0.1742	0.2123	0.1992	0.6907	0.6714	0.2243	0.2106
Guainía							0.2122	0.1390	0.8194	0.7628	0.2171	0.1390
Guaviare	0.2787	0.2716	0.8936	0.8742	0.2828	0.2716	0.1863	0.2387	0.7766	0.7416	0.1938	0.2454
Huila	0.2494	0.1616	0.7444	0.6718	0.2540	0.1646	0.2369	0.2006	0.6930	0.6396	0.2531	0.2154
La Guajira	0.2048	0.2231	0.7645	0.7378	0.2112	0.2239	0.2445	0.2944	0.7221	0.7379	0.2607	0.3085
Magdalena	0.3023	0.2761	0.6873	0.7244	0.3243	0.2819	0.3071	0.3286	0.7345	0.7654	0.3262	0.3491
Meta	0.1890	0.1208	0.7644	0.6847	0.1910	0.1236	0.1951	0.1904	0.7198	0.7286	0.2025	0.1973
Nariño	0.2375	0.2054	0.6775	0.6770	0.2532	0.2137	0.1738	0.1706	0.6544	0.4602	0.1802	0.1761
Norte de Santander	0.2165	0.1275	0.6769	0.5660	0.2317	0.1334	0.2008	0.1408	0.6981	0.5541	0.2113	0.1469
Putumayo	0.4514	0.0502	0.7828	0.4973	0.4796	0.0502	0.2176	0.2107	0.6957	0.6761	0.2353	0.2225
Quindío	0.2371	0.1452	0.6777	0.7321	0.2484	0.1460	0.1605	0.2403	0.6450	0.7468	0.2296	0.2513
Risaralda	0.2020	0.1565	0.6475	0.6830	0.2121	0.1588	0.2168	0.2324	0.6872	0.7463	0.2279	0.2393
Santander	0.1672	0.1071	0.7037	0.6587	0.1716	0.1095	0.1727	0.1599	0.7105	0.7006	0.1783	0.1641
Sucre	0.2133	0.1708	0.7044	0.6054	0.2220	0.1771	0.2360	0.2456	0.6949	0.7413	0.2506	0.2567
Tolima	0.2601	0.1892	0.7147	0.6329	0.2690	0.1987	0.2443	0.2548	0.7168	0.7021	0.2552	0.2679
Valle del Cauca	0.2586	0.2218	0.7587	0.6442	0.2708	0.2374	0.1961	0.2206	0.6618	0.6475	0.2096	0.2371
Vaupés							0.3687	0.3597	0.8387	0.8236	0.3847	0.3614
Vichada							0.3129	0.3218	0.8389	0.8020	0.3170	0.3257
Geometric mean	0.1969	0.1562	0.6549	0.5715	0.2121	0.1618	0.2101	0.2079	0.6754	0.6613	0.2227	0.2169

Source: self-devise

2.5.2. Temporary analysis of educational efficiency

Temporary analysis is carried out through a MML index described in the methodology section for the years 2014 and 2017, disaggregated by education sector and type of orientation. Table 2.4 shows the results of the scores for the Metafrontier Malmquist Luenberger index and its decomposition for all departments of Colombia according to education sector. Table 2.7 shows the summary of applying the MML with three orientations. First, following the orientation g = (y, b); that is, it aims to increase the desirable outputs (y) by percentage β and reduce the undesirable outputs (b) in the same proportion. Second, with orientation g = (0, b); in this case, the objective is to minimize the bad outputs without considering the desirable outputs. Finally, the results with the orientation g = (y, 0), where the objective is to maximize good outputs, and bad outputs are not considered.

Table 2.4 shows the results of the estimation of the MML index and its components with a simultaneous orientation towards good output and bad output. Changes in productivity are positive when the coefficients are greater than unity and negative when lower values are obtained. The aggregate results offer an overview of the whole system, although the analysis is broken down at the departmental level for a more detailed analysis. The education system, in general, shows a decrease in productivity of 4.14% (column 4) in the private sector and 1.55% (column 8) in the public sector, the latter showing a better performance by 2.59%. The behavior in the private sector is mainly driven by a decrease in the BPC and TGC of 4.54% (column 2) and 3.20% (column 3) respectively, offset by an EC improvement of 3.74% (column 1). In the public

sector, the behavior of the TGC (0.91%), the BPC (0.42%) and the EC (0.23 deteriorates in all cases.

Table 2.4. Educational improvement (orientation towards good and bad output) between 2014 and 2017

Department	Private				Public			
	EC	BPC	TGC	MML	EC	BPC	TGC	MML
Amazonas	1.1378	0.9129	0.9766	1.0145	0.9859	1.0111	1.0072	1.0040
Antioquia	1.0153	0.9566	0.9580	0.9304	0.9984	0.9881	0.9924	0.9790
Arauca	1.0507	0.9395	0.9897	0.9769	1.0366	0.9682	0.9928	0.9964
Archipiélago de San Andrés	0.9776	1.0595	0.9666	1.0011	0.9469	1.0302	0.9983	0.9739
Atlántico	1.0403	0.9508	0.9809	0.9703	1.0129	0.9720	0.9976	0.9823
Bogotá, D.C	1.0281	0.9649	0.9611	0.9534	1.0051	0.9682	0.9815	0.9551
Bolívar	1.0222	0.9774	0.9686	0.9677	0.9953	0.9964	0.9964	0.9882
Boyacá	1.0499	0.9582	0.9517	0.9575	1.0143	1.0287	0.9795	1.0220
Caldas	1.0352	0.9753	0.9537	0.9629	0.9811	1.0104	0.9934	0.9847
Caquetá	1.0265	1.0185	0.9771	1.0216	0.9882	1.0273	0.9933	1.0084
Casanare	1.0436	0.9912	0.9804	1.0141	1.0044	1.0106	0.9967	1.0117
Cauca	1.0849	0.8755	1.0200	0.9688	0.9385	1.0402	1.0091	0.9851
Cesar	1.0521	0.9184	0.9861	0.9529	1.0194	0.9743	0.9964	0.9896
Chocó					0.9615	1.0308	0.9973	0.9885
Córdoba	1.0808	0.9698	0.9607	1.0070	0.9895	1.0089	0.9912	0.9894
Cundinamarca	1.0352	0.9589	0.9720	0.9649	1.0080	0.9931	0.9879	0.9889
Guainía					1.0332	0.9590	0.9990	0.9899
Guaviare	1.0056	0.9473	1.0128	0.9648	0.9286	0.9630	0.9987	0.8931
Huila	1.0668	0.9552	0.9449	0.9628	1.0175	1.0258	0.9849	1.0279
La Guajira	0.9838	1.0268	0.9786	0.9886	0.9541	1.0376	0.9986	0.9886
Magdalena	1.0156	0.9544	0.9703	0.9405	0.9861	1.0033	0.9898	0.9793
Meta	1.0453	0.9401	0.9522	0.9356	0.9886	0.9911	1.0046	0.9843
Nariño	1.0299	0.9603	0.9653	0.9547	1.0050	1.0167	0.9745	0.9957
Norte de Santander	1.0695	0.9066	0.9798	0.9500	1.0328	0.9710	0.9909	0.9938
Putumayo	1.3821	0.7326	1.0089	1.0216	1.0181	1.0175	0.9859	1.0213
Quindío	1.0805	0.9194	0.9629	0.9566	0.9833	1.0034	0.9922	0.9790
Risaralda	1.0457	0.9386	0.9535	0.9360	0.9875	0.9950	0.9950	0.9777
Santander	1.0491	0.9482	0.9506	0.9457	1.0070	0.9968	0.9856	0.9893
Sucre	1.0348	0.9676	0.9702	0.9714	0.9826	0.9952	0.9936	0.9715
Tolima	1.0464	0.9691	0.9587	0.9722	0.9781	1.0184	0.9919	0.9880
Valle del Cauca	1.0462	0.9436	0.9954	0.9827	0.9932	0.9777	0.9984	0.9695
Vaupés					1.0065	0.9984	0.9987	1.0035
Vichada					0.9921	1.0205	0.9963	1.0087
Total	1.0374***	0.9546**	0.9680***	0.9586**	0.9977***	0.9958**	0.9909***	0.9845**

MML: Metafrontier Malmquist Luenberger
EC: Efficiency Change
BPC: Best Practices Change
TGC: Technical Change Gap

* 10%
** 5%
*** 1%
Source: self-devised

The EC is the component with the best performance in the private sector as behavior improves in 84% of the departments. In the BPC (Archipelago of San Andrés, Caquetá, La Guajira) and TGC (Cauca, Guaviare, Putumayo), only 9%

of the departments show positive behavior. In the public sector, the component with the highest number of departments with positive behavior is the BPC (51%), followed by the EC (41%) and the TGC (9%).

Table 2.5. Educational improvement (orientation towards bad output) between 2014 and 2017

Departament	Private				Public			
	EC	BPC	TGC	MML	EC	BPC	TGC	MML
Amazonas	1.1369	0.9127	0.9735	0.9766	0.9463	1.0567	1.0032	1.0072
Antioquia	0.9771	0.9908	0.9611	0.9580	0.9909	1.0001	0.9936	0.9924
Arauca	0.9944	0.9939	0.9867	0.9897	1.0201	0.9855	0.9917	0.9928
Archipiélago de San Andrés	1.0624	0.9528	0.9720	0.9666	1.0023	0.9807	1.0005	0.9983
Atlántico	1.0528	0.9409	0.9751	0.9809	1.0087	0.9758	0.9954	0.9976
Bogotá, D.C	1.0384	0.9550	0.9545	0.9611	0.9918	0.9821	0.9793	0.9815
Bolívar	1.0363	0.9624	0.9698	0.9686	1.0158	0.9812	0.9974	0.9964
Boyacá	1.0457	0.9436	0.9478	0.9517	1.0327	1.0165	0.9781	0.9795
Caldas	1.0271	0.9672	0.9572	0.9537	0.9724	1.0283	0.9957	0.9934
Caquetá	1.0377	0.9797	0.9770	0.9771	0.9989	1.0289	0.9932	0.9933
Casanare	1.1294	0.8944	0.9708	0.9804	1.0165	1.0028	0.9968	0.9967
Cauca	1.0324	0.9161	1.0266	1.0200	0.9772	1.0099	1.0095	1.0091
Cesar	1.0285	0.9385	0.9884	0.9861	1.0138	0.9837	0.9973	0.9964
Chocó					0.9980	1.0025	0.9968	0.9973
Córdoba	1.0691	0.9597	0.9478	0.9607	1.0031	1.0028	0.9905	0.9912
Cundinamarca	1.0294	0.9631	0.9711	0.9720	1.0120	0.9932	0.9877	0.9879
Guainía					1.0279	0.9658	1.0008	0.9990
Guaviare	1.0103	0.9726	0.9931	1.0128	0.9103	0.9896	0.9933	0.9987
Huila	1.0418	0.9556	0.9515	0.9449	1.0173	1.0280	0.9855	0.9849
La Guajira	1.0186	0.9807	0.9784	0.9786	0.9834	1.0084	0.9989	0.9986
Magdalena	0.9826	0.9887	0.9666	0.9703	0.9960	0.9964	0.9928	0.9898
Meta	1.0014	0.9764	0.9595	0.9522	0.9750	1.0075	1.0077	1.0046
Nariño	1.0036	0.9749	0.9683	0.9653	1.0442	0.9862	0.9769	0.9745
Norte de Santander	1.0512	0.9259	0.9758	0.9798	1.0330	0.9737	0.9891	0.9909
Putumayo	1.1906	0.8401	1.0253	1.0089	1.0508	0.9908	0.9866	0.9859
Quindío	1.0117	0.9700	0.9618	0.9629	0.9823	1.0060	0.9925	0.9922
Risaralda	0.9748	1.0144	0.9541	0.9535	0.9734	1.0174	0.9955	0.9950
Santander	1.0012	0.9909	0.9484	0.9506	0.9948	1.0115	0.9847	0.9856
Sucre	1.0453	0.9423	0.9798	0.9702	0.9776	1.0100	0.9958	0.9936
Tolima	1.0425	0.9625	0.9619	0.9587	0.9901	1.0109	0.9934	0.9919
Valle del Cauca	1.0653	0.9248	0.9902	0.9954	0.9932	0.9804	0.9967	0.9984
Vaupés					1.0088	1.0033	0.9962	0.9987
Vichada					1.0196	1.0041	0.9953	0.9963
Total	1.0302***	0.9583	0.9655***	0.9680***	1.0005***	0.9973	0.9908***	0.9909***

MML: Metafrontier Malmquist Luenberger
EC: Efficiency Change
BPC: Best Practices Change
TGC: Technical Change Gap
* 10%
** 5%
*** 1%
Source: self-devised

Table 2.6. Educational improvement (orientation towards good output) between 2014 and 2017

Departament	Private				Public			
	EC	BPC	TGC	MML	EC	BPC	TGC	MML
Amazonas	1.1376	0.8798	0.7960	0.7967	0.9890	0.9859	1.0184	0.9930
Antioquia	1.0178	0.8393	0.8577	0.7327	0.9990	0.9943	0.9304	0.9242
Arauca	1.0525	0.8356	0.9358	0.8229	1.0391	1.1398	0.8644	1.0238
Archipiélago de San Andrés	0.9908	0.8940	0.8126	0.7198	0.9567	0.8526	0.9709	0.7920
Atlántico	1.0392	0.9131	0.9362	0.8883	1.0141	0.9682	0.9640	0.9466
Bogotá, D.C	1.0295	0.9181	0.8934	0.8445	1.0066	0.9087	0.9447	0.8641
Bolívar	1.0179	0.9334	0.8839	0.8399	0.9924	0.9965	0.9468	0.9363
Boyacá	1.0503	0.9447	0.8662	0.8595	1.0123	1.1074	0.8967	1.0052
Caldas	1.0365	0.9660	0.8212	0.8222	0.9849	0.9672	0.9515	0.9064
Caquetá	1.0277	1.0594	0.8521	0.9277	0.9843	1.0511	0.9280	0.9601
Casanare	1.0426	1.0155	0.8524	0.9025	1.0049	1.1294	0.8864	1.0061
Cauca	1.0900	0.7766	1.0335	0.8748	0.9380	1.1093	0.9026	0.9391
Cesar	1.0695	0.8421	0.9052	0.8153	1.0261	0.9825	0.9348	0.9423
Chocó					0.9537	1.0524	0.9446	0.9480
Córdoba	1.0842	0.9896	0.8922	0.9573	0.9923	1.0967	0.8747	0.9520
Cundinamarca	1.0381	0.8984	0.9528	0.8887	1.0095	0.9891	0.9507	0.9493
Guainía					1.0374	1.0375	0.9886	1.0641
Guaviare	1.0088	0.8465	0.9531	0.8139	0.9304	0.7720	0.9171	0.6587
Huila	1.0671	0.9496	0.8492	0.8605	1.0173	1.1038	0.9153	1.0278
La Guajira	0.9877	1.0153	0.8790	0.8816	0.9545	1.0230	0.9699	0.9471
Magdalena	1.0274	0.8131	0.9206	0.7691	0.9848	1.0289	0.9153	0.9274
Meta	1.0447	0.8100	0.8326	0.7046	0.9887	0.9830	0.9598	0.9328
Nariño	1.0343	0.9119	0.8718	0.8222	1.0056	1.1852	0.8101	0.9655
Norte de Santander	1.0793	0.7699	0.9328	0.7751	1.0370	1.0072	0.9236	0.9647
Putumayo	1.4089	0.6842	1.1069	1.0670	1.0207	1.1516	0.8859	1.0412
Quindío	1.0875	0.8647	0.8235	0.7743	0.9860	0.9671	0.9511	0.9070
Risaralda	1.0526	0.8054	0.8557	0.7254	0.9905	0.9716	0.9467	0.9112
Santander	1.0522	0.8792	0.8555	0.7914	1.0086	1.0174	0.9188	0.9428
Sucre	1.0392	0.9355	0.8377	0.8145	0.9843	1.0489	0.8590	0.8869
Tolima	1.0453	0.9158	0.9029	0.8644	0.9756	1.0021	0.9279	0.9072
Valle del Cauca	1.0462	0.8839	0.9739	0.9005	0.9931	0.9169	0.9701	0.8833
Vaupés					1.0166	1.2441	0.8268	1.0457
Vichada					0.9936	1.0487	0.9503	0.9902
Total	1.0396***	0.8911***	0.9024***	0.8360***	0.9985***	1.0080***	0.9258***	0.9318***

MML: Metafrontier Malmquist Luenberger
EC: Efficiency Change
BPC: Best Practices Change
TGC: Technical Change Gap
* 10%
** 5%
*** 1%
Source: self-devised

The gaps between departments are different for each of the components, although the difference between the best and worst department evaluated in each component is always greater in the private than in the public sector. The gaps are 40.5%, 32.7% and 7.5% in the private sector and 10.8%, 8.1% and 3.5% in the public sector for the EC, BPC, and TGC, respectively, and the MML index presents a 9.1% gap for the private and 13.5% for the public sector. The results

of the estimation of the index oriented to good output and bad output simultaneously show a better change in public sector performance except for the component directly related to the change in efficiency.

Tables 2.5 and 2.6 present the results of the estimation of the MML index and its components, with an exclusive orientation towards bad output and good output respectively. On average, for the orientation towards bad output, the public sector has a better change in performance in both the MML index and the BPC and TGC components than the private sector.

Table 2.7. Summary of educational improvement (three orientations) between 2014 and 2017

Orientation	Component	Private	Public
Good and bad outputs	**EC**	1.0374***	0.9977***
	BPC	0.9546**	0.9958**
	TGC	0.9680***	0.9909***
	MML	0.9586**	0.9845**
Bad outputs	**EC**	1.0302***	1.0005***
	BPC	0.9583	0.9973
	TGC	0.9655***	0.9908***
	MML	0.9680***	0.9909***
Good outputs	**EC**	1.0396***	0.9985***
	BPC	0.8911***	1.0080***
	TGC	0.9024***	0.9258***
	MML	0.8360***	0.9318***

MML: Metafrontier Malmquist Luenberger
EC: Efficiency Change
BPC: Best Practices Change
TGC: Technical Change Gap

* 10%
** 5%
*** 1%
Source: self-devised

The differences in favor of the public sector considering the orientation to bad output are 3.90%, 2.53% and 2.30% for the components BPC, TGC, and MML, respectively, and the difference in EC in favor of the private sector is 2.97%. When the orientation to good output is followed, the differences in average increase to 11.69%, 2.34% and 9.58% for the BPC, TGC and MML components,

and the EC has a difference in favor of the private sector of 4.11%. The orientation towards bad outputs focuses on equality in the education system, showing differences between sectors and highlighting the gaps. The results reveal that for both sectors the greatest participation in increasing productivity is provided by the EC. Table 2.7 presents the summary of the results of the estimation of the MML index and its components with all orientations.

Table 2.8 Departmental classification by academic achievement and sector

Group	Classification	Department	
		Private	Public
G1	General	Putumayo	
G2	Equality	Cauca, Guaviare, Putumayo	Amazonas, Cauca, Meta
G3	Performance	Putumayo.	Arauca, Boyacá, Casanare, Guainía, Huila, Putumayo, Vaupés
G4	Simultaneous	Amazonas, Archipiélago de San Andrés, Caquetá, Casanare, Córdoba, Putumayo	Amazonas, Boyacá, Caquetá, Casanare, Huila, Putumayo, Vaupés, Vichada

Source: Giménez (2019).

Due to the heterogeneity of the results at the departmental level, a classification is made along the lines of Giménez et al. (2019) based on the results of the MML index, the orientation of the evaluation, and the educational sector. Table 2.8 shows four groups. The first (G1) includes the departments that presented improvements at a general level, taking into account the three types of orientation. The second (G2) contains those that had a positive evolution in productivity considering only the bad outputs orientation, those that have focused efforts on improving equality in the educational system. The third (G3) comprises the departments that show an improvement in productivity in terms of student performance. Finally, the fourth group contains the departments that presented an improvement in productivity when there is a simultaneous approach (performance and equality) during the analyzed period.

The results of estimates with a static and dynamic approach considering multiple orientations reveal a difference between the approaches and orientations; four common patterns emerge. First, overall performance deteriorates in the private sector, and to a greater extent when it is oriented towards performance. Second, the EC is the component that drives positive changes in productivity. Third, the least efficient departments (Amazonas, Putumayo) at the initial moment, considering the static approach (DEA), are those that are marginally more easily able to improve their productivity. Finally, large gaps are evident between the departments.

2.6. Conclusions

The present study evaluates the evolution in the productivity of the Colombian education system between 2014 and 2017, taking into account students' results in the Saber 11 test and the endowments of educational institutions, and differentiating between orientations towards the types of results (performance and equality) and the education sectors.

The methodological approach is based on the Metafrontier Malmquist Luenberger index (MML), and to our knowledge, this study is the first application in the education sector. This is a relevant tool to analyze the educational context since it allows bad outputs to be incorporated into the process while considering both performance and different groups in the evaluation. From an empirical point of view, the study aimed to analyze the change in the productivity of the Colombian education system and the similarities and differences between the sectors, and to discover the performance of the different units in a context of

quality incentives. It also seeks to offer a robust tool with greater scope for measuring efficiency than the Quality Index explained in the introductory section.

The results of the MML index according to the different orientations show, on average, deterioration in the private sector of 16.4% (good output), 3.20% (bad output) and 4.14% (good and bad output), depending on their orientation. For the public sector, there is a deterioration of 6.82% (good output), 0.91% (bad output) and 1.55% (good output and bad output). The results confirm that the public sector performs better than the private sector, regardless of the orientation. The superior productivity of the public sector is in line with the study by Mancebón et al. (2012), who find better levels of performance in public schools than in their private counterparts in the Spanish education system. On the other hand, Perelman and Santin (2011) find that once the inputs, the background of the students, the peer effect and the choice of school are controlled, the differences between the sectors disappear.

The components of the index show great differences in behavior depending on the sector analyzed. The private sector is mainly driven by the change in efficiency (EC), and to a greater extent when the performance orientation is followed (3.96%). At the departmental level and considering each of the components, the results are as follows: (i) high variability among departments and, in general, their level of productivity is correlated with the efficiency in the initial situation; (ii) less dispersion of the results in the public than in the private sector; (iii) greater variance in the index when focusing on performance.

The results of the educational tests, in general, are analyzed directly, without considering either bad outputs or the available resources. This is one of the reasons why the findings of the present study do not coincide with current

discussions surrounding academic results of public and private schools. From a public policy point of view, 75% of the schools evaluated are public; therefore, there should be a concern for access to a more egalitarian education without sacrificing good performance. In conclusion, a simple analysis must be distinguished in absolute terms as in the present study, in which the focus is on the productivity and equality of the education system.

The MEN *Estimulos a la Calidad* program in Colombia, introduced in 2016 to evaluate and encourage academic quality, is one of the motivators of this study. The results confirm that, on average, the program had no positive effects on the evolution of productivity of schools in the education system. That is, school productivity decreased from 2014 to 2017. This decrease may be due to various reasons, of which we identified two. First, the program applies a blanket educational policy to the whole country, regardless of the context. The second reason is related to the *Estimulos a la Calidad* program and the new measurement of schools' quality. One component of the measurement is the students that pass the academic year (promotion in the index), which can incentivize teachers to raise students´ grades, which may not guarantee the minimum learning standards.

There are several implications for education policy. First, the *Estimulos a la Calidad* program and its adaptability should be restructured according to the context. Additionally, variables that cannot be biased by the MEN's design of incentives must be taken into account. Finally, public policy must focus on all students in the education system. For this reason, maximum attention should be paid to guaranteeing minimum learning standards for all students and not simply to the results of standardized tests.

Although the study met its objectives and the results are relevant to the context in which it was developed, three limitations should be addressed in future research. First, the availability of a restricted period in the databases; expanding this period would provide a better overview of the approach. Second, this study, like many others, carries out analyses with the schools as its unit of analysis; however, there is a tendency towards considering the student as the unit of analysis. Additionally, taking into account different academic courses, instead of standardized tests, could yield results with greater scope. Third, the effects of departmental characteristics should be analyzed, since, in an environment such as Colombia, institutions and location can play an important role in educational productivity.

CHAPTER 3

THE RELATIONSHIP BETWEEN ARMED CONFLICT AND EFFICIENCY OF EDUCATIONAL QUALITY IN COLOMBIA

3. The effect of armed conflict on the efficiency of educational quality in Colombia

3.1. Introduction

Education plays a fundamental role in the economic development and well-being of society, mainly because it is the main source of capital accumulation in a country. It has therefore been included in different development plans and is recognized as a priority due to the social externalities it presents (McMahon, 2004). One global example of this is the Agenda for Sustainable Development 2030 (Naciones Unidas, 2016), which prioritizes educational improvement as a way of escaping the cycle of poverty.

The main objective of recent educational policies has been to close social gaps around the world (Hanushek & Kimko, 2000), especially those in academic performance due to their role as a determinant of well-being (Krueger & Lindahl, 2001). The importance of education in a context of social development, and the constant budgetary restrictions at the government level, has led to growing research interest in educational efficiency (Cordero, et al., 2018), which is now highly dynamic research line.

The context in which children grow up plays a fundamental role both in their education, and in their well-being and development. Specifically, armed conflicts have been shown to have devastating effects on human capital in multiple ways, and studies have found that exposure at an early age is much more persistent (Gianmarco, 2012). During their schooling, children are exposed to multiple dangers in the context of armed conflict, such as death, recruitment, loss of family members, and forced migration, among others (Naciones Unidas, 2018). Based

on the above, in this study special relevance is given to the armed conflict as an environmental variable, since as a phenomenon it is related with the educational system in multiple ways (World Bank, 2003), and due to its high prevalence and intensity in the last decades, we need a better understanding of its relationship with educational outcomes (Gómez Soler, 2016).

Armed conflicts are a global phenomenon where approximately three out of every four countries have experienced an internal conflict in the last four decades (Blattman & Miguel, 2010), with economic, political, and social repercussions that can affect educational achievement (Justino, 2010). In 2017, armed conflicts produced more than 6,000 violations of international humanitarian law (death, mutilation, recruitment, among others) certified against children by government groups and 15,000 by non-state armed groups (Naciones Unidas, 2018).

The World Bank report (2003) highlights that the social and economic costs of armed conflict are large and persistent, even after the end of the conflict. The economic costs of conflicts are mainly associated with five factors (Collier, 1999): destruction of resources, interruption of social order, diversion of public spending, dissaving, and flight of assets outside the country. In a more recent context, Baez (2011) associates armed conflict with environmental destruction, weakened institutions, limitations on political governance, and the deterioration of civil liberties.

In recent years, special attention has been paid to the effects of armed conflict on education (Gianmarco, 2012). The literature suggests multiple ways in which conflict can affect educational performance. In general, analyses differentiate between direct and indirect effects of conflict, in the short and long term, and distinguish between quantity and quality in educational outcome variables

(Shemyakina, 2011). Direct effects range from greater exposure to an attack to damage to infrastructure; indirect effects are related to fear or stress generated by such events, which reduces quality of life and hinders accumulation of human capital. When the difference is based on temporality, short-term effects are associated with the absence of students in schools or the forced migration of students, teachers, and the general population, and long-term effects are related to greater expected difficulties of insertion in the labor market, loss of income-generating capacity, and perpetuation of poverty in the affected territories (Gómez Soler, 2017; Shemyakina, 2011).

As mentioned above, educational outcome variables have been analyzed in terms of the quantity or quality of educational services. Some empirical studies investigate the effects of armed conflict mainly through variables related to quantity, for example, years of education (Valente, 2014), or enrollment (Shemyakina, 2011), educational levels reached (Verwimp & Van Bavel, 2014), and dropout rates (Guariso & Verpoorten, 2019). The literature has also highlighted the lack of attention to the relationship with the results in terms of quality, when measured through standardized tests; indeed only four contributions have examined this problem (Gómez Soler, 2016, 2017; Kibris, 2015; Rodríguez et al., 2010). Additionally, most studies analyze the effects during the conflict, and consequently there is little evidence of the costs once peace agreements have been signed (Chen et al., 2008). Therefore, to our knowledge, this study is the first analysis to focus on the relationship between armed conflict and the efficiency of an educational system.

The objective of this research is to evaluate the change in educational efficiency related with the homicides linked to the armed conflict in Colombian

municipalities. For this purpose, we analyze the performance of students in schools that administered the Saber 11 standardized test between the years 2014 and 2018. From a methodological point of view, a robust conditional non-parametric approach is followed to determine the relationship of conflict, as an environmental variable, to efficiency levels. Giménez et al. (2007) explain four ways to control the influence of environmental variables, highlighting that there is no consensus in the literature (Bifulco & Bretschneider, 2001). However, recent studies are increasingly calling for environmental variables to be considered and incorporated (De Witte & López-Torres, 2017) using robust methodology that is not over-sensitive to atypical observations, as is the case of conditional models.

This paper analyzes the relationship between armed conflict on the educational efficiency of 912 Colombian municipalities between 2014 and 2018. The selection of this period is relevant for two reasons. First, the Colombian Ministry of Education has reaffirmed the importance of having measurements related to efficiency and specific indicators, where the resources and results of the process are taken into account by implementing the Synthetic Index of Educational Quality; the results of these research indicators can then be used for decision-making. Second, in 2016 the peace agreement between the government and *Fuerzas Armadas Revolucionarias de Colombia-Ejército del Pueblo (FARC-EP)* was signed, (partially) ending five decades of conflict and allowing better child protection (Naciones Unidas, 2018).

This study makes four contributions to the literature. First, it responds to the call to develop the intersection of research on education and armed conflict, using quality variables in the form of standardized tests to measure the relationship with armed conflict (Gómez Soler, 2016, 2017; Kibris, 2015). Second, this is the first

study to measure the relationship between armed conflict and educational efficiency. Third, a robust non-parametric conditional model is applied for the first time in the line of research on armed conflict. Fourth, the intensity of the conflict in neighboring municipalities is incorporated with spatial contagion models. Furthermore, results such as these should be taken into account as a contribution to political decision making, since it has been suggested that for peace agreements to remain stable, the way conflict affects different municipalities should be analyzed, mainly because environmental variables are beyond the control or influence of educational managers.

The study is organized in six sections. After this section, the main characteristics of the armed conflict in Colombia are described (section 2), followed by the literature review (section 3). The methodological aspects related to conditional models are then presented (section 4), after which the databases used in the educational system evaluation process are mentioned, the variables are explained, and the main results are presented (section 5). Finally, the main conclusions are drawn (section 6).

3.2. The armed conflict in Colombia

Colombia has a long history with multiple manifestations of conflict, which affect the civilian population in different ways. This conflict has varied in intensity and geographic areas are affected asymmetrically, with remote rural areas bearing the worst effects. The National Center for Historical Memory (CNMH) confirms that between 1985 and 2012, more than 220,000 murders took place as a result of the war and more than six million people were displaced. Importantly, land-

related problems and the country's precarious democracy were among the main causes of conflict.

The armed conflict in Colombia was principally led by guerrilla and paramilitary groups, both of which underwent organizational modifications in the early nineties, resulting in changes in their forms of financing. The two most important sources of funding at this time were drugs and the kidnapping of civilians, which together with a change in strategy that prioritized the generation of fear, led to the time known as the "escalation of violence" (Restrepo et al., 2006). This situation became more acute until 2002, the most critical moment of the conflict, which coincides with the peace process led by former President Andrés Pastrana (1998–2002) and the San Vicente del Caguan demilitarized zone. Additionally, technological changes in the armament of the Colombian army led to a long-term conflict that affected a large part of the country with variable intensity.

The intensity of the armed conflict was not constant during its different stages. The conflict involved multiple actors and took different forms including homicides, kidnappings, confrontations and the involvement of minors, among others. Although all manifestations of the armed conflict are important and show different facets, in the present study homicides are taken as a proxy for the conflict, mainly because this variable has the most accurate levels of reporting and consistency over time, and it is maintained regardless of the dynamics of the dominant conflict at a given moment.

Finally, the *Autodefensas Unidas de Colombia* reached an agreement with the government to end the conflict in 2006, when they voluntarily surrendered their weapons. This ceasefire allowed the *FARC-EP* to expand its power, until 2016 when negotiations with the government brought an end to the conflict with the

signing of the peace agreement. The peace processes resulted in a decrease in the country's internal conflict, as well as a fall in the number of homicides, kidnappings, and other associated crimes. However, the conflict is still perpetuated by the smaller outlawed groups that have appeared and that carry out criminal actions of various kinds. For example, the United Nations[15] verified at least 42 massacres in the first half of 2020, as well as 297 attacks against former FARC-EP members, including 224 murders, 20 disappearances, and 53 attempted homicides. These figures illustrate the importance of working to consolidate the peace agreements, since the armed conflict in Colombia continues to be a problem that affects the social order.

3.3. Literature review

There is no question that education is important for society, due to the benefits it brings at the individual level and its collective positive externalities (Hanushek & Woessmann, 2008). At the societal level, the literature has demonstrated the relationship between a higher educational level and improvements in well-being and development (Evans et al., 2000), economic growth (Krueger & Lindahl, 2001), and greater equity in the distribution of resources (Hanushek & Woessmann, 2012).

In the literature on education, there are two main areas of study: efficiency ('doing things right') and effectiveness ('doing the right things') (De Witte & López-Torres, 2017). A balance must always be sought between the two, as they are both essential in designing educational policies (Aparicio et al., 2022; Cherchye et al., 2019; OCDE, 2006). Educational efficiency is a highly dynamic line of research,

[15] https://news.un.org/es/story/2020/10/1482392

which has mainly been developed using non-parametric (Cherchye & De Witte, 2015; Haelermans & De Witte, 2012) and parametric (Mastromarco & Ghosh, 2009) frontier methods.

Armed conflicts are considered one of the major factors that affect the deterioration of the educational process (Poirier, 2012). Likewise, the existing relationship between education, well-being and social development supposes that if some factor hinders the educational process within a society, its long-term development will deteriorate in multiple respects (Kibris, 2015). The consequences of armed conflict are of greater magnitude for children. Ouili (2017) describes five ways in which conflict affects children: killings and mutilations among exposed communities; forced recruitment; sexual violence; reluctance to going to the school due to personal insecurity, and disruption due to destruction of infrastructure. Education is fundamental to development and economic growth, and the magnitude and prevalence of armed conflicts around the world has led scholars to call for greater understanding of the subject (Gómez Soler, 2016), highlighting that the literature on the topic is still scarce (Di Maio & Nandi, 2013).

Based on the importance of education for economic and social development and relationship of armed conflicts with education, we carried out a systematic review to compile a section of the literature, synthesize the research evidence (Grant & Booth, 2009), and show the relevance of the present study. Thus, we consulted the Web Of Science (WOS) and Scopus® databases to gather scientific articles resulting from the search terms “education”, “school”, “terrorism”, “armed conflict”, “civil conflict” and “civil war”. A total of 132 articles were found in WOS, and 434 in Scopus. Additionally, filters were applied since many of the results

were not directly related to the object of study, specifically, “economics”, “business”, “political science”, “education educational research”, “development studies”, “management”, “operations research management” and “social sciences interdisciplinary”. When these fields were included, the number of articles fell to 30 on WOS and 40 on Scopus. Of these, 15 were repeated, resulting in 55 articles that form the empirical material for this review covering a period of 17 years (2003–2019).

Table 3.1. Objectives and variables of study

Variable of study	Observed in
Achievement	Gershenson & Tekin, 2018; Gómez Soler, 2016, 2017; Khamis, 2013; Kibris, 2015.
Attendance	Di Maio & Nandi, 2013; Quintero et al., 2018.
Drop out	Guariso & Verpoorten, 2019; Rodríguez & Sánchez, 2012.
Enrollment	Diwakar, 2015; Gates et al., 2012; Guariso & Verpoorten, 2019; Lai & Thyne, 2007; Márquez-Padilla, Pérez-Arce, & Rodríguez-Castelán, 2019; Ouili, 2017; Oyvat & Tekgüç, 2019; Pivovarova & Swee, 2015; Poirier, 2012; Shemyakina, 2011; Shields & Paulson, 2015; Tfaily, Diab, & Kulczycki, 2013.
Grades of education (obtain/complete an academic level. e.g., primary; secondary)	Chamarbagwala & Morán, 2011; Kecmanovic, 2013; Swee, 2015a; Valente, 2014; Verwimp & Van Bavel, 2014.
Years of education (accumulation of years of schooling)	Baez, 2011; Brown & Velásquez, 2017; Chamarbagwala & Morán, 2011; Dabalen & Paul, 2014; Diwakar, 2015; Gianmarco, 2012; Guariso & Verpoorten, 2019; Islam et al., 2016; 2017; La Mattina, 2018; Merrouche, 2011; Ouili, 2017; Pivovarova & Swee, 2015; Poirier, 2012; Saing & Kazianga, 2019; Singh & Shemyakina, 2016; Swee, 2015b; Valente, 2014.

Source: self-devised.

Table *3.1* classifies the study objectives depending on the variables analyzed. Tables 3.2 – 3.4 show the characterization by approach or methodology used, variables used as a measure of the armed conflict, and future lines of research. The variables related to educational objectives were modeled from the literature and differentiated by quantity and quality. Of the variables related to quantity, there is an emphasis on years of education and enrollment, which were two of the main objectives of educational policies for many years around the world. On the other hand, the review shows that although quality plays a very important role

in current educational systems, only five studies investigate the relationship between armed conflict and educational quality.

According to Kibris (2015), it is more important to focus on variables related to quality than to quantity since the former have been shown to have a more direct relationship with a country's development and social welfare. The relationship between armed conflict on educational quality, measured through standardized tests, has been little studied, leaving a significant gap in the literature (Gómez Soler, 2017); to our knowledge, no previous studies have aimed to determine relationship with the efficiency of educational quality, the objective of this research.

Table *3.2* shows the different methodological approaches. Most of the studies use methods of causal inference (difference-in-differences, propensity score matching, among others). Although non-parametric methods related to efficiency or productivity offer advantages over explanatory parametric methods (Thieme et al., 2013), we are unaware of any application studying the relationship or the effects of armed conflict on educational efficiency.

Table 3.2. Observed approaches, methods, and model

Technique/approach	Observed in
Causal effect	Baez, 2011; Brown & Velásquez, 2017; Chamarbagwala & Morán, 2011; Diwakar, 2015; Gershenson & Tekin, 2018; Gianmarco, 2012; Guariso & Verpoorten, 2019; Kecmanovic, 2013; La Mattina, 2018; Merrouche, 2011; Pivovarova & Swee, 2015; Saing & Kazianga, 2019; Shemyakina, 2011; Singh & Shemyakina, 2016; Swee, 2015b; Verwimp & Van Bavel, 2014.
Duration analysis	Rodríguez & Sánchez, 2012.
Multilevel	Gómez Soler, 2017; Khamis, 2013; Kibris, 2015; Shields & Paulson, 2015.
Non-parametric approach	Quintero et al., 2018.
Panel data	Gates et al., 2012; Gómez Soler, 2016; Islam et al., 2016, 2017; Lai & Thyne, 2007; Márquez-Padilla et al., 2019; Ouili, 2017; Oyvat & Tekgüç, 2019.

Source: self-devised.

Armed conflict has been measured in different ways and although there is no consensus in the literature, Table *3.3* shows the main variables used. Those generally considered to measure the intensity of the conflict are battle-related deaths, incidents, or the number of confrontations between the different actors and destroyed property. On the other hand, the exposure or presence of children or young people in conflict zones has been measured through the number of exposure years to armed conflict, depending on the stage of life (Gianmarco, 2012), dismantled laboratories or anti-drug operations (Gómez Soler, 2017), years of exposure (Verwimp & Van Bavel, 2014), and on other occasions, offensive actions by illegal groups (Rodríguez & Sánchez, 2012) and property damage (Shemyakina, 2011). Finally, given the multiplicity of variables used, some studies and government organizations have opted to make synthetic indicators through principal component analyses that combine and summarize most of the variables mentioned above (La Mattina, 2017, 2018).

Table 3.3. Variables used to measure armed conflict

Type of variables	Observed in
Clashes	Diwakar, 2015; Gershenson & Tekin, 2018; Gómez Soler, 2016; Khamis, 2013; Lai & Thyne, 2007; Ouili, 2017; Poirier, 2012; Quintero et al., 2018; Rodríguez & Sánchez, 2012; Saing & Kazianga, 2019; Shields & Paulson, 2015; Singh & Shemyakina, 2016.
Deaths	Brown & Velásquez, 2017; Chamarbagwala & Morán, 2011; Diwakar, 2015; Gates et al., 2012; Gómez Soler, 2016; Guariso & Verpoorten, 2019; Islam et al., 2017; Khamis, 2013; Kibris, 2015; La Mattina, 2018; Márquez-Padilla et al., 2019; Oyvat & Tekgüç, 2019; Pivovarova & Swee, 2015; Poirier, 2012; Singh & Shemyakina, 2016; Valente, 2014.
Destroyed properties	Khamis, 2013; Shemyakina, 2011; Valente, 2014.
Exposure years to armed conflict	Baez, 2011; Chamarbagwala & Morán, 2011; Di Maio & Nandi, 2013; Gianmarco, 2012; Guariso & Verpoorten, 2019; Islam et al., 2016; Kecmanovic, 2013; Khamis, 2013; Merrouche, 2011; Pivovarova & Swee, 2015; Verwimp & Van Bavel, 2014.

Source: self-devised.

The complexity of armed conflict requires different empirical strategies and approaches, which has necessitated some additional decisions when selecting

variables. These include, first, selecting the number of years taken into account before the period of analysis due to the cumulative effects of the conflict, which are not usually immediately (Márquez-Padilla et al., 2019); second, considering the place of residence and birth (Verwimp & Van Bavel, 2014) to identify migratory patterns; and finally, considering the geographical characteristics of the places of conflict, since there may be correlations or geographical "spillovers" (Gómez Soler, 2017; Islam et al., 2016).

Explicit suggestions for future lines of research were found in the systematic literature review (see Table *3.4*). These recommendations include, first, carrying out measurements related to educational quality; second, broadening the general understanding of the effects of armed conflict; and finally, extending the temporal scope beyond the end of the conflict.

Table 3.4. Future research lines

Topic of interest	Observed in
Educational quality	Di Maio & Nandi, 2013; Gómez Soler, 2016, 2017; Khamis, 2013; Kibris, 2015; Márquez-Padilla et al., 2019; Shemyakina, 2011; Shields & Paulson, 2015; Valente, 2014.
General understanding	Chamarbagwala & Morán, 2011; Di Maio & Nandi, 2013; Diwakar, 2015; Kecmanovic, 2013; Kibris, 2015; La Mattina, 2018; Merrouche, 2011; Ouili, 2017; Pivovarova & Swee, 2015; Poirier, 2012; Shemyakina, 2011; Shields & Paulson, 2015; Swee, 2015b; Valente, 2014; Verwimp & Van Bavel, 2014.
Post-conflict	Buvinić et al., 2014; Gates et al., 2012; Lai & Thyne, 2007.

Source: self-devised.

Finally, the literature review leads to two conclusions that contribute to reinforcing the gap covered by this study. First, it is important to conduct studies that use standardized tests as outputs of the educational process. Second, to date, no approaches have considered the relationship between armed conflict and educational efficiency.

3.4. Methodology

The main objective of this study is to determine the relationship between armed conflict and educational efficiency in Colombia, for which both the armed conflict and other environmental variables must be analyzed. Non-parametric two-stage efficiency models have often been used for this purpose (Agasisti & Zoido, 2015; Aparicio, Cordero, et al., 2018). In the first stage of these models, the efficiency coefficients are estimated, and in the second, econometric models are applied to explain the levels of efficiency as a function of the environmental variables. However, this procedure assumes that environmental factors affect the entire distribution in the same way, when in matters related to education, a large part of the efficiency depends on the school and socioeconomic characteristics (Cordero et al., 2018), thus making this assumption unrealistic. In this regard, Daraio and Simar (2005; 2007a; 2007b) suggest that if the assumption of separability of the boundary estimate with the environmental variables is not tested, conditional models should be used, since they include the environmental factors in a single stage. These types of models have been recently applied in the educational sector (Cordero, et al., 2018; Cordero, Santín, & Simancas, 2017; De Witte & Kortelainen, 2013).

Additionally, Daraio and Simar's (2005; 2007a; 2007b) methodological developments allow researchers to include the environmental variables at different levels and determine their relationship with the educational production process. Generally, conditional models are based on the probabilistic formulation

proposed by Cazals et al. (2002), although other alternatives can be seen in Daraio and Simar (2007b).

To estimate both conditional and unconditional models, a production technology is considered where the units are characterized by a set of inputs *x* ($x \epsilon R_+^p$) and outputs *y* ($y \epsilon R_+^q$); the production technology can be established as the set of viable combinations of outputs and inputs, such that:

$$\Psi = \{(x, y)\ \epsilon\ R_+^{p+q} | x\ can\ produce\ y\} \quad \textbf{(1)}$$

Following the formulation of the production process proposed by Cazals et al. (2002), it should be taken into account that intuitively we want to know the probability that one of the evaluated units *(x, y)* is being dominated by the joint probability function

$$H_{XY}(x, y) = \Pr(X \leq x,\ \mathrm{Y} \geq y) \quad \textbf{(2)}$$

where the joint probability function can be decomposed into $S_Y(y|x)$, which represents the survival function of *Y*, and $F_X(x)$, which is the cumulative distribution function of *X*.

$$\begin{aligned} H_{XY}(x, y) &= \Pr(\mathrm{Y} \geq y, X \leq x) \Pr(X \leq x) \quad \textbf{(3)} \\ &= \mathrm{S_{Y|X}}(\mathrm{Y} \geq y, X \leq x)\, \mathrm{F_X}(X \leq x) \\ &= \mathrm{S_Y}(\mathrm{y|x})\, \mathrm{F_X}(x) \end{aligned}$$

In order to estimate the efficiency coefficients using the proposed probabilistic formulation, we must replace the corresponding empirical distribution, such that we have $\widehat{H}_{XY,n}(x, y)$ for $H_{XY,}(x, y)$ and $\hat{S}_{Y,n}(y|x)$ for $S_Y(y|x)$; these analogies can be expressed as follows:

$$\widehat{H}_{XY,n}(x, y) = \frac{1}{n}\sum_{i=1}^{n} I(x_i \leq x, y_i \geq y) \quad \textbf{(4)}$$

$$\hat{S}_{Y,n}(y|x) = \frac{\widehat{H}_{XY,n}(x,y)}{\widehat{F}_{X,n}(x)} = \frac{\widehat{H}_{XY,n}(x,y)}{\widehat{H}_{XY,n}(x,0)}$$

where $I(x_i \leq x, y_i \geq y)$ is an indicator function. On the other hand, using the *plug-in* principle of the Free Disposal Hull (FDH) estimators having an orientation toward the output, the efficiency coefficients can be obtained such that $\hat{\lambda}_{FDH}(x,y) = \sup\{\lambda | \hat{S}_{Y,n}(\lambda_y|x) > 0\}$. Note that because traditional FDH estimators are sensitive to outliers and extreme values, we use the order-m $\hat{\lambda}_m(x,y)$ estimator; Cazals et al. (2002) show that these efficiency coefficients have an expression that depends only on their conditional distributions $S_Y(y|x)$.

$$\hat{\lambda}_m(x,y) = \int_0^\infty (1 - (1 - S_Y(uy|x))^m) du \qquad \textbf{(5)}$$

Based on the previous equation, and similar to the case of the FDH, the estimators for the order-m can be obtained by replacing $\hat{S}_{Y,n}(y|x)$ in equation 5, which yields the expression of the unconditional order-m estimators:

$$\hat{\lambda}_{m,n}(x,y) = \int_0^\infty (1 - (1 - S_{Y,n}(uy|x))^m) du \qquad \textbf{(6)}$$

In the same way, following the probabilistic formulation by Cazals et al. (2002), a conditional model is formulated, where the environmental factors $Z \epsilon R_+^k$ are taken into account, because they affect school performance and efficiency. With this we want to show how a unit operating at a certain level *(x, y)* can be compared with another that operates in similar environmental conditions *(Z = z)* using the joint production function $H_{XY|Z}$, where *Z* is the set of variables that characterize a specific operating environment. Following Cazals et al. 2002 and Daraio and Simar (2005; 2007a; 2007b), it can be expressed as:

$$H_{XY|Z}(x,y|z) = \Pr(X \leq x, Y \geq y | Z = z) \qquad \textbf{(7)}$$

Moreover, as with the unconditioned function, the expression can be decomposed into $S_Y(y|x,z)$ and $F_X(x|z)$, which represent the survival function of *Y* and the cumulative distribution function of *X*, respectively:

$$H_{XY|Z}(x,y|z) = \Pr(X \leq x, Y \geq y|Z = z)\Pr(X \leq x|Z = z) = S_Y(y|x,z)F_X(x|z) \quad \textbf{(8)}$$

To solve problems with the extreme values and outliers, an order-m frontier evaluation process can be defined (Cazals, 2002) that allows us to calculate the conditional estimators $\lambda(x,y|z)$ and unconditional $\lambda(x,y)$ efficiency. Order-m models require the parameter, *m*, to be established, where *m* indicates the number of units randomly drawn from the sample with which it is compared. Analogously to the expression of the unconditional model, the output-oriented measures of the conditional efficiency model can be expressed using the following integral:

$$\lambda_m(x,y|z) = \int_0^\infty [1-(1-S_Y(uy|x,z))]^m du \quad \textbf{(9)}$$

To calculate the conditional estimates, smoothing techniques are applied for the environmental variables, due to the equality constraint *(Z = z)*:

$$\hat{S}_{Y|n}(y|x,z) = \frac{\sum_{i=1}^n I(x_i \leq x, y_i \geq y)K_{\hat{h}}(\frac{z-z_i}{h})}{\sum_{i=1}^n I(x_i \leq x)K_{\hat{h}}(\frac{z-z_i}{h})} \quad (\mathbf{10})$$

where $K_{\hat{h}}(\frac{z-z_i}{h})$ is a kernel function and $\hat{h}$ is an estimate of the bandwidth parameter, using for this case, the data-based selection method developed by Badin, Daraio, and Simar, (2010), mainly because it detects and smoothes irrelevant factors by providing large bandwidth parameters. The conditional order-m estimator $\hat{\lambda}_{m,n}(x,y|z)$ is obtained by replacing $\hat{S}_{Y|n}(y|x,z)$ in equation 9, therefore:

$$\hat{\lambda}_{m,n}(x,y|z) = \int_0^{\infty}[1-\left(1-S_{Y,n}(uy|x,z)\right)]^m du \quad \textbf{(11)}$$

Finally, following the approach of Badin, Daraio, and Simar, (2012), the ratios of the conditional and unconditional order-m estimators are analyzed to determine the impact of the context variables *(Z)* on the frontier:

$$\hat{Q}_m = \frac{\hat{\lambda}_m(x,y|z)}{\hat{\lambda}_m(x,y)} \quad (\mathbf{12})$$

With the ratio of the two estimators, a non-parametric regression can be used to analyze which of the environmental variables are significant or not. Additionally, the marginal effects can be interpreted through the smoothed regression slope, showing that, for an output-oriented model, a line with a positive slope indicates a positive effect of the variable z. It is also important to highlight the significance of environmental variables; the procedure proposed by Li and Racine (2008) is applied, which is a non-parametric equivalent of the standard t-tests in ordinary least squares regression (De Witte and Kortelainen, 2013).

3.5. Empirical study

This section is divided into three parts. First, the variables used in the conditional model are described, along with the sources and the selected sample. The second part details the empirical strategy used to approach the research objective. Finally, the results of the conditional model are described and a non-parametric regression is performed, which shows the significance of the environmental variables.

3.5.1 Data

To determine the level of efficiency of the municipalities and their relationship with the relevant environmental variables, a database was built from four sources. The

first is the National Administrative Department of Statistics (DANE), which provides information through an official census of all the country's schools. The second is the Colombian Institute for the Promotion of Higher Education (ICFES), which is responsible for conducting standardized tests. The third is the Center for Economic Development Studies of the Andes University (CEDE), which collects information at the municipal level on various topics. Its information on the armed conflict was especially useful for this study. The last source of information was the National Planning Department, from which data related to the municipal education budget and its category were obtained.

Based on the educational efficiency literature (De Witte & López-Torres, 2017; Giménez, Thieme, Prior, & Tortosa-Ausina, 2018) and the armed conflict literature (Gómez Soler, 2016, 2017; Kibris, 2015), and following the methodological proposal described in the previous section, this study uses two outputs, four inputs, and five environmental variables to calculate the educational efficiency of 912 Colombian municipalities between the years 2014 and 2018.

Multiple outputs have been used in the literature to measure the educational process. The variables related to academic quality most commonly used as outputs are results in language or reading, mathematics, and science in different standardized tests (Cordero, Prior, & Simancas, 2016; Tavana, et al., 2018). Some authors have even suggested using composite indices from multiple tests (Hauser, 2009). On the other hand, the main variables related to quantity used as outputs are dropout rate (Mancebón et al., 2012), enrollment (Johnes, 2014) or acceptance rate (Thieme et al., 2013) among others.

Based on the above, the first output *(y1)* was defined as the average at the municipal level of the generalized global score for schools. The global score is

the weighted sum of the tests of the Saber 11 exam (3 points each for mathematics, critical reading, social studies, and natural sciences, and 1 point for English). A two-stage process is carried out to convert the variable at the municipality level. First, the sum of the global score of all students is divided by the number of students who took the exam and multiplied by the total enrollment of the school. Second, the previous value at the school level is averaged with all the schools in the municipality. The global score is used as an output for three reasons. First, its use is supported in the literature as a standardized test. Second, it responds to a call in the related literature to apply compound tests (Hauser, 2009). Finally, as the exam taken before entering the university cycle, it is relevant as a basis for educational policies.

School pass rate is the second output *(y2)*. This variable is captured by the average of the municipality through the indicators of the schools, and it was chosen because in the places most affected by the armed conflict, high school interruption affects variables such as enrollment, dropout, or pass rates (Khan et al., 2018; Kibris, 2015; Márquez-Padilla et al., 2019). Additionally, in some municipalities affected by the armed conflict, educational policy has prioritized keeping students in school even more than performance in standardized tests.

The four selected inputs are: amount of electronic equipment *(x1)*, number of teachers as managers *(x2)*, number of teachers in classrooms *(x3)*, and number of students enrolled *(x4)*. The environmental variables are: number of homicides due to the armed conflict *(z1)*; schools' socioeconomic index and culture *(z2)*; education budget *(z3)*; category of the municipality *(z4)* and homicides caused by the armed conflict in neighboring municipalities *(z5)*.

The number of computers has frequently been used as a variable in the literature (Agasisti, 2011; Mancebón et al., 2012). In this study, electronic equipment *(x1)* includes tablets, laptops, and desktop computers in use, reflecting the resources available at the school. The second and third inputs are related to human capital within the school. The teacher managers *(x2)* are those mainly in charge of administrative tasks, coordination and decision-making, and the classroom teachers *(x3)*[16] are those whose main function is teaching. Institutional personnel has been one of the main inputs in educational efficiency research. Some studies distinguish between permanent and non-permanent staff (López-Torres & Prior, 2016) or classify it according to specific functions (Agasisti & Pérez-Esparrells, 2010; Mayston, 2014), whereas others use staff in general without distinguishing among groups (Haelermans & Ruggiero, 2017; Tran & Villano, 2018). Student enrollment is one of the main objectives of educational policy and one of the main inputs in the academic literature (De Witte & López-Torres, 2017; Podinovski et al., 2014); the number of students enrolled in the school was therefore chosen as the fourth input *(x4)*.

The production function is complemented with the environmental variables in accordance with their importance to the educational process as recognized in the literature, and particularly, the manifestation of the armed conflict, the main objective of the study. Specifically, the manifestation of armed conflict taken into account are the homicides caused by the armed conflict. The number of homicides *(z1)* is the most commonly used variable in the literature to measure armed conflict intensity (Gómez Soler, 2016; La Mattina, 2018; Márquez-Padilla et al., 2019; Oyvat & Tekgüç, 2019), mainly because it is associated with other

[16] The number of full-time equivalent hours is not taken into account due to the lack of the data in DANE

manifestations of conflict in its various forms. Note that the presence and intensity of the manifestation of armed conflict in schools largely reflects the depth of the conflict in their populations (Ariza-Ortiz et al., 2018), since in some cases schools have been used as recruitment or operation centers (Romero Medina, 2013). Thus, for example, in Colombia between 1996 and 2003, 71 schools suffered attacks from various groups (Novelli, 2010) that directly affected their infrastructure. In our application, the relevant variable is defined as the sum of the homicides in the municipality divided by the total population of that municipality.

Municipal efficiency estimation is done in two steps. First, variables are generalized at the school level, using data from students who complete the evaluation process of Saber 11. This is then used to compute the estimation with the average of all the schools in a given municipality, for each of the 912 municipalities. Conflict and municipal development serve as environment control variables.

The third environmental variable, the average of the socioeconomic and cultural index *(z2)* of the schools is used, which is calculated by constructing a latent variable, estimated through a multiple correspondence analysis (Tenenhaus & Young, 1985), and taking into account the parents' educational level and the socioeconomic level of the household. This variable has been used repeatedly in previous studies (Cordero et al., 2017; Giménez et al., 2017). The variables related to the educational budget *(z3)* and the municipal category *(z4)* are selected following Cordero et al. (2018), who find that the differences in the estimates between different countries are explained by environmental variables related to economic indicators.

Table 3.5. Descriptive statistics of the variables included in the conditional model for municipalities

Variables	Description	Average	Q1	Q3	Standard Deviation	Source
Output						
y1: global score	(Sum of the global score / Number of students Saber 11) * Educational institution enrollment	13,272.58	7,527.55	17,523.33	7,629.95	ICFES
y2: successful students	Number of students who pass the school grade	509.88	281.88	689.81	289.77	DANE
Input						
x1: electronic equipment	Number of tablets, desktops, or laptops in use	139.62	63.78	175.22	113.86	DANE
x2: teachers in management roles	Number of teachers who carry out management, planning, coordination, administration and orientation tasks	2.34	1.80	3.00	0.87	DANE
x3: teachers	Number of teachers in educational work in classrooms	24.20	15.98	30.95	10.74	DANE
x4: enrollment	Total number of students enrolled in the educational institution	587.05	321.70	800.98	340.24	DANE
Environmental variables						
z1: homicides due to the armed conflict	Number of homicides due to the armed conflict (incidence) / municipal population	364.50	32.84	404.74	597.68	Registro Único de Víctimas - CEDE
z2: socioeconomic and cultural index	Multiple factor analysis of mother's education, father's education, and socioeconomic status at the school level	4.543	4.295	4.728	0.400	ICFES
z3: educational budget[17]	Total transfers from the Central Government for education. Current weights. (millions of current pesos)	$ 10,315M	$ 291M	$ 1,194M	$ 69,001M	DNP - CEDE
z4: municipal category	Characterization of the municipality based on six factors: urban-regional, economic dynamics, quality of life, environment, security, and institutional performance	NA	NA	NA	NA	DNP - CEDE
z5: homicides due to the armed conflict in neighboring municipalities	Number of homicides due to the armed conflict (same as z1) in neighboring municipalities	310.59	49.49	421.61	376.82	Registro Único de Víctimas - CEDE

Source: self-devised.

Finally, to capture the spatial effects of the armed conflict, in addition to the variables mentioned above, we consider homicides *(z5)* in neighboring municipalities. The conflict and education literature reveals that the geographical differences among territories are important and significant to explain the impact of the armed conflict on the educational system or the relationship between them

[17] The budget of the General Participation System is taken into account, which depends on the population served, social equity, and efficiency. (More information https://www.dnp.gov.co/). In other words, the variable is in relative terms like the other environment variables.

(Gómez Soler, 2017; Merrouche, 2011; Valente, 2014). Table *3.5* shows the definition, source and main descriptive statistics of the variables used to estimate the robust conditional models.

3.5.2 Empirical strategy

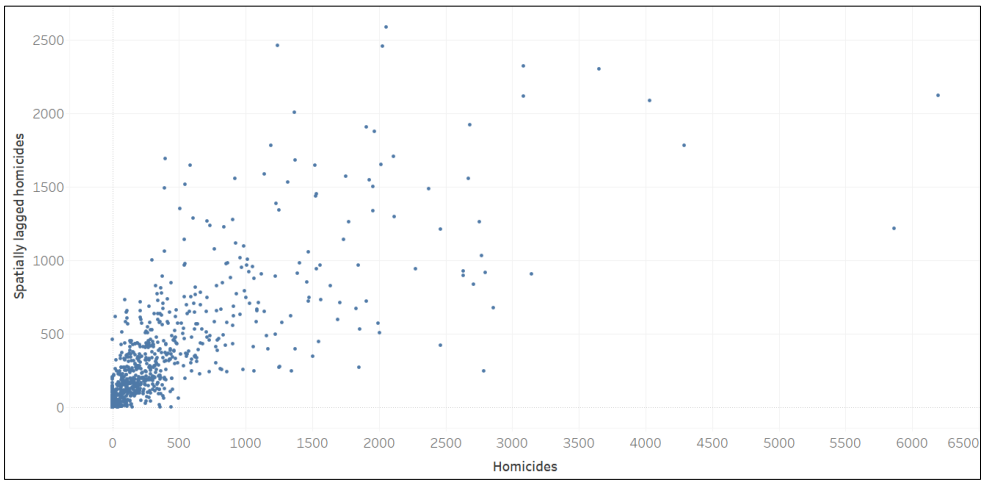
This subsection details relevant characteristics regarding the unit of analysis, together with conflict variables that are temporally and spatially lagged in the empirical application. The academic literature has used multiple units in efficiency analysis in the education sector. In general, due to the nested structures of the sector, the tendency is to carry out studies with the greatest possible disaggregation (Thieme et al., 2013). In our case, although we have the option of choosing the school as the unit of analysis, we selected the municipality due to the limitation of the databases providing the relative information on the environmental variables at the municipal level.

The armed conflict literature finds that its relationship with education goes beyond the short term (Gates et al., 2012), which has meant that most studies include variables that are temporarily lagged to better approximate the problem. Because y2 takes into account students at different stages of the educational cycle, their exposure to conflict varies. For this reason, in this study we consider that the conflict affects children six years before the evaluation. There are three reasons for this decision. First, it is equivalent to the complete educational cycle[18] of secondary education (4 years) and secondary education (2 years) in Colombia. Second, it is possible to capture years with greater intensity in the conflict before

[18] The educational system in Colombia consists of initial education, preschool education, basic education (primary five grades), secondary education (four grades), upper secondary education (two grades ending with a baccalaureate diploma), and higher education.

the signing of the peace process in 2016. And third, this type of lag is supported in the literature; similar lags have been used in studies related to conflict and educational performance: five years (Gómez Soler, 2017) when the effect was studied in Colombia, and 15 years in Turkey, referring to the number of years of the educational cycle (Kibris, 2015) in that country. Based on the above and due to the different exposures of the students at different times of the process, a Colombian student in their last year of study will have had an average exposure of 12 years from entering secondary education until they take the Saber 11 standardized test. Likewise, a student who enters the first year of secondary education has had an exposure of 6 years. Therefore, we decided to lag the variable 9 years (12 years maximum exposure and 6 years minimum exposure).

Figure 3.1. Spatial autocorrelation of homicides caused by the armed conflict



Source: self-devised.

The relationship of the local armed conflict to the armed conflict of neighboring municipalities both globally and locally is not distributed evenly at the geographical level, which suggests the conflict may have a "spillover" relationship with nearby municipalities and thus with their educational performance. For this reason, the Moran Test (Moran, 1950) was carried out to test whether there is

spatial self-correlation between the homicides (z1) caused by the armed conflict in the municipalities and those in their neighbors (municipalities that share a border). The results show a significant relationship, motivating the inclusion of these spatially lagged variables as environmental variables (z5), through physical neighborhood matrices of the municipalities. Note that the only spatial approximation in this type of efficiency model is that of Ramajo et al. (2017). Figure 3.1 shows the spatial correlation between homicides in a municipality and that of its neighbors. In this graph, you can see a high correlation (73.45%), positive and significant between the two variables.

3.5.3 Results

In this section, the efficiency estimates are shown through the methodology described in section 3.4. To estimate an *order-m* model, the value of the parameter *m* must be determined, which is the size of the partial frontier. This is the number of municipalities drawn at random with which each municipality is compared. In our case, it was determined at 100, since this is the number with which there is 10% of super-efficient units in the unconditional estimation (Bonaccorsi et al., 2006; Felder & Tauchmann, 2013). The value of the parameter *b* necessary for statistical inference was set at 500, which is higher than 200, the most commonly used parameter in the literature (Thieme et al., 2013). The orientation toward output is because, in general, managers do not have the power to reduce their inputs, but rather their objective is to maximize performance with the given resources. Additionally, it is the recurrent focus in academic literature (Arbona et al., 2021; Giménez et al., 2017; Thieme et al., 2013).

Table 3.6. Descriptive statistics of the results of the (in) efficiency estimation models.

Deciles	Unconditional model 1	Conditional model 2	Conditional model 3
Mean	1.4025	1.4020	**1.4038**
SD	0.5619	0.5695	**0.5684**
Min	0.5690	0.5575	**0.5450**
Q1	1.0195	1.0212	**1.0191**
Median	1.2574	1.2537	**1.2595**
Q3	1.5984	1.5894	**1.6026**
Super-efficient units	97 (10.64%)	103(11.29%)	**132(14.47%)**

Source: self-devised.

For this study, three estimations are made: first, an unconditional estimation (model 1); second, a conditional estimation taking into account both variables related to the armed conflict and the general context to control the state of the municipality (model 2); and third, a conditional estimation that only takes into account the general context variables, but not the variables related to the armed conflict (model 3). The general results of the estimation are shown in Table *3.6*. The first column shows the unconditional estimate, which does not impose the limitation of similarity of environmental variables in the comparison between municipalities. The second column considers the homicides caused directly by the armed conflict, the socioeconomic and cultural index, the educational budget, the category of the municipality, and the level of conflict of the neighboring municipalities are also included.

The average efficiency level for the unconditional model is 1.4025. That is, if all the municipalities performed as well as the best peers, regardless of their environmental conditions, they could increase their test scores and the number of students who pass the exam by 40% without using a higher level of inputs. Likewise, conditioned model reflects average efficiency values of 1.4020,

showing a potential improvement of 40%. Table *3.6* does not show large differences at the global level in the averages between the different models.

Table 3.7. Ranking of municipalities according to their average efficiency conditional model.

Rank	Municipality	Conditional model 2
898	Puerto Triunfo	3.1641
899	Buenavista	3.2917
900	Sitionuevo	3.2999
901	Rosas	3.3971
902	San Zenon	3.5779
903	Guaranda	3.5842
904	San Juanito	3.8314
905	El Roble	4.0296
906	Chaparral	4.0666
907	Barrancas	4.1368
908	Pore	4.1450
909	Nilo	4.5396
910	Bosconia	4.5445
911	Manaure	4.7295
912	Simiti	5.7911

Source: self-devised.

In turn, Table *3.7* shows the ranking of municipalities that have the highest relationship in a negative way between armed conflict and educational efficiency. The analysis is carried out with the conditional model since it is used to determine the influence of the environmental variables through a non-parametric regression. First, large differences are shown between the municipalities. Second, values in the coefficient higher than unity are obtained; that is, for the most related municipalities there is a potential improvement of up to 479%[19].

As mentioned above, to determine if the environmental variables are significant, we performed a non-parametric regression of the ratio between the unconditional model and each of the conditional models. Table *3.8* presents the *p-values* of each of the variables. Significance tests were carried out following those proposed by Li and Racine (2008) and Racine and Li (2004). The model includes

[19] This value is obtained by comparing the estimated inefficiency value of the Simiti municipality (5.7911) with the efficiency value (1.0000) and converting the result into a percentage (5.7911-1.0000=4.7911).

the measurement of the armed conflict through the number of homicides, where high significance is shown for the homicides of the municipality analyzed and those of its neighboring municipalities; significance is also observed in the socioeconomic and cultural index.

Table 3.8. Influence of environmental factors on educational performance

Variables	Conditional model 2 p-value
z1: homicides due to the armed conflict	0.0040
z2: socioeconomic and cultural index	0.0860
z3: educational budget	0.5680
z4: municipal category	0.9840
z5: homicides due to the armed conflict in neighboring municipalities	0.0810

Source: self-devised.

Three findings can be deduced from the above results. First, homicides caused by the armed conflict have relationships with efficiency in education. Second, both the conflict in the municipality and that in neighboring municipalities are related to the educational efficiency of the municipality under analysis, meaning geographic variations are relevant. Third, the importance of socioeconomic indicators *(z2)* is highlighted, in line with previous studies (Cordero et al., 2018; Cordero et al., 2017).

Taking into account the significance of the conflict variables in the non-parametric regression, the analysis is clearly relevant. However, it is not possible to determine the magnitude of the difference in educational efficiency between those municipalities that operate in the presence of armed conflict and those who do not. For this reason, we estimate an additional conditional model, which takes into account only those variables used in the estimation that do not measure the armed conflict (model 3), and then a ratio between the previous conditional

models and the new estimate, to calculate the net magnitude of operating or not operating in an environment with armed conflict.

Table 3.9. Results of the 15 most negative related municipalities, by magnitude, operating in an environment with armed conflict

Rank	Municipality	Model 3	Model 2	Ratio Model 3/ Model 2
1	Padilla	0.9199	0.6901	1.3329
2	Valparaiso	1.0000	0.7615	1.3132
3	Saboya	1.4000	1.2470	1.1227
4	Gameza	1.4831	1.3245	1.1197
5	Enciso	1.6310	1.4613	1.1162
6	Boyaca	1.4103	1.2706	1.1099
7	Sacama	2.0851	1.8965	1.0994
8	Jurado	2.2748	2.0699	1.0990
9	Cumbitara	0.9979	0.9119	1.0943
10	Purace	1.9910	1.8203	1.0938
11	El Aguila	0.9997	0.9161	1.0913
12	Mongui	1.7114	1.5699	1.0901
13	San Jose del Fragua	0.9144	0.8505	1.0751
14	Taminango	0.9069	0.8443	1.0742
15	Caceres	2.1327	1.9861	1.0738
	Average (all municipalities)	1.4038	1.4020	1.0012

*Model 2: y_1, y_2:x_1, x_2, x_3, x_4 |z_1, z_2, z_3, z_4, z_5.

*Model 3: y_1, y_2:x_1, x_2, x_3, x_4 |z_2, z_3, z_4.

Table *3.9* presents the results of the ratio between models 2 and 3, reporting the top 15 affected municipalities by magnitude. The results show that operating in an environment where homicides due to armed conflict are present coincides with a fall in efficiency of up to 33% in the most affected municipality. In general, potential improvement is less than 1%; less developed municipalities on average have a greater potential deterioration due to the armed conflict.

Taking into account the results of previous tables, the four most important findings of this research are as follows: first, armed conflict is relevant and significant when analyzing educational efficiency; second, both the armed conflict of the municipality under analysis and that of its neighbors is relevant and significant;

third, municipalities behave differently; and fourth, there is a potential loss of efficiency of up to 33% in the most affected municipalities.

3.6. Conclusions

Educational efficiency is a topic of intense debate in multiple areas, both academic and political and some points on the importance of education are common across the world. First, education has been recognized as a priority due to its social externalities (McMahon, 2004). Second, measurements through standardized tests are accepted as a good way to measure the quality of schools (Cordero et al., 2018). Finally, analyses made using comparative evaluations with estimations based on efficiency techniques provide results with practical implications for management and help decision making in educational policies.

This article uses robust non-parametric conditional models to evaluate the relationship between the armed conflict and the efficiency of education in Colombia, based on the standardized Saber 11 tests and school pass rates. This is done by applying methodologies developed by Daraio and Simar (2005, 2007a, 2007b) to explain the heterogeneity between different contexts, without the need to assume separability. This is the first approach in the academic literature to analyze the relationship between this type of conflict and educational efficiency. Therefore, although the results contribute to the knowledge in this field of research, more studies are needed to better understand the behavior of such a complex problem.

Four important conclusions can be drawn from the study. First, including problems related to armed conflict in analyses of educational efficiency is shown to be relevant. Second, the municipalities with the greatest intensity in the conflict

have, on average, lower levels of efficiency. Third, both the conflict in the territory under analysis and in neighboring municipalities is significant when evaluating the relationship between the armed conflict and educational efficiency. Finally, this relationship is associated with low economic and social development, since a municipality with a lower level of development, on average, is more affected by the armed conflict.

Decision makers and policymakers must take into account the difference in results between municipalities. It is also important to develop specific territorial development policies, in which the interactions between different environmental variables are considered, since, although there is evidence of a relationship with armed conflict, this is a first approximation, and we have yet to understand how this problem interacts with different environments. Policy makers must consider several factors; however, the environments in some municipalities are so challenging and they have experienced violence for so many years that any change is difficult to implement. This possibility should be taken into account and policy makers should attempt to improve efficiency through inputs as much as possible. One of the most effective ways in many countries is through public-private alliances or cooperation agreements between institutions in the same territory. Budget allocations can also be made to factor educational institutions' efficiency into their process. Finally, public policy must make every effort to maintain peace agreements with demobilized groups, since, apart from the immediate social benefits, they help to improve the efficiency of education systems.

The approach taken in this study is important for research on educational efficiency. However, deeper analysis of the problem discussed is needed, mainly

by exploring four limitations of the study. First, because the results in the Saber 11 standardized test are used as representative of the entire school, other educational levels should be taken into account, if relevant. Second, an average analysis was performed for one period; extensions should therefore monitor students or schools over time to test cumulative effects. Third, other environmental variables that have been significant in similar studies could be incorporated, such as cultural indicators or institutional and educational sector variables. Fourth, future approaches could combine quasi-experimental methodologies, thus allowing researchers to isolate the causal effect of the armed conflict on the efficiency levels by controlling the potential bias caused by endogeneity problems (Santín & Sicilia, 2018), which would allow inference of causality conclusions.

CHAPTER 4

ALTERNATIVE SOURCES OF FUNDING AND THEIR EFFECTS ON EDUCATIONAL EFFICIENCY: THE CAUSAL IMPACT OF THE *AULA GLOBAL* PROGRAM ON PERFORMANCE

4. Alternative sources of funding and their effects on educational efficiency: the causal impact of the *Aula Global* program on performance

4.1. Introduction

Education is a priority mainly because of the externalities it presents in terms of well-being (McMahon, 2004; Wolfe & Haveman, 2002), labor productivity (Mankiw et al., 1992) and economic development (Hanushek & Woessmann, 2008). Globally, it is at the center of the 2030 Sustainable Development Goals (SDG) agenda, where a commitment is made to "guarantee inclusive, equitable and quality education and promote lifelong learning opportunities for all" (PNUD & UNESCO, 2015). Educational efficiency is a subject of intense political, social and academic debate (De Witte & López-Torres, 2017). In recent years, concern has grown due to the increase in education costs (Eurostat, 2014) and the high rates of private financing in developing countries (Aksoy, 2015). It is therefore important to ensure that education spending is carried out with a high level of efficiency and that it has a positive effect on improving quality.

In general, responsibility for spending on education lies with the government (Rahman & Uddin, 2009); however, private organizations have increased their contributions, particularly in developing countries (Aksoy, 2015). It is therefore, essential to understand this type of initiative for economic and social development (Gibson & Davies, 2008) and inequity (Tran & Villano, 2018). Furthermore, the SDGs involve companies in accelerating development (Rosati & Faria, 2019); for example, the United Nations Global Compact report highlights that 51% of companies participate in public-private partnerships (United Nations, 2018).

However, in many of these initiatives, it is a challenge to reach agreement on evaluation metrics and data collection (Rosati & Faria, 2019), and the evidence with which to evaluate results is scarce (United Nations, 2018, p. 19).

According to Mizala and Urquiola (2013), interest is growing among both academics and policymakers in evaluating and generating reliable results from private sector participation in education. One of the reasons for this interest is the high involvement of private organizations in social services; for instance, between 1960 and 2002, donations in the United States increased by 300% (Andreoni, 2006). In the case of Colombia, the Information System of Public-Private Investment in Education (SIIPE) lists more than 500 programs or projects, from 137 private organizations and in 3,825 schools aiming to close the gaps between public and private education in a context of inequality and high private household spending that hinders improvements to well-being (OECD, 2006).

Different types of programs have been used to improve aspects such as educational quality, enrollment, attendance, etc., through public policies and private organizations. For example, scholarships (Kondakci et al., 2014; Yilmaz, 2013), monetary incentives, vouchers and conditional cash transfers (Angrist, Bettinger, & Kremer, 2006; Barrera-Osorio, Bertrand, Linden, & Perez-Calle, 2011) show consistency with positive effects on performance. In addition, coupon programs (Muralidharan & Sundararaman, 2015), class size reduction (Duflo et al., 2015), and additional funding (Leuven et al., 2007) are promoted by governments to reduce the impact of socioeconomic status. However, tutoring is one of the most commonly used program types, and that has shown the most significant effectiveness, especially in the primary grades (Lauer et al., 2006).

Lauer et al. (2006) performed a meta-analysis of 35 studies that use Out of School Time programs, where a positive effect is found in reading and mathematics and a more significant impact in specific programs. Peer-tutoring models are also sometimes used (Dineen et al., 1977), and have shown positive results for both the tutor and the students, highlighting a slight difference in effect between children instructed by the tutor and those by their peers. Finally, although tutorials are used and recognized among educational programs as having their positive impact and methodological robustness, a greater understanding of the interventions is needed (Forsman & Vinnerljung, 2012).

The objective of this study is to evaluate the causal impact of the *Aula Global* program on school efficiency through an innovative procedure (De Witte & Smet, 2018) combining literature on the evaluation of social policies (Abadie & Cattaneo, 2018) and efficiency (Simar et al., 2016). Following the approach of De Witte and Smet (2018), this study assesses for the first time, to the best of our knowledge, the causal impact on educational efficiency of a program (*Aula Global*) financed by private organizations. Importantly, the impact evaluation also takes into account multiple outputs and inputs, an aspect not considered in the policy or program evaluation literature. In the line of research, there are three studies that have the same approach, where in the first stage discontinuous regressions and differences in differences are estimated to control endogeneity, and later, Order-m models or Malmquist index are used to estimate the efficiency or productivity (D'Inverno et al., 2020; Feliciano et al., 2021; Mergoni & De Witte, 2021).

The empirical application of this study is carried out by evaluating the effects of the Carvajal Foundation's *Aula Global* program on the educational efficiency of

6455 students in 25 schools in Cali, Colombia. It specifically evaluates the impact of tutoring for students who lag behind academically in primary education in disadvantaged socioeconomic contexts. Many programs are implemented around the world to close socioeconomic gaps and increase educational quality because the socioeconomic level of students is recognized as one of the main determinants of their results (Agasisti et al., 2018; Thieme et al., 2013).

The present empirical application follows the production function proposed by Hanushek (1979), where outputs are obtained based on multiple inputs. Here it is necessary to clarify that, in both educational efficiency and effectiveness, ambiguous results have been found following the same basis as a production function; these contradictory findings are attributed, on many occasions, to endogeneity problems (Jackson et al., 2016). This generally happens for multiple reasons (Cordero, Santín, et al., 2015; Simar et al., 2016); in the educational sector, it is frequently associated with self-selection, innate ability and student motivations. In light of the above, it is important to note that the methodological treatment used in the present study is robust since it controls endogeneity through the proposed design.

The main result of the present study is to find evidence about the *Aula Global* program positively affects the efficiency of students who are lagging behind. The study's main contribution lies in its empirical application, which combines social policy and efficiency methodologies. Additionally, it addresses calls in the literature for evidence on the effect private contributions have on educational quality.

This study is organized into five sections. This introduction is followed by a literature review (Section 4.2). Then the *Aula Global* program and the context in

which it takes place are presented (Section 4.3). This section is followed by a description of the methodological aspects and an explanation of the three steps of the suggested approach to handle endogeneity problems in evaluating efficiency programs, combining economic impact evaluation techniques and efficiency analysis tools (Section 4.4). The empirical application is then presented, including an explanation of the databases used, the inputs, outputs and environmental variables (Section 4.5). The main results are reported (Section 4.6) and finally, the main conclusions and recommendations for educational policy are detailed (Section 4.7).

4.2. Literature review

This literature review mentions the two main research perspectives on educational issues: efficiency and effectiveness. An evaluation of the efficiency of a program like *Aula Global* is noteworthy because it is innovatory in the literature. The types of private initiatives are then explained, according to their objective of analysis. The section ends with a general description of the essential characteristics of Out of School Time programs, the type of program *Aula Global* belongs to.

The role of education in economic and social development has led numerous public and private actors to focus on its operation, management, and results (Hanushek & Woessmann, 2008), mainly due to individual and collective externalities. Both governments and private organizations have developed and promoted policies to reduce the impact of socioeconomic status on educational performance (Duflo et al., 2015; Muralidharan & Sundararaman, 2015). In turn, because of its relevance, education receives funding from both the public and

private sectors, as well as non-governmental organizations (NGOs); however, regardless of their source of funding, the evidence for measuring their effects is insufficient (Kumari, 2016).

Generally, educational outcomes are studied from two points of view: efficiency (meaning doing things right) and effectiveness (meaning doing the right things) (De Witte & López-Torres, 2017), among which a balance is important for the creation of educational policies (Aparicio et al., 2022; Cherchye et al., 2019; OCDE, 2006). In this line of research, most studies on policy evaluation have to date focused on studying the impact on effectiveness because of the techniques used to control for the problems of endogeneity (Abadie & Cattaneo, 2018). However, following De Witte and Smet (2018), experimental or quasi-experimental techniques can be applied in the first stage to control for the effects of endogeneity, and the results obtained with efficiency techniques can be interpreted causally and not just relationally.

The *Aula Global* program is led by a private organization in cooperation with educational sector institutions. The program falls into what are known in the literature as school-based interventions, since their objective is to improve their community (student, family, teachers, managers, and environment). In this research line, the literature reports multiple types of privately financed contributions with different objectives and scopes; however, following Arbona (2018), six types can be identified according to their objectives: access and permanence, information and communication technologies (ICTs), academic programs, and those related to the quality of teachers, school management and pedagogical innovations.

Initiatives focused on student access and retention are mainly divided into two groups. The first group includes infrastructure-based initiatives, generally designed to expand coverage (Amjad & MacLeod, 2014). The second group focuses on reducing attendance costs (Pugatch & Wilson, 2018). In their review of 39 studies analyzing the impact of infrastructure on school performance, Cuesta et al. (2016) conclude that roofs, walls, and floors in optimal conditions help improve learning. On the other hand, initiatives designed to increase access and permanence by reducing costs offer positive evidence for an impact on attendance (Pugatch & Wilson, 2018), but not on school performance (Ganimian & Murnane, 2016). The main ways to execute this type of initiative are through free lunches (Conroy & Arguea, 2008), scholarships (Kondakci et al., 2014; Yilmaz, 2013) and monetary incentives, vouchers and conditional cash transfers (Angrist, Bettinger, & Kremer, 2006; Barrera-Osorio, Bertrand, Linden, & Perez-Calle, 2011).

The literature reports mixed results for contributions that implement information and communication technologies, depending on their use. When they are directly involved with teaching practice, positive results are reported in academic performance (Comi et al., 2017); however, when they are used by students in the classroom, negative effects are obtained (Kim, 2018). As for the next type, interventions that focus directly on academic issues, these are studied from a psychological approach (Barry et al., 2017; Mychailyszyn, 2017), and implement activities that develop students' civic and socio-emotional competencies.

The contributions associated with the quality of teachers are studied due to their importance as a determinant of educational performance (Hanushek, 1979); however, the evidence of the results is ambiguous (Amjad & MacLeod, 2014;

Angrist et al., 2013). One of the main ways this type of contribution is implanted is through monetary incentives to attract qualified human capital (De Talancé, 2017). In addition, the contributions that focus on school management have yielded robust results, concluding that quality management is associated with better educational outcomes (Bloom et al., 2015; Crawfurd, 2017). However, it should be noted that these results depend on managers' autonomy in their administrative functions, salaries, and other aspects (Schutz et al., 2007).

The last type of private contribution is directly related to pedagogy, which, as mentioned above, in addition to contributing to academic improvement, stands out for its low cost (Glewwe & Muralidharan, 2016). The effect of pedagogical innovations on school performance is ambiguous (Lauer et al., 2006); when long-term tutoring or remedial education programs are applied, a positive impact on effectiveness is observed (Banerjee et al., 2007; García-Pérez & Hidalgo-Hidalgo, 2017). Notable among the tutorials or remedial education programs are the so-called Out of School Time (OST) programs, which have been used by public and private institutions to complement the education of low-achieving students with extracurricular programs or summer schools (Lauer et al., 2006).

Because *Aula Global* has the characteristics of an OST program, the final part of this literature review will mention its importance, its main effects, and the moderators of this type of program on educational effectiveness. More in-depth information can be found in Lauer et al.'s (2006) rigorous meta-analysis of 35 studies that analyze different types of programs designed to improve effectiveness in mathematics and reading, where mixed results have been found.

Kugler (2001) affirms that OST programs have increased for three main reasons: first, the lack of caregivers in the home after school; second, as an attempt to

give opportunities to children with disadvantaged social backgrounds, to improve their academic performance and their level of learning; and finally, the high incidence of crimes committed by adolescents after school. Additionally, this type of program has been found to help prevent crime and drug use in young people and adolescents. Furthermore, Fashola (2002) suggests that they help improve the socialization process of school-age children. Finally, Lauer et al. (2006) affirm that the emphasis on this type of program is due to the failure of social institutions to support children, specifically in the family and school environment.

Some of the main findings of the OST programs are as follows. First, children in low-income families have a greater need for after-school programs and are therefore more likely to benefit than children from middle-income families (Cosden et al., 2001; Jones & Christian, 2020). Second, the lower the children's academic performance at the beginning of the program, the more significant the benefit is likely to be. Also, the greater the frequency of attendance, the greater the benefit (McComb & Scott-Little, 2003). Third, effectiveness does not differ significantly between after-school programs or summer schools (Lauer et al., 2006).

Likewise, Lauer et al. (2006) find some results of interest to researchers and policymakers in education. First, coinciding with the studies by Lindo et al. (2018), these authors show positive and significant evidence of OST programs in reading. Second, they affirm that program timeframes do not lead to differences in effectiveness. These findings therefore suggest efforts should be focused on the management of recruitment or location of the program. Third, there is a positive effect on reading in both primary and secondary schools; however, for mathematics, the effect is only significant in secondary schools. Fourth,

suggestions have been made to complement programs with social activities, since they have a positive effect on performance, usually by enhancing children's development (Halpern, 2002). Fifth, the duration of the program depends on the content area: longer programs do not necessarily have a greater effect. Additionally, Budd et al. (2020) find that longer participation in extracurricular programs is associated with greater growth in multiple outcomes. Likewise, age, executive functioning, and caregivers who control participation in schoolwork are identified as moderators in the functioning of tutoring (Hickey & Flynn, 2019).

Extracurricular programs are commonplace in many countries and mainly focus on improving students' educational process; however, the purpose of all the evaluations we are aware of is to analyze the impact on students' effectiveness, not efficiency. De Witte and Smet (2018) carry out the only methodologically robust evaluation that investigates how efficiency is impacted through a program, proposing an innovative approach to evaluate the Equal Educational Opportunity (EEO) program in Flanders, which combines impact assessment techniques and efficiency analysis techniques. Note that the present study is based on the methodological proposal of De Witte and Smet (2018). However, there are significant differences in first stage of the methodology, in which endogeneity is controlled for, and the type of program evaluated.

Finally, the literature review leads to two conclusions that help to highlight the gap covered by this study. First, evaluations of programs, such as *Aula Global*, are relevant to help private organizations make decisions about their contributions to the education system. Second, this is the first methodologically robust assessment of how efficiency is affected by a program funded by private organizations.

4.3. Context and the Aula Global program

4.3.1 Context

Cali is the capital of the department of Valle del Cauca, in Colombia, the third most important city in the country and the first in the Pacific region. In 2017, according to the National Planning Department, it obtained 77.2 (out of 100) points in the economic and social performance index, only below Bogotá and Medellín. Cali has a population of approximately 2.2 million people, of whom about 17% are of school age. In the urban and rural areas there are 993 schools; 350 belong to the public sector. The educational cycle in Colombia runs from preschool, through basic (primary five years and secondary four years) to middle (two years) education.

In Cali, the objective of policymakers and private organizations is to improve both coverage and educational quality. One example of this is the *Aula Global* program, in which the Carvajal Foundation, in line with its mission "as a non-profit institution, which wants to promote the improvement of the quality of life of the neediest communities in the prioritized territories of Cali and Buenaventura" (for more information, see https://www.fundacioncarvajal.org.co/), works in collaboration with the city's Ministry of Education to help strengthen basic skills in language and mathematics among children from second to fifth grade in the city's public schools.

4.3.2 *Aula Global* Program

The *Aula Global* program is led and run by the Carvajal Foundation. It aims to enhance the skills and competencies in mathematics and language of students

who are lagging behind, responding to social, cultural, and educational dynamics such as dropout, repetition, and school absenteeism in the most affected communities in the city of Cali. The program was developed between 2017 and 2021, and comprised four stages: exploration, enlistment, implementation and evaluation, and monitoring.

In the first stage, experiences of similar programs in the country were identified as references, exploratory visits were made, and a pilot test was run, aiming to apply, validate and refine the methodology for strengthening language skills in three schools in Cali. In the second enlistment stage, alliances were managed, the eligible schools were chosen, and the team that would run the program was approached and trained. The schools selected as eligible met three criteria: they were public schools, serving primary school students in a vulnerable situation, and they were located in areas of influence of the Carvajal Foundation (a large area in the city of Cali mainly covering vulnerable populations). Finally, the schools where the tutorials would be carried out were selected through a random lottery, and the directors of the institutions were contacted to present the program and verify their willingness to participate.

To finalize the enlistment stage, the team was selected and trained. The Carvajal Foundation defined two roles within the team, the pedagogical advisers and the tutors, to guarantee the proper development of the program. The role of the pedagogical advisers is to design and guide the program conceptually and methodologically, in addition to guaranteeing communication between managers, teachers, tutors, and the Carvajal Foundation. All the tutors are professionals with experience in teaching vulnerable populations; their main objective is to strengthen the language and mathematics skills of these students.

Table 4.1. EGRA and EGRA tests. Subtests and number of questions according to the level of education

Test	Sub-test	Grade 2 - 3	Grade 4 - 5
EGRA	Letter sounds	50	-
	Made up words	50	-
	Reading a passage	132	164
	Understanding passage	5	5
	Oral compression	4	4
	Total questions	241	173

Test	Sub-test	Grade 2 - 3	Grade 4 - 5
EGMA	Comparison of numbers	10	-
	Missing numbers	10	10
	Sums	25	25
	Subtraction	27	27
	Problem solving	-	5
	Total questions	72	67

Source: self-devised.

The implementation stage is divided into three phases: training of the operational team, characterization and pedagogical implementation, and accompaniment. First, tutors are trained in relevant technical and social topics, for example, language, mathematics, inclusive education, teamwork, EGRA, and EGMA methodology. In turn, the characterization phase implies awareness of the initial conditions of the schools and students. All the schools lie within the territories of inclusion and opportunities suggested by the “Development Plan 2016 - 2019, Cali progresses with you”; these territories are characterized by high rates of homicides, infant mortality, infant malnutrition, school dropout, a high number of victims of the armed conflict, among other social indicators.

Likewise, the students are characterized through the baseline of the EGRA (Early Grade Reading Assessment) and EGMA (Early Grade Math Assessment) tests, internationally validated as a standardized test, to obtain information on their language and math skills, respectively. These tests are divided by components,

where specific aspects of each area are evaluated, and in turn, differ by type of grade evaluated, as shown in Table *4.1*.

The baseline application is carried out at the individual level and administered by a previously trained group. With the baseline results, and according to Decree 1290 of 2009 of the Ministry of National Education, students are categorized into four performance scales: low, basic, high, and superior. For the year 2019, the EGMA and EGRA tests were applied in 25 schools; in the baseline, 6963 students were taken into account, and after discounting the students who drop out, the final line was applied to 6455 students. After applying the baseline, students with low performance became eligible to join the treatment group, which consists of one-hour tutorials twice a week for 20 weeks. The objective is to work on the language and mathematics skills of students who are lagging behind.

Participation in tutorials involves mechanisms for learning through games, and avoids judging students. In addition, the tutors take into account three fundamental elements: first, return to the students' context; second, use play as the main axis; and third, enable students to achieve different types of performance. Finally, the last phase consists of evaluation and monitoring, in which tutors, students, teachers, and managers are questioned about the progress of students in the program.

4.4. Methodological procedure

In this research, a methodology divided into three stages is used to calculate the causal impact of the *Aula Global* program on educational efficiency, following the application of De Witte and Smet (2018). First, drawing from methodologies related to the program evaluation literature, a randomized controlled trial design

is applied, since its experimental design allows endogeneity problems to be controlled for and causality can be inferred in the students' efficiency estimates, which is relatively novel in this area of the literature. Second, efficiency is decomposed to identify managerial efficiency and program efficiency across partial boundaries. Finally, a robust conditional model is applied to explore how environmental variables potentially affect student efficiency.

4.4.1 Randomization controlled trial

In the first stage, the *Aula Global* program implemented in 2019 allowed a randomized controlled trial, in which 6455 students from 25 schools participated, all of whom met the participation criteria described above. This trial was run, first, to control for endogeneity, and second, to isolate the impact of the intervention (Schlotter et al., 2011). In 2019, 25 schools were randomly selected and the EGRA and EGMA tests were applied; with these results, 707 low-performing students were selected and assigned to the treatment group. Note that the evaluation was not carried out in the other years during the program due to slight changes in implementation (years 2017 and 2018) or to radical changes due to the Covid-19 pandemic (2020 and 2021).

The program design involves three activities: first, the application of baseline tests; second, development of tutorials; third, final test application. The baseline results are used to select 48 poorly performing students from each school to enter the tutoring program (treatment), where the objective is to improve performance in language and mathematics through workshops. The 48 students (12 for each school grade from second to fifth) are divided into groups of 6, according to grade, and receive two one-hour tutorials per week for 20 weeks. Life skills workshops

are also included in the tutorials, since they fall within the mission of the Foundation, and according to the literature (Halpern, 2002) they complement the potential improvement in the children's educational performance and development. The design of the program allows the baseline results to be used to compare the students who participated in the tutorials with the other students who did not participate, both from the same schools and from the schools that were not selected for the tutorials, to estimate the causal effect of the program on learning mathematics and reading.

4.4.2 Order-m estimator

Given that in the first stage of the methodology it has been possible to control for endogeneity and define the control and treatment groups, in the second stage, two points are covered: first, the decomposition into managerial efficiency and program efficiency is defined; and second, the *order-m* model is explained, and the formulation is used to calculate student efficiency.

To achieve the decomposition of efficiency using multiple inputs and multiple outputs, a production technology is considered where the student are characterized by a set of inputs **x** $(x \epsilon R_+^K)$ and outputs ***y*** $(y \epsilon R_+^L)$, and a standard production function is considered:

$$\Psi = \{(x, y)\ \epsilon\ R_+^{p+q} | x\ can\ produce\ y\} \qquad \textbf{(1)}$$

where $f(x)$ is the technology through which the level of production is determined for a given level of inputs. However, this function does not take into account possible inefficiencies given in the process (Santín & Sicilia, 2017), so a component is added that considers it μ:

$$y = f(x).\mu \qquad \textbf{(2)}$$

In equation 2, it is understood that the level of production depends on the level of inputs, technology, and management (μ), where $\mu \in (0,1)$; therefore, if μ is less than one, it can be stated that the decision-making unit (DMU) is not utilizing the full potential of its capacity, in other words, there is evidence of mismanagement. On the other hand, if $\mu = 1$, it is understood that the maximum achievable production is being obtained given the available technology.

Each student is evaluated based on best practices following a production frontier approach. In other words, ideally it should be as close to the frontier as possible. According to equation 2, it is understood that the level of production may change due to an increase in the level of inputs, a technological change, or a change in a management capacity. Therefore, the possible relationships between these factors must be considered; for example, possible economies of scale, given an increase in inputs, could affect management capacity. On the other hand, the relationship between multiple inputs and multiple outputs is not linear; therefore, an increase in inputs does not result in an equal increase in all outputs.

Following the formulation of the production process proposed by Cazals et al. (2002), it should be taken into account that intuitively, we want to know the probability that the joint probability function is dominating one of the evaluated units *(x, y)*.

$$H_{XY}(x, y) = \Pr(X \leq x,\ \mathrm{Y} \geq y) \qquad \textbf{(3)}$$

where the joint probability function can be decomposed into $S_Y(y|x)$, which characterizes the survival function of *Y*, and $F_X(x)$, which is the cumulative distribution function of *X*.

$$H_{XY}(x, y) = \Pr(\mathrm{Y} \geq y, X \leq x) \Pr(X \leq x) \qquad \textbf{(4)}$$

$$= \mathrm{S_{Y|X}}(\mathrm{Y} \geq y, X \leq x)\, \mathrm{F_X}(X \leq x)$$

$$= \mathrm{S_Y}(\mathrm{y|x})\, \mathrm{F_X}(x)$$

Following the objective to estimate the efficiency coefficients using the proposed probabilistic formulation, we replace the corresponding empirical distribution, such that we have $\widehat{H}_{XY,n}(x,y)$ for $H_{XY,}(x,y)$ and $\hat{S}_{Y,n}(y|x)$ for $S_Y(y|x)$; these analogies can be expressed as follows:

$$\widehat{H}_{XY,n}(x,y) = \frac{1}{n}\sum_{i=1}^{n} I(x_i \leq x, y_i \geq y) \qquad \textbf{(5)}$$

$$\hat{S}_{Y,n}(y|x) = \frac{\widehat{H}_{XY,n}(x,y)}{\widehat{F}_{X,n}(x)} = \frac{\widehat{H}_{XY,n}(x,y)}{\widehat{H}_{XY,n}(x,0)}$$

where $I(x_i \leq x, y_i \geq y)$ is an indicator function. Note we use the *order-m* $\hat{\lambda}_m(x,y)$ estimator because traditional FDH estimators are sensitive to outliers and extreme values; Cazals et al. (2002) show that these efficiency coefficients have an expression that depends only on their conditional distributions $\mathrm{S}_Y(y|x)$.

$$\hat{\lambda}_m(x,y) = \int_0^{\infty} (1 - (1 - S_Y(uy|x))^m) du \qquad \textbf{(6)}$$

Based on the above, and similar to the FDH case, the estimators for the *order-m* can be obtained by replacing $\hat{S}_{Y,n}(y|x)$ in equation 6, which yields the expression of the unconditional *order-m* estimators:

$$\hat{\lambda}_{m,n}(x,y) = \int_0^{\infty} (1 - (1 - S_{Y,n}(uy|x))^m) du \qquad \textbf{(7)}$$

The previous equation shows the *order-m* estimator. This is a non-parametric frontier method (Cazals et al., 2002; Daraio & Simar, 2005) that can evaluate the efficiency of units taking into account multiple inputs and multiple outputs, without having to assume a functional form (Charnes et al., 1978). These are two methodological advantages over the traditional estimates of the program evaluation literature, in which evaluations can only be carried out by taking into

account one outcome variable. Additionally, it does not assume convexity (Deprins et al., 1984), allowing comparisons with feasible observable units and not with linear combinations. Finally, this estimator is robust against atypical and extreme values since partial frontiers of size *m* are randomly extracted from the global sample for the procedure.

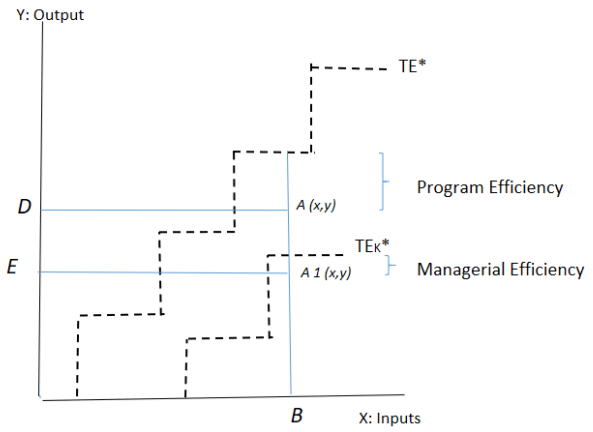
To decompose total efficiency into program efficiency and managerial efficiency, metafrontiers are used to distinguish the effects; this is a frequent process in this literature (Battese et al., 2004; De Witte & Smet, 2018; Thieme et al., 2013). In addition, it is developed taking into account the program evaluation approach in a context of efficiency (Charnes et al., 1981). For the process, the two groups identified in the first methodological phase, the treatment group and the control group, are considered; thus, specific local frontiers are estimated for each group (TE^K) and a global frontier (TE^*), where all the units of both groups are taken into account. The efficiency of the *Aula Global* program is estimated for each DMU of the *K* groups, as follows:

$$Program\ efficiency^K = \frac{TE^*}{TE^K} = \frac{Overall\ efficiency}{Managerial\ efficiency^k} \qquad \textbf{(8)}$$

According to equation 8, there are *k* groups, where $k = \{treatment\ group;\ control\ group\}$, therefore, two distances are estimated: the first one measures the distance from each student to its local frontier, in other words, it measures managerial efficiency, which is associated with internal management within each group. The second distance is estimated between each local frontier and the global frontier, obtaining the program efficiency; this distance can be explained as the effect of being part of the *Aula Global* program. Therefore, this decomposition allows us to know the participation of the program

and the internal management in the efficiency of the students, as reflected in Figure 4.1.

Figure 4.1 Estimated efficiency decomposition (program efficiency and managerial efficiency)



Source: (Picazo-Tadeo & Prior, 2009; Choi et al., 2015)

The change in efficiency of the Aula Global program caused by the decomposition is computed in two steps. First, estimates are made at the global frontier and the two partial frontiers (treatment and control groups). The global estimated distance is then divided by that of the partial frontiers as in Eq. (8), which will then allow us to calculate the effect on the treatment group.

4.4.3 Environmental variable influence

In the third stage of the methodology, we seek to know the influence of environmental variables on student efficiency; in other words, we want to determine if managerial efficiency and program efficiency are affected in any way by the students' environment. To this end, a conditional efficiency framework is used, where the estimates are not only determined by the inputs *(x)* and the outputs *(y)* but the relevance of the environmental variables *(z)* must also be determined.

The educational efficiency literature that seeks to determine the effect or relationship with the environmental variables usually applies two-stage methods (Afonso & St. Aubyn, 2006; Agasisti, 2014; Agasisti & Zoido, 2015; Aparicio et al., 2018; Moreno & González, 2010).Generally, estimation is performed first through non-parametric methods, and later, an econometric model explains how the efficiency levels behave as a function of the environmental variables. Concerning the above, Daraio and Simar (2005; 2007a; 2007b) show that, if the factor separability assumption is not tested, conditional models should be used since they manage to include the environmental variables in a single stage.

The output-oriented conditional order-m efficiency estimator ($\hat{\lambda}^{S}_{m,n}$) can be defined as follows:

$$\hat{\lambda}^{S}_{m,n}(x, y|z) = \int_0^{\infty} \left(1 - \hat{\lambda}_{Y|X,Z,n}(uy|x, z)\right)^{m} du \qquad \textbf{(9)}$$

where $S = \{treatment\ group; control\ group\}$, *x* are the inputs, *y* are the outputs, and *n* is the sample size. As mentioned above, resampling is likely to give rise to "super-efficient" units since the observations can be compared with linear combinations of the reference set. To make this estimation, smoothing techniques must be adopted in the computation of conditional efficiency estimators for the exogenous variables in *z.* To this end, the non-parametric kernel function is estimated to select the appropriate reference pairs with which the comparison will be made. Additionally, a bandwidth parameter *h* is needed; the Li and Racine (2008) option is selected because it has the advantage of detecting and smoothing out irrelevant factors by providing large bandwidth parameters. The environmental variables added to the conditional estimation, unlike the analysis made through equation 7, are to control for the heterogeneity

of the context of the different students. Additionally, they provide more information to achieve more precise estimates and compare the differences between the two results.

Finally, following the approach of Badin et al. (2012), the ratios of the conditional and unconditional *order-m* estimators are analyzed to determine the impact of the context variables *(Z)* on the frontier:

$$\lambda_m^{S,Z} = \hat{\lambda}^{\mathrm{S}}_{m,n}(x, y|z) / \hat{\lambda}^{\mathrm{S}}_{m,n}(x, y) \qquad \textbf{(10)}$$

With the relationship between the conditional and unconditioned estimators ($\lambda_m^{S,Z}$), a non-parametric regression is carried out to analyze whether the environmental variables causally affect the students' performance (Badin et al., 2012). In addition, the procedure proposed by Li and Racine (2008) is applied, which can be understood as a non-parametric equivalent of the standard t-tests in ordinary least squares regression. Finally, note that these types of models have recently been applied in the educational sector (Cordero, Pedraja-Chaparro, Pisaflores, & Polo, 2017; Cordero, Polo, Santín, & Simancas, 2018; Cordero, Alonso-Morán, Nuño-Solinis, Orueta, & Arce, 2015; Cordero, Santín, & Simancas, 2017).

4.5. Empirical application

The empirical section comprises two parts: the first describes and explains the database and the variables used to estimate efficiency; the second presents the results of the causal impact of tutorials on students lagging behind in their educational efficiency.

4.5.1 Data and variables

This study builds a database from five sources of information to estimate the causal impact of the *Aula Global* program on educational efficiency. The first source is the Carvajal Foundation, which provides the results of the standardized EGMA and EGRA tests. These data are disaggregated at the student and school levels for 2019. In addition, the results of each question were accessed in each of the subtests and in the variable that identifies the treatment groups and control.

The second source of information is the National Administrative Department of Statistics (DANE), which provides data from the official school census (C600) in Colombia. Information related to teachers, teaching directors, and computer resources is selected from this database. The environmental variables are taken from the databases provided by the National Police and the Research Program on Measurement of Well-being in Childhood (PIMBN). The National Police database offers information on homicides in the city of Cali by commune. The PIMBN is a research program measuring the state of childhood in Colombia, especially in the city of Cali, that builds a battery of indicators with various components (health; material well-being; care, education and play; maternal well-being; safety and risks) to create a broad vision of well-being. This program is used to obtain information on children in extreme poverty, lack of access to public services (energy, water, sewage, and garbage collection), among other variables. Finally, the socioeconomic stratum of the neighborhood where the school is located is obtained through the database of the municipal planning department.

Following the educational efficiency literature (De Witte & López-Torres, 2017; Giménez, Thieme, Prior, & Tortosa-Ausina, 2018; Thieme, Prior, Giménez, &

Tortosa-Ausina, 2011; Thieme et al., 2013) and the methodological proposal described in the previous section, this study uses two outputs, five inputs, and five environmental variables to calculate the educational efficiency of 6455 students during the year 2019.

4.5.2 Outputs

The academic literature has used different outputs to measure the educational process; when aspects related to quality are taken into account in terms of standardized tests, the results in the areas of language and mathematics are most commonly used (Ben Yahia, Essid, & Rebai, 2018; Cherchye, De Witte, Ooghe, & Nicaise, 2010; De Witte & Kortelainen, 2013; Cordero, Prior, & Simancas, 2016; Tavana, Ebrahimnejad, Santos-Arteaga, Mansourzadeh, & Matin, 2018). De Witte and López-Torres (2017) offer an extensive systematic literature review of the outputs used. The outputs of the present study are the results of the EGMA *(y1)* and EGRA *(y2)* tests, which have been widely used to measure students' progress in mathematics and reading, respectively (Barrera-Osorio et al., 2020; Davidson & Hobbs, 2013; Gove et al., 2013; Raza et al., 2019).

4.5.3 Inputs

Selection of the inputs for the present study is based on the determinants of educational performance raised in the literature (Hanushek, 1979), which are related to individual and family antecedents, characteristics of the school, teachers, and the environmental variables. Based on the above, and following previous work in educational efficiency, five inputs are selected. At the student level, the EGRA *(x1)* and EGMA *(x2)* tests are considered as standardized tests

previously performed by students (baseline) (Podinovski et al., 2014); the first two inputs, together with the outputs, give a measure of added value during the *Aula Global* program. Inputs at the school level are the teaching directors *(x3)*, the teachers in classrooms *(x4)* and the electronic equipment *(x5)* in the school at the primary level. Note that since the unit of analysis is the student, the inputs at the school level are divided by the number of students at the primary level. The three inputs at the school level have been widely used in the literature. Human capital, both at the managerial level and in direct teaching work with students, is one of the most frequent (Agasisti & Pérez-Esparrells, 2010; López-Torres & Prior, 2016; Cordero et al., 2016; Tran & Villano, 2018). The electronic devices (Agasisti, 2011; Mancebón et al., 2012) considered in the fifth input are tablets, laptops and desktop computers in use.

4.5.4 Contextual variables

As mentioned above, the environment in which the educational activity takes place is a determinant of the process results. Therefore, the environmental variables that are not managed by the school must be controlled for to obtain a correct estimation of the causal impact of the *Aula Global* program. Furthermore, because the program is carried out in a population with economic and social problems, the variables selected are related to poverty, security, and sexual violence, the latter being a major concern in Cali (the city where the program is implemented) according to its development plan.

Five environmental variables are used. At the neighborhood level, the first variable is the socioeconomic stratum *(z1)*, which acts as a proxy variable for the socioeconomic index used in the literature to control for the students' context

(Cordero et al., 2017; Giménez et al., 2017; Thieme et al., 2013). DANE considers the physical characteristics of the students' homes, their immediate surroundings and their urban or rural context to calculate the socioeconomic stratum. There are four context variables at the commune level (an administrative division of cities in Colombia): the number of homicides *(z2)*, the percentage of children (0-4 years) living in extreme poverty *(z3)*, the rate of sexual violence (0-4 years) *(z4)* and the percentage of children (0-4 years) with no access to public services *(z5)*.

Table 4.2. Composition of the students participating in the *Aula Global* program in 2019

Academic grade	Measure	Control group	Treatment group	Total
Fifth	Number of students	1,421	174	1,595
	EGMA entrance	45	34	44
	EGRA entrance	101	56	96
Fourth	Number of students	1,496	187	1,683
	EGMA entrance	40	30	39
	EGRA entrance	85	40	80
Third	Number of students	1,401	176	1,577
	EGMA entrance	41	30	39
	EGRA entrance	141	62	132
Second	Number of students	1,430	170	1,600
	EGMA entrance	32	22	31
	EGRA entrance	96	18	88
Total	Number of students	5,748	707	6,455
	EGMA entrance	40	29	38
	EGRA entrance	105	44	99

Source: self-devised.

The number of homicides in the city is considered for two reasons. First, multiple studies relate crime or violence to education (Brown & Velásquez, 2017; Márquez-Padilla et al., 2015), finding, on average, a negative effect on the accumulation of human capital. Second, number of homicides reflects the social reality of the city, as Cali is among the 50 most violent cities in the world according to the latest report from the Citizen Council for Public Safety and Criminal Justice

(CCSPJP). The additional variables at the commune level are obtained from the PIMBN databases. Although the measurement program has approximately 30 indicators, those most pertinent to the reality of the city are taken into account. In 2020 36% (15 percentage points more than in 2019) of the city's population is considered poor according to DANE, presenting high levels of inequality. Based on this, the percentage of children in extreme poverty, the rate of sexual violence, and the lack of access to public services are selected to most effectively control for the children's environment. Five environmental variables are used. At the neighborhood level, the first variable is the socioeconomic stratum (z1), which acts as a proxy variable for the socioeconomic index used in the literature to control for the students' context (Cordero et al., 2017; Giménez et al., 2017; Thieme et al., 2013). DANE considers the physical characteristics of the students' homes, their immediate surroundings and their urban or rural context to calculate the socioeconomic stratum. There are four context variables at the commune level (an administrative division of cities in Colombia): the number of homicides (z2), the percentage of children (0-4 years) living in extreme poverty (z3), the rate of sexual violence (0-4 years) (z4) and the percentage of children (0-4 years) with no access to public services (z5).

Table 4.2 shows the number of students who were part of the treatment and control group disaggregated by academic grade; approximately 48 students from each school took part in the program. Additionally, this table shows the entry values of the EGRA and EGMA exams for the different grades and groups. The huge difference in their values is mainly because the program is focused on students lagging, hence the initial values are significantly lower in the treatment group.

Table 4.3. Descriptive statistics of the variables included in the conditional model

Variables	Description	Average	Q1	Q3	Standard Deviation	Source
Output						
y1: EGRA exit exam	Early Grade Reading Assessment exam after the treatment	118.8	87.0	154.0	48.6	*Aula Global* Program - Carvajal Foundation
y2: EGMA exit exam	Early Grade Mathematics Assessment exam after the treatment	38.4	30.0	47.0	12.5	*Aula Global* Program - Carvajal Foundation
Input						
x1: EGRA entrance exam	Early Grade Reading Assessment exam before the treatment	98.6	68.0	127.5	44.8	*Aula Global* Program - Carvajal Foundation
x2: EGMA entrance exam	Early Grade Mathematics Assessment exam before the treatment	33.5	26.0	41.0	11.1	*Aula Global* Program - Carvajal Foundation
x1: electronic equipment	Number of tablets, desktops, or laptops in use per student in primary.	35.64%	6.56%	45.06%	42.76%	DANE
x2: teachers in management roles	Number of teachers who carry out tasks of management, planning, coordination, administration and orientation per student in primary.	0.37%	0.23%	0.49%	0.21%	DANE
x3: teachers	Number of teachers in educational work in classrooms per student in primary.	5.25%	3.11%	7.64%	2.52%	DANE
Environmental variables						
*z1:*socioeconomic stratification	Stratification based on housing quality	2.0	2.0	2.0	0.6	DANE-DMP
z2: homicides	Number of homicides in the commune where the school is located/ population of the commune	0.00065	0.00057	0.00081	5.5 e-20	National Police
z3: extreme poverty	% of children (0-5) in extreme poverty in relation to all children (0-5)	9.16%	9.30%	9.50%	0.72%	PIMBN
z4: sexual violence	# of children (0-4) who underwent legal medical examinations for alleged sexual abuse / total of children (0-4) * 100,000	62.4	30.6	85.2	22.5	PIMBN
z5: access to basic public services	# of children (0-5) registered in Sisbén-III who live in homes without connection to: energy, water, sewerage and garbage collection / total of children (0-5) in Sisbén-III * 100	5.30%	0.47%	7.99%	3.46%	PIMBN

Source: self-devised

The *Aula Global* program database is linked with databases from DANE, PIMBN, the National Police and the Municipal Planning Department. Based on the above, the program considers second, third, fourth and fifth grade students, the

academic grades composing primary education in Colombia. Additionally, the treatment is carried out with students who lag behind academically; for this reason, the treatment group represents 10% of the total number of students in their respective groups. Table 4.3 shows the definition, source, and main descriptive statistics of the variables used to estimate the robust conditional models.

4.6. Results

This section shows the estimates through the conditional and unconditional models described in the methodology section. To estimate the effect of the program through this type of efficiency model, it is necessary to determine the parameters *m* and *b*, where *m* is the number of schools with which the comparison is made, and *b* is the parameter required to make statistical inference. In this study, *m* is determined by calculating the value of 10% of super-efficient units estimated in the unconditional estimation (Bonaccorsi et al., 2006;Felder & Tauchmann, 2013). Additionally, an output orientation is chosen, mainly because there is no option to reduce the inputs. Although, the objective is to maximize performance with the given resources.

To analyze the effect of the *Aula Global* program, the three steps explained in the methodology section are followed to make 12 estimations which analyze the academic grades of 6455 students from second to fifth grades. First, treatment and control groups are distinguished, as explained in the methodology section. Following this order, the second step seeks to decompose the program's efficiency. To do this, the estimation of the entire sample is first carried out (for each grade independently, from second to fifth), where the calculated coefficient

indicates the general efficiency level of each school under analysis. Then, estimates are made for each specific frontier, separating the treatment group and the control group. Finally, based on the global and local estimates, the managerial (school) efficiency and program efficiency are decomposed. In other words, the coefficients obtained for the local frontiers measure the internal management level of each school, and residually, the distance between the local and global frontiers measures the program's efficiency. Additionally, for the entire process described, unconditional and conditional estimates are made, where the latter considers the environmental variables defined in the previous section.

Table 4.4. (ln) efficiency estimates according to model and academic group (unconditional model)

Academic grade	Decomposition	Control group	Treatment group	Differences
Unconditional model				
Fifth	**Overall efficiency**	1.5388	2.0560	51.72%***
	School efficiency	1.4958	1.9874	49.16%***
	Program efficiency	1.0338	1.0576	2.38%***
Fourth	**Overall efficiency**	1.9803	2.3151	33.48%***
	School efficiency	1.5920	2.2875	69.55%***
	Program efficiency	1.3329	1.0118	-32.11%***
Third	**Overall efficiency**	1.4769	1.8225	34.56%***
	School efficiency	1.3944	1.8051	41.07%***
	Program efficiency	1.0665	1.0138	-5.27%***
Second	**Overall efficiency**	1.9369	3.2366	129.97%***
	School efficiency	1.6336	3.1409	150.73%***
	Program efficiency	1.2263	1.0332	-19.31%***

Sig 1% ***

Source: self-devised

Table *4.4* presents the results obtained from the unconditional estimates (the environment is not considered), distinguishing the average coefficients of general, managerial, and *Aula Global* program efficiency. The calculated coefficients greater than the unit are understood as the potential levels of

efficiency or the levels of inefficiency presented by the unit of analysis, in other words, the percentage of improvement that the students have depending on the model analyzed. For example, regarding global efficiency, Table *4.4* shows higher overall levels of inefficiency in the treatment group than in the control group in all academic grades, with differences of 51.72%, 33.47%, 34.56% and 129.96% from fifth to second, respectively.

The unconditional efficiency of the schools presents better performance in the control group than in the treatment group with differences of 49.16%, 69.54, 41.07% and 150.7% in the fifth, fourth, third and second academic grades, respectively. On the other hand, the program's efficiency shows better performance in the treatment group than in the control group in fourth, third and second grades, with differences of 32.11%, 5.26% and 19.31%. In Fifth grade, the potential efficiency is better in the control than in the treatment group with a difference of 2.37%. Finally, the Li test (1996) is used to confirm any differences in the distributions of the treatment and control groups, and as the p-values in Table *4.5* show, all these differences are statistically significant.

Table *4.5* shows the estimates conditional on the environmental variables (overall, school and program efficiency). The overall efficiency presents better performance for the control group in fifth, fourth, third and second with differences of 52.01%, 33.94%, 34.61% and 129.67% respectively. Regarding school efficiency, the treatment group has higher levels of inefficiency with significant differences.

Table 4.5. (ln) efficiency estimates according to model and academic group (conditional model).

Academic grade	Decomposition	Control group	Treatment group	Differences
Conditional model				
Fifth	Overall efficiency	1.5392	2.0593	52.0%***
	School efficiency	1.4952	1.9879	49.3%***
	Program efficiency	1.0345	1.0584	2.4%***
Fourth	Overall efficiency	1.9778	2.3172	33.9%***
	School efficiency	1.5890	2.2877	69.9%***
	Program efficiency	1.3335	1.0127	-32.1%***
Third	Overall efficiency	1.4764	1.8226	34.6%***
	School efficiency	1.3945	1.8053	41.1%***
	Program efficiency	1.0660	1.0136	-5.2%***
Second	Overall efficiency	1.9302	3.2270	129.7%***
	School efficiency	1.6224	3.1452	152.3%***
	Program efficiency	1.2290	1.0288	-20.0%***

Sig 1% ***

Source: self-devised

Finally, when the efficiency of the *Aula Global* program is analyzed in the conditional estimates, the treatment group presents lower levels of inefficiency in all grades with differences of 32.07%, 5.24% and 20.01% from fourth to second, respectively. Furthermore, the results of the conditional and unconditional models yield similar results; in general, the values of overall and school inefficiencies are found to be higher in the treatment group than in the control group. However, when considering the efficiency of the program, a better behavior is observed in the treatment group across all grades, except for the fifth.

Thanks to the randomized trial design, the interpretations of the conditional and unconditional estimates results can have causal inference and not only at the correlation level. In general, the *Aula Global* program presents low levels of inefficiency in the conditional estimate; the highest average level of inefficiency

in the treatment group occurs in the fifth grade, with a potential improvement of 5.8%.

Table 4.6. (In) efficiency of the *Aula Global* program by school and academic grade (conditional model).

School	Fifth		Fourth		Third		Second	
	Control	Treatment	Control	Treatment	Control	Treatment	Control	Treatment
School A	1.0000		1.0000		1.0000			
School B			0.9952		0.9998		1.1538	
School C	1.0695	0.9989	1.1756	1.0018	1.0119	1.0025	1.0279	1.0533
School D	1.1337	1.0001	1.3013	1.0101	1.1048	1.0048	1.4911	1.0051
School E	0.9987	1.0618	1.0128	1.0487	0.9979	1.0021	1.0083	1.0423
School F	1.0723	1.2506	1.0137	1.0000	1.0091	1.0031	1.1142	1.0933
School G	1.0007	1.1105	1.1035	1.0000	1.1437	1.0001	2.3914	1.0000
School H	0.9986	1.0187	1.1132	1.0276	1.0139	1.0059	1.0037	1.0369
School I	0.9980	1.0262	1.0015	1.0167	1.0265	1.0119	1.0021	1.0540
School J	1.0995	1.0000	1.1433	1.0150	1.0200	1.0037	1.2351	1.0663
School K	1.0361		1.3421		1.4137		0.9948	
School L	1.0808	1.0545	3.5924	1.0002	1.0842	1.0003	1.5728	1.0038
School M	1.0168	1.0000			1.3226	1.0001	1.4839	1.0003
School N	1.0523	1.0000	1.3222	1.0041	1.0517	1.0019	1.3771	1.0107
School R	1.0161	1.0004	1.0331	1.0343	0.9990	1.0032	1.0146	1.0367
School O	1.0037	1.0669	1.2300	1.0045	1.0107	0.9992	1.0185	1.0252
School P	0.9978	1.0896	1.0031	1.0275	0.9988	1.0011	1.0022	1.0539
School Q	0.9998		1.2321		1.0533		1.0101	
School S	1.0213		1.0569		1.3839		1.1388	
School T	1.0046		1.0107		0.9995		0.9941	
School U	1.0559		0.9918		1.0299		1.3403	
School V	1.0171		0.9922		0.9935		1.4066	
School W	1.0084	1.1289	1.2645	1.0000	1.0001	1.0865	1.1163	1.0001
School X	1.0007	1.0689	1.0417	1.0106	1.0056	1.1363	0.9997	1.0000
School Y	1.0009		2.1453		1.1756		1.1437	
Total	1.0345	1.0584	1.3335	1.0127	1.0660	1.0136	1.2290	1.0288

Source: self-devised

On average, better performance is observed in the treatment group than in the control group from fourth to second; however, when the analysis is carried out for

the different schools, better performance is not entirely consistent. Table 4.6 shows the efficiency for the control and treatment groups in the different academic grades; the name of each school is anonymized in accordance with the Carvajal Foundation's data use norms. The table displays the efficiency levels of the program, showing that for the fourth grade, 68% of the schools have a better performance[20] in the treatment group than in the control group, with significant differences. Additionally, the program only has a good effect in 20% of the schools in all academic grades; these are schools D, J, L, M and N.

Table 4.7. Influence of the environmental variables.

Environmental variables	Fifth			Third		
	Control	Treatment	Global	Control	Treatment	Global
z1: socioeconomic stratification	0.09	0.0000	0.03	0.0000	0.0000	1.0000
z2: homicides	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
z3: extreme poverty	0.0000	0.0000	0.0000	0.0000	0.0000	1.0000
z4: sexual violence	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
z5: access to basic public services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Environmental variables	**Fourth**			**Second**		
	Control	**Treatment**	**Global**	**Control**	**Treatment**	**Global**
*z1:*socioeconomic stratification	0.0000	0.0000	0.000	0.0000	0.0000	0.0000
z2: homicides	0.01	0.0000	0.0000	0.0000	0.0000	0.0000
z3: extreme poverty	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
z4: sexual violence	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
z5: access to basic public services	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Source: self-devised

The third step explained in the methodology section allows an additional analysis. A non-parametric regression is performed with the ratio between the results from the conditional and unconditional estimates and the environmental variables to determine their statistical significance (Li & Racine 2008). Table 4.7 shows the p-value of each environmental variable for the four school grades; in general, all

[20] In total, 11 of the 16 schools that present results for the fourth grade present lower inefficiency values in the treatment group than in the control group.

the environmental variables are statistically significant for all the estimated models. Note that in addition to the importance of these variables according to the literature, the availability of relevant neighborhood level variables from the PIMBN database improves the robustness of the conclusions because they can be controlled for in the context of the city of Cali with a sufficient level of disaggregation.

Taking into account the results of the above tables, the two most important findings of this research are, first, the *Aula Global* program has a positive effect on the educational efficiency of students who are lagging behind academically; and second, the environmental variables used are relevant to the present empirical application.

4.7. Conclusions

This study evaluates the causal impact of the *Aula Global* program on the school efficiency of students who are lagging behind, taking into account the results of the EGMA and EGRA tests carried out within the framework of the Carvajal Foundation program in the city of Cali, Colombia. This evaluation implements an innovative procedure that combines the literature on evaluation of social policies and efficiency, initially proposed by De Witte and Smet (2018), in which an initial experimental or quasi-experimental stage is included before the efficiency analysis to infer causality.

In the first stage of the present study, a randomized control trial was carried out to distinguish between the treatment and control groups. Then, a robust non-parametric conditional model was used to evaluate the efficiency of the students while controlling the environmental variables for each school. The analysis was

carried out for the second, third, fourth and fifth academic grades. Additionally, to decompose the effect of the program, a global estimate was made for each academic grade and two local estimates (control group and treatment group). Finally, the distance between the global frontier and the local frontiers was calculated to distinguish the program's effect. The results of the conditional models in the fourth, third and second academic grades show that the *Aula Global* program has positive effects on educational efficiency. The differences in efficiency between the control and treatment groups are 32.07%, 5.24% and 20.01% respectively.

This research is relevant in the educational efficiency literature for two main reasons. First, a methodology (De Witte & Smet, 2018) is used where the literature on evaluating social policies and efficiency interacts to infer causality in educational efficiency. However, unlike De Witte and Smet's (2018) study, in this research a randomized control trial is used instead of a discontinuous regression. Second, it responds to various calls in the literature (Rosati & Faria, 2019) for analysis of how private contributions affect efficiency. The present study provides two important findings. First, the *Aula Global* program has a positive effect on students who are lagging behind; and second, it is very important to control for the environmental variables for this type of analysis, since otherwise, the results may lead to wrong conclusions.

In terms of educational policy, the results should help guide private contributions and their interaction with the public sector toward a more effective and efficient allocation of resources. For example, the Information System on Private Interventions in Education (SIIPE) lists 1133 private interventions in education that could be enhanced through this type of exercise. In addition, the Carvajal

Foundation has benefited from a deeper analysis carried out during the program which will help to improve its implementation in future years, or it may be extended and replicated by other business organizations in other regions. Likewise, this type of program can be applied by the public sector, either using its own resources or those of a third party.

Although the study met its objectives and the results are relevant to the context in which it was developed, an important limitation must be addressed in future research. The program process changed slightly between 2017 and 2019, which limits the comparability between different years for an analysis of efficiency and productivity. In addition, comparability with 2020 is not possible since the treatment changed drastically in that year due to the Covid 19 pandemic.

CHAPTER 5

CONCLUSIONS

5. General conclusions

This thesis analyzes the efficiency of the educational system in Colombia from different perspectives. The analysis is mainly performed with non-parametric frontier techniques since they are ideal for estimating efficiency, considering the complexity of the educational process and environmental variables. This analysis helps both the line of research in educational efficiency and society in general from multiple perspectives. The thesis contributes to define better educational policies by establishing baselines, identifying good practices, and determining which schools, municipalities, or students have the most significant potential for improvement according to their resources. General and specific objectives are established for each chapter to carry out the respective evaluations and estimates.

The three empirical chapters have different approaches but share a common thread, namely to analyze educational efficiency considering the context, particularly social inequality. However, each chapter has specificities that provide valuable contributions. The first chapter examines educational achievement and inequality in educational achievement through the standard deviation of students. The second chapter considers the armed conflict in the municipality and in neighboring municipalities; in addition, result variables related to quality and access are considered simultaneously. Finally, the third chapter analyzes for the first time how a tutoring program for students who are lagging behind affects their efficiency, as an example of the voluntary contributions private organizations make to education.

5.1. Roadmap

This thesis analyzes the educational efficiency of Colombia from different perspectives and is developed in five chapters: the introduction, three empirical chapters and a concluding chapter. The introduction presents the motivation, objectives, and general context of the thesis. In the first empirical chapter, the change in the productivity of 4,587 public and private schools between 2014 and 2017 is estimated with a metafrontier Malmquist-Luenberger index, considering the global score and its standard deviation as outputs of the process. The second empirical chapter analyzes how the armed conflict, a historical problem in Colombia, affects the educational efficiency of the municipalities; in this analysis a conditional order-m model is used, which is ideal for studying the effects of environmental variables. The third empirical chapter evaluates the *Aula Global* program, combining impact evaluation methodologies and efficiency techniques to infer causality on the program results. The final chapter draws conclusions and presents the main findings, contributions, limitations and future lines of research.

5.2. Main findings

In this section, the main conclusions of each empirical chapter and the thesis are mentioned in general. In the case of the first empirical chapter, the two main findings are, first, productivity deteriorated from 2014 to 2017 in the Colombian educational system; and second, the behavior of the productivity evaluation depends on the initial state of efficiency, and in turn, on the department or region under analysis, since there are significant differences in its results that are mainly attributable to context.

The research objective to analyze the differences between the educational sectors resulted in the conclusion that the public sector presents better productivity on average than the private sector, regardless of the orientation analyzed (good output, bad output, good and bad output). In addition, when the results of the different orientations are analyzed, the public sector is found to perform better when only the bad outputs are taken into account, in other words, when inequality in the results of the process is analyzed. Additionally, there is less dispersion of the results in the public sector, to which the majority of schools in the country belong.

The second empirical chapter analyzes how the armed conflict affects the educational efficiency of 912 municipalities in Colombia. Several findings can be highlighted, which in general terms, but not obviously for everyone, lead us to the main conclusion: we must fight for the stability of the peace processes with the groups that are already demobilized and try to reach agreements with outlawed groups that are still operating. These objectives are not only important because they help to improve educational efficiency significantly, but also because each victim of the conflict is not just a number: they are affected individuals and families who must be protected and who must be given the same opportunities as any other citizen, to achieve a country with higher levels of development and narrower social gaps.

The armed conflict is a social problem that has affected Colombia for more than 50 years; the results of this study help us to conclude that it is relevant and pertinent to carry out this type of analysis, to understand how this problem has affected and continues to affect the quality of and access to education, specifically when analyzing efficiency. Likewise, the results show that the

geographical and temporal variability of the phenomenon must be taken into account. Finally, as in the first empirical chapter, there are significant differences in the results between departments, which shows the inequalities in social, educational and development terms of the different regions of the country.

The third empirical chapter provides two main findings. The first, the tutoring program for students who are lagging behind, *Aula Global*, positively affects educational efficiency for approximately two out of three students. Second, the program has a more significant effect on lower academic grades. Additionally, there is significant evidence for the impact of the environmental variables associated with the schools' contexts.

This thesis has helped to uncover multiple findings relevant to the context of the Colombian educational system. In general, the conclusions of the previous chapters coincide with the main aspects highlighted by the Ministry of National Education in the report requested by the OECD in 2016; however, evidence is provided that is significant and novel in terms of educational efficiency, a subject that has received little research attention in the country. The MEN report (2016) suggests that the two main challenges facing the country are, first, to close the gaps in terms of participation, and second, to improve the quality of education for all.

The results of this research show the significant gaps in productivity and efficiency that are found across departments in the country, revealing the importance not only of the socioeconomic context, but also of phenomena such as the armed conflict, which have affected departments unequally, due to such problems as low institutionality, the intensity of the conflict or its different manifestations. The armed conflict directly and indirectly affects education in the

short and long term. Although the way it affects educational effectiveness has been studied on several occasions, this research is the first approximation to know how it affects educational efficiency, which is essential to make better decisions for an educational system with limited resources.

Colombia is aiming to become the best-educated country in Latin America by 2025, as mentioned in the introduction. In order to reach this goal, significant progress has been made in measurement and monitoring; however, tools such as the Synthetic Index of Educational Quality could potentially be improved, as highlighted in the first empirical chapter. Furthermore, having results disaggregated by school, municipality or student helps to target policies, since multiple aspects of the process are taken into account at the same time. In other words, measurement and monitoring tools must be developed with more robust methodologies, which take into account the complexity of the educational process, social inequality, educational inequality and environmental variables, to make better decisions and make better use of resources.

5.3. Limitations

This thesis meets each of the proposed objectives and presents relevant results and contributions for the context in which it is developed and for the Colombian educational system. However, in each of the empirical chapters, limitations have emerged that lead to future lines of research. In the first empirical chapter, three main limitations must be taken into account in the development of future work. First, the results of the Saber 11 standardized test have only been available since 2014 (without a change in methodology), so estimates of schools' productivity cannot be made for previous years, thus precluding a better understanding of the

problem in the long term. Second, like many others, this study takes schools as the unit of analysis; however, there is now a trend in this line of research to consider more disaggregated units of analysis, such as classrooms or students. Third, the context of the units of analysis must be examined with criteria and robust methodologies including social, economic, geographic, and institutional differences, among others. Additionally, in the first empirical chapter, the ISCE is used to motivate the research; however, there are no free access and disaggregated results to analyze the differences between the ISCE and the results of this thesis.

Multiple limitations arise in the second chapter, of which two are highlighted: first, the temporal and geographical variability of the armed conflict was considered by adding the variable in recent years and through a Moran test, respectively; however, the literature shows various options to analyze these problems. Second, other types of environmental variables must be considered, such as cultural, institutional or educational indicators. Additionally, the unit of analysis is the municipality; due to the availability of data related to the armed conflict, having greater disaggregation of this type of data could provide more accurate estimates. Finally, the third empirical chapter has two fundamental limitations. First, changes were made to the program between the pilot test in 2016 and its last application in 2021, therefore limiting the comparability of efficiency and productivity analyses between years; in addition, the comparability with 2020 and 2021 is not possible because of the radical changes in treatment due to the Covid 19 pandemic.

More generally, two of the three empirical chapters make the estimates based on the Saber 11 standardized test, which evaluates students who finish secondary

education; however, it is important to carry out evaluations of added value and relative value over time. Similarly, the evaluations are made using a standardized test at a given moment or period. However, the different educational levels of a school must be taken into account since their resources and results are different.

5.4. Policy recommendations

The results found in this thesis are relevant for educational policymakers. This subsection lists the main recommendations based on the results and approaches taken in each of the empirical chapters. In the first empirical chapter, the methodology offers a robust and integrated way of using efficiency indicators in the educational sector, which can be replicated at different levels in Colombia to evaluate schools, universities or students who take standardized exams and considering different output variables at the same time. In this sense, the results can be used as a market signal in the private sector or as a determinant for providing incentives in the public sector. Therefore, government resources should ideally take into account a balance between criteria as a necessity versus efficiency, based on a joint assessment of quality and inequality.

The second empirical chapter highlights a different approach to social inequality, namely the role of the armed conflict in educational efficiency. The chapter confirms that educational efficiency is being evaluated; however, the armed conflict has multiple effects on society in general. Policymakers should consider the efficiency of each of the municipalities when allocating subsidies and prioritizing territories to maintain the stability of the peace processes. In this chapter, the inefficiencies caused by the armed conflict are calculated; this could be one of the criteria municipalities must meet to receive government or

international aid. In the same way, the geographical approach used in this chapter helps to cluster municipalities according to level of aggregate efficiency; policymakers could use these levels to develop different kinds of strategies for groups of municipalities in different regions.

The third empirical chapter offers evidence on a program that has positive effects on educational efficiency. Policymakers could extrapolate from these results more generally throughout the city to schools that meet the criteria where the program has improved efficiency; likewise, they may be used in other places in the country with similar characteristics through government funds, or by leveraging business foundations or the international community. This type of program can also be used in other academic grades to strengthen specific schools that have low average performance, for example, in the Saber 11 or PISA standardized tests.

5.5. Contributions

This section presents the contributions, identified by chapter, to the literature in general terms and to educational policymakers. The first chapter makes three main contributions: first, results are obtained for each school, which opens up different ways of applying educational policy, since in the public sector, it can serve as a reference for the delivery of incentives, and in the private sector, it can act as a market signal. Second, it responds to calls from other researchers in the field to apply multiple dimensions of standardized tests and incorporate both performance and inequality in the educational process. Finally, this is the first application in which ICFES databases are used, and as such is the first application with results for Colombia. In addition, it is the first use of the

metafrontier Malmquist-Luenberger index for a specific educational system that applies partial frontiers for different sectors.

The second chapter makes four fundamental contributions: first, it responds to numerous calls to explore the intersection between research on education and armed conflict, specifically, calls to use standardized tests to measure the effects of the armed conflict on educational quality. Additionally, as in the first chapter, a variable is used that aggregates different dimensions of standardized tests. Second, to our knowledge, it is the first analysis to study the relationship between the armed conflict and educational efficiency; in addition, variables related to educational quality and access are taken into account simultaneously. Third, it is the first time that a conditional model with a non-parametric approach has been used in the armed conflict research. Fourth, spatial contagion models are used to measure the effect of the armed conflict on neighboring municipalities. Finally, the third empirical chapter shows that voluntary contributions from private organizations positively affect educational efficiency. Additionally, in specific terms of the program, it affects students who are lagging behind more significantly in the lower grades (second and third).

In general, this thesis is the first approach applied to the Colombian educational system that seeks to evaluate the efficiency of educational institutions taking into account the differences in students' environmental variables and their social and educational inequality. The municipal and school-level results are useful for developing educational policies, considering the specificities of the units of analysis or the people to be impacted. In this sense, the third empirical chapter offers empirical evidence to redirect or strengthen the *Aula Global* program, which has been running for more than six years without evaluations of this type.

5.6. Directions for future research

In this section, future lines of research are presented based on the empirical applications and the focus of this thesis; these suggestions are mentioned by chapter and in a general way. However, indirectly each of the limitations mentioned in the previous section opens up possible future applications in this research field.

In the first chapter, higher productivity is found in the public sector, to which most schools belong, than in the private sector. Although the difference between the sectors was calculated through metafrontiers, it could be done more specifically since there are significant differences within the two sectors due to the institutional development of the context in which they are found. Likewise, because of the considerable differences in the productivity of public schools in the largest cities, further research is needed using methodologies that could suggest ways of redistributing resources between schools considering the approach of the thesis, such as the centralized DEA, to improve productivity, and system efficiency in aggregate.

In this sense, the estimates made in the first chapter take into account the standardized Saber 11 test directly; applications could be made with another type of test that considers primary and secondary education to see the differences in productivity when assessing different levels. Likewise, the differences between urban and rural areas should be explored as the realities of public schools in the main city of a developed department differ radically from those of a public school in an isolated municipality in a much less developed department; these differences in environment and evaluation levels must be taken into account.

Early childhood and higher education fell outside the scope of this thesis, but they are fundamental parts of the educational system and as such these educational levels in Colombia should also be analyzed with methodologies similar to the ones applied in this thesis.

As mentioned above, to the authors' knowledge, the second empirical chapter is the first approach made to study the effect of the armed conflict on educational efficiency. Therefore, future research should take into account different manifestations of the conflict in order to further develop the research line. In this vein, the effects of the armed conflict must be analyzed at all educational levels (early childhood, primary, secondary); likewise, the cumulative impact of the armed conflict should be examined in the short and long term, directly and indirectly in the different perspectives of the educational system. Finally, it is important to incorporate approaches that combine quasi-experimental techniques with efficiency methodologies to infer causality in the results.

The third empirical chapter presents a case study with internal and external validity; however, as it evaluates a program, future lines of research could have a more specific focus. The program has run from 2016 to 2021, but in the last two years it was moved online and implemented at a distance. These circumstances makes the *Aula Global* program in the years 2020 and 2021 an ideal example to analyze how a distance tutoring program can affect educational efficiency and effectiveness in the context of a pandemic.

The future lines of research identified in each of the empirical chapters are relevant to the education system and public policy. However, other more general lines of research are also highlighted in the thesis. Six specific lines are mentioned: first, the need to develop value-added research that considers

students' educational processes in each stage, taking into account the approach of social and educational inequality and the efficiency approach. Second, more studies are required that consider causal inference in efficiency research. Third, analysis is needed to study how positive and negative phenomena are offset, such as voluntary contributions from private organizations and armed conflict. Fourth, the short- and long-term effects of Covid 19 must be explored using methodologies that consider the measurement of productivity (Malmquist-Luenberger index) and robustly incorporate the integration of environmental variables (conditional *order-m*). Fifth, students who do not complete their educational processes are to be included in the efficiency evaluations, taking into account the characteristics of the chapters of this thesis and their possible behaviors, with school dropout as an output. Finally, there is a need to analyze the way inefficiencies or potential losses of efficiency present in the educational system affect different outcomes of the educational process, such as insertion in higher education, employment, economic growth or levels of development.

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