What factors are related to the socioeconomic gaps in school achievement between boys and girls in Bogotá, Colombia?

¿Qué factores se relacionan con las brechas socioeconómicas de logro escolar entre niños y niñas en Bogotá, Colombia?

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Abstract

Debate on student achievement, as measured by performance on national and international assessments, has gained worldwide attention because of its relationship to social and economic development. As such, multilateral organizations such as the World Bank and the Inter-American Development Bank have recommended that countries intensify current investments in education to improve school quality and reduce achievement gaps if they wish to boost equity and attain sustainable growth. This paper looks at the relationship between socioeconomic disparities and student achievement in a standardized test administered in 2017 to 5th grade students in Bogotá, Colombia. By using a two-level hierarchical linear model, it is possible to estimate not only the relationship between individual characteristics of the students (sociodemographic information) and performance on the test, but also account for the effect of the characteristics of the schools that they attend. Findings indicate that lengthening the school day, possession of washing machines, and parental education are key predictors of academic achievement.

Keywords: achievement gaps, multilevel modeling, multidimensional poverty, Colombia

Resumen

El debate sobre logro académico, medido como el resultado obtenido en pruebas académicas nacionales e internacionales, se ha intensificado por su relación con el desarrollo socioeconómico. Así, organizaciones multilaterales como el Banco Mundial y el Banco Interamericano de Desarrollo han recomendado que los países incrementen su inversión en educación con el fin de mejorar la calidad educativa y reducir las brechas académicas, lo cual será clave para fomentar equidad y alcanzar desarrollo sostenible. Este artículo analiza la relación entre disparidades socioeconómicas y el logro escolar en las pruebas SABER 5 entre niños y niñas de quinto de primaria en Bogotá para el año 2017. Mediante el uso de modelos multinivel fue posible estimar no solo la relación entre características individuales de los estudiantes (información sociodemográfica) y los resultados en las pruebas académicas, sino también estimar el efecto de variables relacionadas con las escuelas. Los resultados de esta investigación sugieren que la jornada escolar, la posesión de bienes de consumo como la lavadora y la educación de los padres están asociados positivamente con el logro escolar.

Palabras clave: brecha académica, análisis estadístico, pobreza, Colombia

INTRODUCTION

According to the 2018 Poverty and Shared Prosperity report by the World Bank (2018), the number of people who live below $ 1.90 dollars a day, has significantly dropped from 2 billion in 1990 to 736 million in 2015 (Poverty and Shared Prosperity report, 2018). This reduction, however, has only accounted for monetary poverty; that is poverty measured by income (Poverty and Shared Prosperity report, 2018). Nonetheless, poverty is a complex phenomenon. For instance, there are households that despite having a stable income live in communities where there is no drinking water. The Multidimensional Poverty Index is a measure that looks at how people experience poverty beyond income. As such, the index conceptualizes poverty in three dimensions: 1) standard of living, 2) education, and 3) health (United Nations Development Program & Oxford Poverty and Human Development Initiative, 2019).

Of the three dimensions, education is believed to be the great equalizer because of its expected effect on employment, social mobility (Gorski, 2013; Bottery, 2016; World Development Report, 2018) and on rational decision making related to nutrition, prevention of communicable diseases (vaccination), gender equity, and financial education (Child Fund, 2018; World Development Report, 2018). Despite the evidence that links education to poverty reduction, "in 2016, 61 million children of primary school age – 10 percent of all children in low – and lower-middle-income countries – were not in school, along with 202 million children of secondary school age" (World Development Report, 2018, p. 8). In addition, in some countries – mostly low-income countries – attending school has not translated into learning; hence, some children can barely read or solve basic math problems (World Development Report, 2018).

Results from the 2015 Programme for International Student Assessment (PISA), an international test that measures education systems worldwide, show that student performance is highly associated with country-level indicators of economic growth and social development (e.g., high GDP and low multidimensional poverty) and the extent to which education has been consolidated as a top priority. This explains why countries such as Singapore, Japan, Estonia, Chinese Taipei, Finland, and Canada often perform within the top 10% in PISA. Further, with a few exceptions most top performers in PISA are countries which are members of the Organisation of Economic Cooperation and Development (OECD). While OECD countries spend an average of US 10,400 per student annually; in Latin America, annual average investment per student is about US 4,500 and performance on PISA falls within the bottom 25% (Bos et al., 2015; Recuero & Olaberria, 2018). Furthermore, while the average percentage of low-performing students in OECD countries was 21% in 2015, in Latin America the average was 51% (Bos et al., 2015; Recuero & Olaberria, 2018). These results reinforce the story of increasing inequality and widening achievement gaps across regions.

The Coleman report (1968) is perhaps the first study that tried to explain why achievements gaps originate. The report found that besides teacher and school quality, socioeconomic status was the single most important predictor of academic achievement (Coleman, 1968). As such, achievement gaps can be explained, to a great extent, as a result of socioeconomic inequalities. According to Bronfenbrenner's bioecological model of human development, these inequalities need to be interpreted beyond the individual characteristics of the child, and therefore include the social, political and cultural contexts that shape the child's learning experience (e.g., schools and neighborhood composition) (Rosa & Tudge, 2013; Ashiabi & O'Neal, 2015). That is why since the publication of the report numerous studies have been conducted to assess and quantify that gap so that evidence-based policies and programs can be implemented to revert it. For instance, some studies have looked at the differences between public and private schools and their impact on achievement (Braun et al., 2006; Duncan & Sandy, 2007), gender bias in academic performance (Golsteyn & Schils, 2014; Meinck & Brese, 2019; OECD, 2023), the consequences of summer learning loss (Alexander et al., 2007; Leefatt 2015; Quinn & Polikoff, 2017), the impact of extending the school day (Pires & Urzua, 2011; Orkin, 2013; Alfaro et al., 2015; Hincapie,

2016; Dominguez & Ruffini, 2020), and the benefits of improving school quality (Hanushek et al., 2019; Schneider, 2017).

In a longitudinal study to measure socioeconomic achievement gaps across different countries, Chmielewski (2019) found that between 1964 and 2015 the academic achievement gap between students from high and low socioeconomic backgrounds significantly increased. The study used parent education, parent occupation, and number of books available at home as proxies for socioeconomic status (independent variables). To measure academic achievement, the study used 30 large-scale international assessments as the dependent variable. By employing a three-level hierarchical growth curve model, Chmielewski was able to identify that over the span of 51 years the achievement gap based on parent occupation increased by 55%, while the achievement gaps based on parent education and household books grew by 50% and 40%, respectively (Chmielewski, 2019).

Of interest to this study is the impact of gender and length of school day in academic achievement in Colombia. Most research on gender bias in academic performance indicates that girls obtain better results in reading, while boys excel in mathematics (Golsteyn & Schils, 2014; Meinck & Brese, 2019; OECD, 2023). Gender plays a key role in explaining socioeconomic achievement gaps because it reveals the nature of cultural and social inequalities, particularly in relation to gender roles (Meinck & Brese, 2019; OECD, 2023). In most societies, household chores and child-rearing activities have been imposed on women and girls (Drèze & Sen, 1989). In a study about the effect of household assets on school performance in Colombia, Cabra (2022) found that possession of durable goods is positively associated with academic achievement and school attendance. However, findings from this study suggest disparities in school performance after controlling for gender (Cabra, 2022). This means that even when children have access to durable goods, girls seem to benefit less from possession of durable goods. A potential explanation, the author claims, is that in countries like Colombia, domestic activities are assigned to girls (Cabra, 2022). As such, for example, even when families have access to a washing machine or a microwave at home, it is the girls who are responsible for using them to complete domestic chores. This may reduce the time that children have to complete school work, which may have a negative impact on school performance (Cabra, 2022; Meinck & Brese, 2019; OECD, 2023).

Research on school length suggests that longer school days have a positive impact on learning outcomes (Alfaro et al, 2015; Dominguez & Ruffini, 2020; Figlio et al., 2018; Hincapie, 2016; Llach et al., 2009; Orkin, 2013; Parra, 2009; Pires & Urzua, 2011). In terms of improving learning outcomes, for example, Alfaro et al., (2015) analyzed the relationship between instructional time and student learning in Latin America and the Caribbean. By conducting a systematic review analysis of cases in Latin America, they found that countries that have extended the school day have made progress towards closing achievement gaps and improving academic outcomes such as decreasing dropout rates and increasing graduation rates (Alfaro et al., 2015). Similarly, reach on this topic indicates that longer school days increase instructional time, which is the time devoted to teaching. More instructional time is highly related to academic activities, which in the long run have a positive impact on students´ school performance (Dominguez & Ruffini, 2020; Figlio et al., 2018; Hincapie, 2016; Llach et al., 2009; Orkin, 2013; Parra, 2009; Pires & Urzua, 2011). In a study about the impact of longer school days in academic achievement, Hincapie (2016) found that extending the school day has a positive effect in math scores (an increase in 0.08 standard deviations) for 5th grade students, and strong positive effects in math scores (0.14 standard deviations) for 9th grade students (Hincapie, 2016). In relation to school attendance, research on this area shows that schools that operate longer hours a day generate positive externalities. The rationale for this is that most schools that operate longer hours offer extracurricular activities and school meals. This creates opportunities to fulfill basic needs, particularly for students from marginalized identities. Therefore, there is conclusive evidence that pinpoints to lengthening the school days as an alternative to create equality of educational opportunities for bridging

socioeconomic achievement gaps (Alfaro et al, 2015; Dominguez & Ruffini, 2020; Figlio et al., 2018; Hincapie, 2016; Llach et al., 2009; Orkin, 2013; Parra, 2009; Pires & Urzua, 2011).

According to the 2017 World Bank GINI index, a measure of inequality based on income distribution within a country, Colombia is one of the most unequal countries in the world (World Bank, 2020). In the Latin American and Caribbean region, Colombia is the second most unequal country, after Brazil (ECLAC, 2019). Additionally, in 2019 17.5% of the population were multidimensionally poor; being standard of living and education the dimensions with most deprivations (United Nations Development Program & Oxford Poverty and Human Development Initiative, 2019). In terms with standard of living, for example, this means that people lack basic services such as drinking water and sanitation. In relation to education, this suggests that some children are not going to school (either not enrolled or dropping out), some are going but are not completing their programs (promotion and graduation rates are low) or what is worse some are going but not learning. Research on quality of education in Colombia highlights, for instance, that 49% of children in Colombia of late primary school age are not proficient in reading (World Bank, 2019). Poor school quality (not enough schools or under-resourced schools) and lack of a support system outside of school (social capital) are considered the main barriers to student success, which create achievement gaps (World Development Report, 2018).

In Colombia, academic achievement is measured by a set of national standardized exams at different school grades called Pruebas SABER ("SABER tests"). At the elementary and middle school level, the test assesses proficiency in reading and math (students from grades 3, 5 and 9) (ICFES, 2018). Students are grouped according to proficiency levels: unsatisfactory, basic, satisfactory and advanced. According to a government evaluation for the 2017 SABER test for 3, 5 and 9 graders, there are significant achievement gaps in all grades. In reading, for example, 54% of 3rd graders students attain unsatisfactory and basic proficiency levels (ICFES, 2018). In math, 72% of 5th graders achieve unsatisfactory and basic proficiency levels (ICFES, 2018). When considering socioeconomic disparities, only 36% of 3rd graders who come from high poverty backgrounds achieve advanced and satisfactory reading proficiency levels in comparison to 83% of students from affluent backgrounds (Duarte et al., 2012; ICFES, 2018).

Bogotá has experienced similar trends in achievement gaps than the country. In a study about opportunity gaps in education in Bogotá, Lopez et al. (2017) found that controlling for socioeconomic status and sociodemographic characteristics, private school students perform better in reading and math on the SABER tests than public school students (an average of 1.5 points higher). This suggests that unless we consider multiple factors when analyzing what drives socioeconomic achievement gaps disparities will persist, thus perpetuating poverty.

Using a two-level hierarchical linear model with data from a standardized test administered to 5th graders in Bogotá, Colombia this study explores the relationship between socioeconomic disparities (at the individual and school level) and achievement gap. Using this method facilitates a holistic analysis of nested data, which can yield more precise estimates. This research aims to answer three questions; 1) What factors explain the socioeconomic achievement gap among 5th grade students in Bogotá, Colombia? 2) How big is the gap? and 3) What policy or program interventions can be implemented to reduce the gap? Answers to these questions will shed light not only on how we understand socioeconomic achievement gaps in developing countries, but it will also provide evidence to help policymakers make informed decisions about specific policy or program interventions. The paper is organized in four sections, as follows. Section one corresponds to the methods used for addressing the research questions. This includes a description of the research design, data, participants, variables and data analysis. Section two presents the results. Section three entails a discussion of the results and a description of the limitations. The last section presents the conclusions of the research and some policy recommendations.

METHODS

Design

This study used a quantitative design, including descriptive statistics, correlation, and hierarchical linear modeling (HLM), a type of Ordinary Least Square regression method that takes into account when the predictor variables are structured or nested at varying hierarchical levels (Raudenbush & Bryk, 2002; Raudenbush & Bryk, 2019). HML is used to examine the decomposition of the variation in the 2017 SABER test results in reading and math for a sample of 5th grade students in Bogotá and how much of that variation in results is associated with sociodemographic and socioeconomic variables (student level) and characteristics of the school (school level). For this two-level model, I estimated equation (1), which took the basic form of

$$Y_{ij} = \beta_0 + \beta_1 X_{ij} + (e_{0ij} + u_{0j}) \qquad (1)$$

Where Y_{ij} is one of the academic outcomes for child i nested in school j. In this model, X_{ij} is a vector of covariates, and the random effects e_{0ij}, u_{0j} are the residual differentials for children and schools. It is important to stress that in this two-level model, the residual differentials for children and schools are assumed to be normally distributed with a mean of 0 and a variance of σ_{e0}^2 and σ_{u0}^2. The variances in the two-level models are the parameters of interest and indicate the between-child (σ_{e0}^2) and between-school variations in child i experiencing the academic outcomes (reading and math).

Settings

Data was provided by the Instituto Colombiano para el Fomento de la Educación Superior (ICFES) – Colombian institute for the promotion of postsecondary education – as part of their Open Data policy. This study used the 2017 SABER test because it is the most recent dataset available. The dataset provides information about all the population of children in 3, 5, and 9 grades on academic achievement in reading and mathematics, as well as students' sociodemographic and socioeconomic information (e.g., age, gender, parent education, parent occupation, possession of durable goods, etc.) (ICFES, 2019). The data also contain information about schools such as type (public or private), location (urban or rural), length of school day, and school program (academic, technical or vocational). A subset of the data that focuses exclusively on 5th grade students from Bogotá was used. Hence, the number of 5th graders from Bogotá who took the SABER test in 2017 was 55,881. This paper used HLM software to run the models. However, the software does not have the capacity to analyze more than 7,000 data points at once. As such, a random sample from the subset (less than 13% of the total) was selected. Therefore, the final sample for this study comprised 6,932 students.

Participants

The study totaled 6,932 students selected from a random sample of a subset of the 2017 SABER test for 5th grade students in Bogotá. Approximately, 52% identified as males and 48% as females. Age of students ranged from 9 to 12 years old. Close to 99% of the participants attended a public school. Data were de-identified, thus posing little to no risk to participants. Sociodemographic and socioeconomic information of the students was strictly used for research purposes.

Variables

Dependent Variables

The dependent variables used in this model are the 2017 SABER test results for reading and math for a random sample of 6,932 students in 5th grade from Bogotá. Test scores range from 100 – 500 (with 100 being the lowest and 500 the highest). Depending on the score obtained, and in order to measure the level of proficiency on each subject, students are placed in 1 out of 4 categories. Table 1 summarizes these categories.

Table 1

Proficiency levels in 2017 SABER test for 5th grade students in reading and math

Reading		Math	
Proficiency level	**Definition**	**Proficiency level**	**Definition**
Unsatisfactory 100 - 241	Understands basic information	Unsatisfactory 100 – 279	Understands measurement units
Basic 242 – 318	Recognizes different types of literary texts	Basic 280 – 334	Uses basic operations to problem solving
Satisfactory 319 – 384	Identifies the main ideas of a text and its arguments. Also understands grammar rules	Satisfactory 335 – 382	Understands and uses properties of operations to problem solving, understand basic statistics and basic probability
Advanced 385 – 500	Understands the text and makes inferences about the content. Recognizes specific rhetoric styles	Advanced 383 – 500	Understands and uses division, fractions and data representation

Note: Adapted from SABER 5th Guidelines (SABER 5 Guía de Orientación) (ICFES, 2019)

Independent Variables

This study uses a two-level Hierarchical Lineal Model. Level 1 refers to all the variables that are associated with individual characteristics of the students such as sociodemographic and socioeconomic status. Level 2 refers to all the variables that are related to the schools that children attend such as type of school (public or private), location (urban or rural), length of school day (half day or full day), and school program (academic, technical or vocational).

Level 1 variables were selected based on research on socioeconomic achievement gaps that points to parent education and parent occupation as estimators of socioeconomic status (Chmielewski, 2019). Although both variables are available in the dataset, only parent education was selected because of a potential issue of collinearity (usually people with higher levels of education are people who have high paying jobs or "more skilled" jobs). This variable was recoded from ordinal to a dummy variable (1 if the mother has a bachelor's degree or more and 0 if the mother has less than a bachelor's degree) in order to analyze the overall effect of postsecondary education.

In relation to sex, research on achievement gaps suggests significant differences in elementary school performance between boys and girls. In general, boys perform better in math, while girls perform better than boys in reading and humanities or social sciences (Golsteyn & Schils, 2014; Meinck & Brese, 2019; OECD, 2023). Therefore, the variable sex was chosen to control for any potential differences in test performance.

The dataset also contains information on a variable called standard of living. This is a composite variable that assesses multidimensional poverty. The variable includes indicators such as number of bedrooms in the house, access to internet, number of books at home, access to a washer at home, etc. Based on the Multidimensional Poverty Index, two variables were selected: Access to Internet and possession of a washing machine at home. These variables were used as proxies to account for socioeconomic status (United Nations Development Program & Oxford Poverty and Human Development Initiative, 2019). These variables were recoded into a dummy (1=yes, 0=no).

Level 2 variables explain the characteristics of the schools that 5th graders attend in Bogotá. Four variables were selected: School program, length of school day, school type and school location. Given the nature of the education system of Colombia, it is important to explain each variable:

School program. Schools can offer an academic program or a technical/vocational program. Academic programs offer the traditional science-based and humanities-based curriculum. If it is a technical program, students graduate with a vocational degree (associates degree) besides their traditional high school diploma. There is debate around achievement gaps between academic and technical schools. It is believed that technical schools perform better in math than academic schools. This variable was coded into a dummy variable (1 if the school is academic and 0 if otherwise).

School day. Because of lack of infrastructure (not enough classrooms nor schools) schools currently operate in shifts: morning shifts, afternoon shifts, and full day programs. Children can go in the morning (6 am – 12 am), evening (12:30 pm – 6:30 pm), night (7 pm – 10 pm), full day (6:30 am – 4 pm), Saturdays (7 am – 6 pm). Government reports indicate that more than 70% of Colombian children attend schools that operate in a half-day format (morning or afternoon shifts) (Vega, 2018). Nonetheless, the government is pushing to extend the school day because there is research that suggests that longer school days improve learning outcomes (Alfaro et al, 2015; Dominguez & Ruffini, 2020; Figlio et al., 2018; Hincapie, 2016; Llach et al., 2009; Orkin, 2013; Parra, 2009; Pires & Urzua, 2011). There is still a long way to go because making that shift will entail building schools and that will take time. For the purpose of this paper, this variable was coded into a dummy variable (1 if the school operates full day and 0 if otherwise).

School type. Schools can be public or private. Research on this topic indicates that private schools outperform public schools because they have more resources and more flexibility in relation to curriculum design and pedagogical practices (Braun et al, 2006; Duncan & Sandy, 2007; Lopez et al, 2017). This variable was coded as a dummy variable (1 if the school is public and 0 if private).

Location of school. Schools can be located in urban or rural settings. There is research that suggests that schools located in rural areas perform lower than schools located in urban areas (Duarte et al, 2012; Gaviria, 2017). This variable was coded as a dummy variable (1 if the school is located in urban and 0 if located in a rural setting).

Table 2 summarizes the different variables used at the level 1 and level 2 for the Hierarchical Linear Model.

Table 2

Level 1 and Level 2 variables for HLM

Variables	Label	Description
Student level (level 1)		
Sex	SEX	Sex of child
Mother's education	MOTHER'S EDUCATION	Level of education of the mother
Washer at home	WASHING MACHINE	Access to a washer at home
Internet at home	INTERNET	Access to internet at home
School level (level 2)		
School program	SCHOOL PROGRAM	Academic or technical/vocational curriculum
School day	SCHOOL DAY	Half day or full day
School type	SCHOOL TYPE	Public or private
Location of school	URBAN_RURAL	Urban or rural setting

Note: Information obtained from Level 1 and Level 2 data file (n=6,932)

Data Analysis and Validation

Descriptive quantitative and correlation analyses were conducted at first. Given that the models have multiple predictors, and in order to identify potential collinearity problems at level-1 (particularly between variables such as parent education and possession of a washing machine at home) and level-2, different bivariate analyses and independent t-tests were performed to observe the relationship between each of the independent variables at level-1 and level-2 and the outcome variables (reading and math test results).

Second, multilevel modeling was used to explore the hypothesis that socioeconomic status (in particular variables such as possession of a washing machines and Internet access) may be a key predictor of achievement in the 2017 SABER test for 5th graders in Bogotá. Other alternative explanations were considered by including other student (Level 1) and school (Level 2) variables in the analyses, which account for the fact that students were nested within schools. Multilevel analysis was used to examine the effects of sociodemographic and socioeconomic characteristics of students nested within schools. All HLM analyses were conducted in HLM software using restricted maximum likelihood (REML) estimation, which produces less biased estimates of random effects than maximum likelihood (ML) estimation (Raudenbush & Bryk, 2002; Raudenbush et al., 2019).

Conducting the HLM analyses involved different steps. The first step entailed estimating the unconditional models for each of the outcome variables. The unconditional model is used to examine how much of the variation between the 2017 SABER test scores is associated with each individual student or the level 2 group examined. This involved calculating the intraclass correlation coefficient (ICC) to see how much of the variance in the 2017 SABER test was explained by the model. Then, separate single predictor and multiple predictor models were run for level-1 and level-2 variables for each of the outcome variables. Finally, a full model that combines level-1 and level-2 variables was run for each of the outcome variables. It is important to highlight that test scores were not standardized because one of the expected results of this research was to estimate the value of the achievement gap in units. Additionally, missing values were omitted from the data analysis given that, for some variables, the share of missing values accounted for less than 3%.

RESULTS

Descriptive Statistics

In relation to the outcome variables, test scores were normally distributed. Readings scores were normally distributed with a mean score of 316.29 and a standard deviation of 61.258. This means that roughly 68% of the students scored between 1 standard deviation from the mean (255 and 377 units). For math, scores were normally distributed with a mean score of 300.3 and a standard deviation of 63.998. Similar to reading scores, this means that roughly 68% of the students scored between 1 standard deviation from the mean (236 and 364 units).

Level-1 variables showed interesting sociodemographic characteristics of this sample. Regarding sex, for example, most 5th graders identified as males (51.7%). In terms of parental education, 20% of the students in the sample reported that their mothers had an educational level equal or higher than a college degree. Additionally, the percentage of students who reported having a washing machine at home and Internet access was relatively high (88.1% and 78.2% respectively).

Level-2 variables indicated that most students in the sample were enrolled in public schools (98.9%) and that students attended schools that operate in half day shifts (90.3%). Moreover, most students attended schools that offer an academic-based curriculum (85.9%). The random sample did not capture any schools that are located in rural settings. Thus, this variable was dropped from the rest of the data analyses and HLM models.

Table 3 summarizes the descriptive statistics for the level-1 and level-2 predictor variables.

Table 3

Descriptive statistics for the level-1 and level-2 predictor variables of the SABER 2017 reading and math test

Variables	Values
Level-1 (student level)	
Sex Total respondents: 6,917 Missing: 15	Male (51.7%) Female (48.3%)
Mother's education Total respondents: 6,932 Missing: 0	Less than bachelors (80.4%) Bachelors or more (19.6%)
Washing machine at home Total respondents: 6,868 Missing: 64	Yes (88.1%) No (11.9%)
Internet at home Total respondents: 6,851 Missing: 81	Yes (78.2%) No (21.8%)
Level-2 (school level)	
School program Total respondents: 6,707 Missing: 225	Academic (85.9%) Technical or vocational (14.1%)
School day Total respondents: 6,932 Missing: 0	Full day (9.7%) Half day (90.3%)
School type Total respondents: 6,932 Missing: 0	Public (98.9%) Private (1.1%)
Location of school Total respondents: 6,932 Missing: 0	Urban (100%) Rural (0%)

Note: Information obtained from Level 1 and Level 2 data file (n=6,932)

Bivariate Analyses and Independent T-tests

Level – 1 variables

Regarding bivariate analyses, no correlations were found between the variables mother education and Internet access (0.090, p<0.01). Similarly, no correlation was found between mother education and possession of a washing machine at home (0.058, p<0.01). A small positive correlation was found between the variables Internet access and possession of a washing machine at home (0.159, p<0.01). Sex was not correlated with any of the variables.

Results from the t-test analyses showed that there was a statistically significant difference between the mean reading and math scores for 5th graders by sex, parent education, Internet access, and possession of a washing machine. In relation to sex, males scored, on average, 314.03 units and females 318.78 in reading, a gap of 4.75 units. In math, males scored, on average, 304.20 units and females 296.20, a gap of 8 units.

In relation to parental education, there was a statistically significant difference between the mean reading and math scores of children by level of education of the mother. For example, students whose mothers completed a bachelor's degree or more scored, on average, 326.53 units in reading while students whose mothers completed less than a bachelors score 313.79, a gap of 12.74 units. In math, students whose mothers completed a bachelor's degree or more scored, on average, 309.96 units while students whose mothers had less than a bachelors score 297.95, a gap of 12.01 units.

In relation to Internet access, there was a statistically significant difference between the mean score for students who had Internet access and students who did not. In reading, students who had Internet access scored, on average, 319.83 units while students who did not have access scored 304.74 units, a gap of 15.09 units. In math, students who had Internet access scored, on average, 303.29 units while students who did not have Internet access scored 291.59 units, a gap of 11.7 units.

Regarding possession of a washing machine at home, there was also a statistically significant difference between the mean reading and math scores of students. In reading, students whose families owned a washing machine scored, on average, 318.32 units while students who did not possess a washing machine scored 303.32 units, a gap of 15 units. In math, students who owned a washing machine scored, on average, 302.28 units while students who did not have a washing machine scored 288.49 units, a gap of 13.79 units.

Level – 2 variables

In bivariate analyses, no correlation was found between the variable length of school day and school program (0.090, p<0.447). A negative correlation was found between the variable length of school day and school type (0.314, p<0.00). Similarly, a small negative correlation was found between the variable school program and school type (0.041, p<0.01). Thus, there were no collinearity issues associated with the independent variables at level 2.

Results from the t-test analyses for the level 2 variables showed that there was a statistically significant difference between the mean reading and math scores for 5th graders by length of day and type of school. However, there was no statistically significant difference for type of program. In relation to length of school day, for example, students who attended half day schools scored, on average, 314.88 units while students who attended full day schools score 329.34 in reading, a gap of 14.46 units. In math, students who attended half day schools scored, on average, 298.01 units while students who attended full day schools score 321.52, which represents a gap of 23.51 units.

In relation to type of school, students who attended public schools scored, on average, 315.90 units while students who attended private schools score 352.40 units in reading, a gap of 36.5 units. In math, students who attended public schools score, on average, 299.78 units while students who attended private schools score 349.62 units, a gap of 49.84 units.

HLM models

Results are presented by outcome variable (reading and then math). For each outcome variable, we show the unconditional model as well as the full models.

Results for Reading Scores

The Unconditional Model

The unconditional model was used to examine how much of the variation of the 2017 SABER reading scores was associated with each individual student or the level 2 group. In this first step, no other predictor variables were taken into account.

The level 1 equation for 2017 SABER reading scores as an outcome is:

$$PUNT\_LEN_{ij} = \beta_{0j} + r_{ij}$$

Where $PUNT\_LEN_{ij}$ is the reading score for an individual student, β_{0j} is the intercept or mean score for 5th grade students and r_{ij} is the error term. Using the Least-squares estimates of fixed effects (with robust standard errors) from the HLM output, the mean score was 316.336926 units with a standard error of 1.327752 units ($p<0.001$). The ICC for this model was 0.08056, which means that this model accounted for 8% of the variance in the 2017 SABER reading score.

Full Model

In order to gain a better understanding of the effect of student-level and school-level predictor variables on SABER 2017 reading scores, a two-level model was built. At the level-1 and level-2, we started with a single predictor and then we added additional predictors. In order to test the model, we first let it vary randomly. Variables were grand-mean centered, by which each data point was subtracted by its variable's overall mean.

After running these models, we ran a combined model (full model) that would account for the level-1 and level-2 variables as predictors of the 2017 SABER test for reading. Table 4 summarizes the results of this full model. We are interested in the coefficients for each of the estimators (INTERCEPT) and their standard errors.

Table 4

Full Model for the 2017 SABER Test for Reading (INTERCEPT)

Fixed Effect	Coefficient	Standard error	t-ratio	Approx. d.f.	p-value
For INTERCEPT1, β0					
INTERCEPT2, γ00	316.342115	1.214107	260.555	280	<0.001
Level 2 predictors					
SCHOOL PROGRAM, γ01	-1.577842	3.005850	-0.525	280	0.600
SCHOOL DAY, γ02	14.499216	5.541959	2.616	280	0.009
SCHOOL TYPE, γ03	-18.403583	16.093412	-1.144	280	0.254
Level 1 predictors					
MOTHER EDUCATION slope, β1					
INTERCEPT2, γ10	6.887456	2.046352	3.366	283	<0.001
INTERNET slope, β2					
INTERCEPT2, γ20	10.259383	1.821007	5.634	283	<0.001
WASHER slope, β3					
INTERCEPT2, γ30	10.194778	2.261645	4.508	283	<0.001
SEX slope, β4					
INTERCEPT2, γ40	5.119741	1.456979	3.514	283	<0.001

Note: Output generated from HLM software

At the student level, results indicated that mean reading scores increased, on average, 6.887456 units for students whose mothers had a college degree or higher education level. Similarly, results showed that reading scores increased, on average, 10.259383 units for students who had Internet access; 10.194778 units if the student had a washing machine at home, and 5.119741 units if students identified as females. At the school level, only the length of the school day was positively associated with reading scores. As such, students mean scores for reading increased, on average, 14.499216 units if students attended a full day school controlling for student level socioeconomic characteristics (0.2 standard deviations higher). Thus, this model highlights that while student level socioeconomic characteristics are good predictors of reading achievement, the length of the school day matters.

Results for Math Scores

The Unconditional Model

The level 1 equation for the 2017 SABER math scores as an outcome is:

$PUNT\_MAT_{ij} = β0j + rij$

Where $PUNT\_MAT_{ij}$ is the math score for an individual student, β0j is the intercept or mean score for 5th grade students and rij is the error term. Mean score was 300.871007 units with a standard error of 1.431724 units (p<0.001). The ICC for this model was 0.08829, which means that this model accounted for 9% of the variance.

Full Model

Table 5 summarizes the results of the full models for math scores.

Table 5

Full Model for the 2017 SABER Test for Math (INTERCEPT)

Fixed Effect	Coefficient	Standard error	t-ratio	Approx. d.f.	p-value
For INTERCEPT1, β0					
INTERCEPT2, γ00	300.698810	1.296067	232.009	280	<0.001
Level 2 predictors					
SCHOOL PROGRAM, γ01	-0.684316	3.597262	-0.190	280	0.849
SCHOOL DAY, γ02	24.089749	5.690448	4.233	280	<0.001
SCHOOL TYPE, γ03	-23.646400	32.240290	-0.733	280	0.464
Level 1 predictors					
MOTHER EDUCATION slope, β1					
INTERCEPT2, γ10	6.034106	2.041357	2.956	283	0.003
INTERNET slope, β2					
INTERCEPT2, γ20	6.490774	1.902876	3.411	283	<0.001
WASHER slope, β3					
INTERCEPT2, γ30	9.695626	2.393342	4.051	283	<0.001
SEX slope, β4					
INTERCEPT2, γ40	-8.278402	1.498826	-5.523	283	<0.001

Note: Output generated from HLM software

Similar to the model for predicting reading scores, this model highlights that after controlling for student level variables, length of school day is a key predictor of math achievement, a result that is statistically significant. In fact, school mean math scores increased, on average, 24.089749 units for students who attended full day schools (0.4 standard deviations higher). Other school level variables were not associated with math achievement. At the student level, the model suggests that mean math scores increased, on average, 6.034106 units for students whose mothers had a college degree or a higher education level; 6.490774 units if student had Internet access, and 9.695626 units students had a washing machine at home. The mean math score decreased, however, by 8.278402 units if students identified as females.

DISCUSSION

The estimation models used in this paper corroborate existing research on inequality of education that suggests the presence of socioeconomic achievement gaps among students (Alfaro et al, 2015; Cabra, 2022; Chmielewski, 2019; Coleman, 1968; Dominguez & Ruffini, 2020; Figlio et al., 2018; Gorski, 2013; Hincapie, 2016; Llach et al., 2009; OECD, 2023 Orkin, 2013; Parra, 2009; Pires & Urzua, 2011). Using HLM models, it was possible to estimate the magnitude of such gaps in reading and math at the student and school level for a sample of 5th grade students in Bogotá, Colombia.

At the student level, mother education (having completed a postsecondary education degree), Internet access at home, and possession of a washing machine at home constituted good predictors of academic achievement. Thus, for instance, students whose mothers had a college degree or higher and whose households had Internet access and washing machines gained, on average, 26 units in reading and 21 units in math (0.4 and 0.3 standards deviations higher, respectively) than students whose mothers had less than a college degree and whose households did not have those durable goods. This suggests that student level socioeconomic achievement gap has grown over the years (between 2002 and 2017): from 0.067 to 0.4 standard deviations in reading, and from 0.08 to 0.3 standard deviations in math. Similarly, this study found that gender bias in academic performance is still a pressing issue, hence, revealing structural inequalities. For example, results indicate that girls perform better than boys in reading while boys do better in math, which corroborates previous research on gender-based achievement gaps (Meinck & Brese, 2019; OECD, 2023). Overall, these findings validate existing research on the effect of socioeconomic status on achievement: Students from low-income

backgrounds perform lower than their more affluent peers (Gorski, 2013; World Development Report, 2018; Chmielewski, 2019).

And while the findings are not new, the selection of Internet access and possession of washing machines as proxies of socioeconomic status proved helpful for understanding the negative effects of poverty on achievement. As explained in the introduction, the Multidimensional Poverty Index assesses poverty beyond income. In fact, the index attempts to gauge how people experience poverty. As such, the index considers, aside from education and health, a dimension called "standard of living". This dimension encompasses basic social services that are crucial for living (electricity, housing, drinking water, cooking fuel, sanitation, and assets). Internet and washers are part of the "assets" indicator (United Nations Development Program & Oxford Poverty and Human Development Initiative, 2019). This means that not having access to them or being deprived from accessing them constitute a risk factor for becoming multidimensionally poor.

Moreover, deprivation in one dimension can lead to deprivation in another. For instance, lack of access to a washing machine at home could lead to low school attendance, which in turn can hinder academic achievement. Research on poverty suggests that the experience of poverty has negative welfare effects, which hinder human development (Doi et al., 2019; Kyomuhendo & Mwiine, 2011; World Bank, 2018; World Bank, 2022). Therefore, the experience of poverty can negatively impact other dimensions of well-being. For instance, people living in poverty may develop feelings of shame and negative perceptions about how they live, which may contribute to create social stereotypes and negative narratives of what poverty is (Doi et al., 2019; Kyomuhendo & Mwiine, 2011). Studies about the impact of water, sanitation, and hygiene in women´s well-being, suggest that lack of menstrual products for girls is highly associated with school absenteeism (Fisher et al., 2017; Kayser et al., 2019; Mills & Cumming, 2016; WaterAid, 2013). Findings show that one of the reasons why girls do not go to school when they have their menstruation cycle is because they feel embarrassed (Inthaphatha et al., 2021; Miiro et al., 2018; Vashisht et al., 2018).

At the school level, length of the school day was the only variable that was found to be positively associated with academic achievement. For example, mean reading scores were about 0.2 standard deviations higher, on average, for students that attended full day schools. Similarly, mean math scores were, on average, about 0.4 standard deviations higher for students who attended full day schools. In comparison with the student level findings, this means that a longer school day has almost the same effect as socioeconomic factors in predicting test performance on the 2017 SABER test for reading and math for 5th grade students. Therefore, length of school day matters as much as socioeconomic factors in closing the achievement gap at the 5th grade level in Bogotá, particularly in math. This result corroborates previous research on the impact of extending the school day in closing achievements gaps (Alfaro et al, 2015; Dominguez & Ruffini, 2020; Figlio et al., 2018; Hincapie, 2016; Llach et al., 2009; Orkin, 2013; Parra, 2009; Pires & Urzua, 2011). As highlighted in the introduction, extending the school day can improve learning outcomes by decreasing dropout rates and increasing graduation rates. Furthermore, this finding is noteworthy for advancing the debate on equity and education in Colombia as the country shifts towards the implementation of a full-day school policy.

Limitations

The main limitation of this study was the sample selection. Given that the HLM software could not take all the available data, we had to select a random sample. Doing so affected the variance of some variables. For example, we could not use school location (urban or rural) as a school level variable, which research in education quality in Colombia suggest is a key predictor of achievement. Other limitations of this study were the number of variables chosen and the decisions pertaining the coding process. In terms of the number of variables, we chose only the ones that were mostly associated with

socioeconomic status. However, the data contain multiple variables associated with living standard (e.g., number of books, number of bedrooms in the house, materials used to build the house, etc.). Including more variables at the student level could have produced a more robust estimate of socioeconomic status. Another way to deal with this is perhaps by grouping all the student level socioeconomic variables into one. Creating a household asset index or creating a composite variable for socioeconomic status could yield a more robust effect. In relation to decisions about coding variables, it is possible that the way some variables were coded lowered their statistical power in the model (e.g., type of school programs and mother education).

CONCLUSION

In conclusion, the HLM models used in this paper show that achievement gaps are a function of sociodemographic characteristics of students, but also a function of school's characteristics (context). By using HLM models, it was possible to quantify the socioeconomic achievement gap for a sample of 5th grade students in the SABER test for reading and math from Bogotá. The results suggest that, in general, the gap for reading is between 0.2 and 0.3 standard deviations, while for math it is close to 0.4 standard deviations. Efforts to close these gaps will need to be tailored to address poverty and implement rapid cost-effective solutions. This will be much needed after COVID-19.

Moreover, the fact that factors such as Internet access and possession of durable goods such as washing machines proved to be key in predicting achievement entail that they need to be included in any policy design so that marginalized children can access those opportunities and reap the benefits of a high-quality education. Doing so will not only guarantee that we can close achievement gaps, but that we can tackle poverty and inequality effectively.

RECOMMENDATIONS

While issues such as poverty and inequality are structural problems that require structural and complex solutions, we can start small. The following are some policy recommendations based on the findings of this research:

Implement afterschool programs as an alternative to extending the school day. This alternative aims at providing afterschool programs for children and youth, particularly for girls. Because findings from this study showcase important gender bias in academic performance, it is important that these programs foster participation of girls and provide high quality academic and extracurricular activities. This policy option would work as a transition strategy to the full day school policy. Research on afterschool programs highlight that, if well-designed, these programs can have a positive effect in children's social emotional skills, improving behavior in and outside of school, and fostering motivation to engage in learning (Alfaro et al., 2015). These outcomes, most research suggest, are the foundation for active learning; a component that can contribute not only to closing the achievement gap between children (Alexander et al., 2007); but promoting healthy lifestyles.

Implement a community-based washing machine program. Findings from this research showed a positive relation between possession of washing machines and academic achievement. Thus, this intervention aims at providing low-income communities with affordable services for washing clothes. One possible solution is to build community-based laundromats where families can go and wash their clothes. While very common in developed countries, it is a completely new idea in high poverty communities in developing countries. Similar to the first policy recommendation, this alternative must be formulated with an equity framework, so that household roles are evenly distributed among families. Doing so may prevent that domestic activities such as washing clothes are assigned exclusively to women and girls; hence, fostering gender equity.

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