A multi-method approach to study the determinants of academic performance of secondary students: the case of Cartagena de Indias (Colombia)

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ABSTRACT

The main objective of the paper is to investigate the determinant factors affecting academic performance of students in secondary education in the city of Cartagena de Indias (Colombia). The study consists of two parts. In the first part, a probit regression analysis is applied to identify potential factors affecting the results of students in the Colombian National Quality Test. It focuses on measuring the impact of students' socioeconomic conditions and the characteristics of the school on the results obtained. In the second part, using an AHP model, local education managers evaluate the same variables in relation to academic performance. Preliminary results show that being male, studying in an urban area, having access to the internet and a computer, as well as the educational level of the fathers, increase the probability of high performance in the critical reading and mathematics components. On the other hand, studying in a public school and having a job reduce the probability of obtaining good results. The managers consulted so far consider that socioeconomic status and time devoted to reading are the two main factors that affect student performance.

Keywords: Performance, secondary education, academic performance, probit, AHP.

1. Introduction

The current education system shows some difficulties in promoting students' human development (United Nations, 2022). Good results in education are a consequence of the quality of institutions, but also of structural factors that can explain the results and the quality of the education received. In Colombia, the results of the Programme for International Student Assessment (PISA) remain among the lowest. Furthermore, results vary internally due to factors such as socioeconomic status, ethnicity, gender and geographical location (OECD, 2019). In the city of Cartagena de Indias, results remain among the lowest in the country. Sixty-two percent of the city's schools do not have a good performance and are ranked at the lowest levels. The situation worsens in public and rural schools (Cartagena Cómo Vamos, 2022).

We conducted a two-stage study of probit and Analytic Hierarchy Process AHP to analyze potential determinants of student performance in high school. In the first part, we used an ordered probit analysis to study the relationships between the results and in relation to other

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variables related to socioeconomic conditions of the student, their home, and the characteristics of the school in order to identify factors associated with good academic performance. In the second part, we focused on identifying, through an AHP model, the perception of education managers and policy-makers regarding these variables.

2. Literature Review

Our approach supports on three theoretical frameworks. The first is related to the capabilities approach (Nussbaum, 2011; Saito, 2003), which allows us to approach and understand the problem with the person at the center of development. The second is based on the effect of non-cognitive and contextual factors on student performances (Muelle, 2020; Wanzer et al., 2019); and finally, the last is the multi-criteria approach that allows us to study the problem of students' academic performance based on its decomposition into different variables, organized into different hierarchical levels (Saaty, 2008; Sipahi & Timor, 2010).

3. Hypotheses/Objectives

Our objective is to study the determinants of secondary school students' performance using a multi-method approach to contrast students' results with structural factors and the perceptions of decision-makers in the sector.

4. Research Design/Methodology/Data/Model

This study conducted a two-stage analysis presented in the next figure:

Stage	Data	Variables	Analytic method	Meaning	
1st	Secondary data: National test results (Saber 11[4]) 2021. Source: Colombian Institute for the Evaluation of Education ICFES	Dependent: Results on critical reading and mathematics Independent: • Gender • Ethnic minority group • Nationality • Socioeconomic status • Father's education • Mother's education • Internet access • Computer ownership • Books in the house • Job • Time spent reading • Nature of the school (Private/public) • School location (Rural/Urban)	Ordered probit	Correlation between the results and structural variables	Determinants of students' performance
2nd	In-depth survey (questionnaires) Source: Managers and policy-makers		AHP	Importance for decision-makers	

Figure 1. Research flow

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[4] Standardized external evaluations applied by the ICFES. They assess the performance achieved by students according to the basic competencies defined by the Ministry of National Education.

In the first part, the ordered probit analysis was carried out based on the results of the national quality test of 10,616 students. The dependent variable is the result obtained. This is an ordinal dependent variable for which the potential values have a natural ordering: insufficient, regular, satisfactory and advanced. Two groups were included as independent variables: socioeconomic conditions and the characteristics of the school.

The AHP model (Figure 2) was defined with the independent variables. The pairwise comparisons of the criteria are done by local experts with experience in management and decision-making in the education sector. Since this is a work in progress, to date we have collected the judgments of two experts: a school principal and a member of the local government. The geometric average of the judgments is used in the calculations.
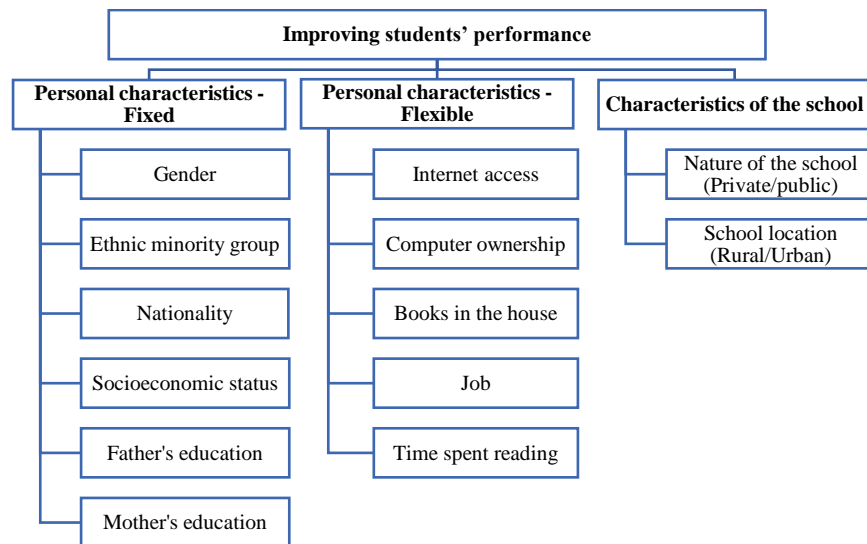

Figure 2. AHP model

5. Analysis

The results of the probit analysis can be found in Appendix 1. The results demonstrate the influence of structural characteristics on students' academic performance. Books, computers and the internet are tools that effectively stimulate learning and improve results. Gender is a key variable. The results show the positive effect that the male gender (student and father) can have on mathematics.

On the other hand, the variables that can most affect a student's performance are school environment, having a job, and the fact of belonging to an ethnic minority group. In Colombia, and especially in Cartagena, attending a public school in a rural area has a negative relationship with performance

The results of the AHP analysis are given in Table 1. Characteristics associated with students are found as the most important main criteria, followed by aspects associated with the school. When the global importance of the sub-criteria is analyzed, socioeconomic status, time spent in reading, and the location of the school are found as the first three sub-criteria. Mother's education, internet access and the nature of the school are the second most important group.

Table 1. AHP Results

Criteria	Weights	Sub-criteria	Local Weights	Global Weights
Fixed characteristics	40,9%	Gender	6,0%	2,4%
		Ethnic minority group	11,1%	4,5%
		Socioeconomic status	31,3%	12,8%
		Nationality	9,6%	3,9%
		Father's education	19,1%	7,8%
		Mother's education	22,9%	9,3%
Flexible characteristics	40,9%	Internet access	19,9%	8,1%
		Computer ownership	17,6%	7,2%
		Books in the house	6,6%	2,7%
		Job	14,8%	6,1%
		Time spent reading	41,1%	16,8%
Characteristics of the school	18,3%	Nature of the school (Private/public)	46,9%	8,6%
		School location (Rural/Urban)	53,1%	9,7%

6. Limitations

Our model is exploratory and is based on the variables collected by the national education quality agency. Therefore, one of the main limitations is the lack of some variables. Also, it is possible that there are interdependent relationships between variables that may change the focus from an AHP model to an ANP model.

7. Conclusions

One of the novelties of our results lies in the inclusion and assessment of variables such as time spent reading, number of books in the home and belonging to an ethnic minority group. The results found so far also allow us to build a picture of what education managers value most with respect to the quality of education.

Among the main contributions of this study, we highlight the role of non-cognitive and contextual factors in students' performance. likewise, the inequality of the results responds to a differentiated effect of family and educational context. Secondly, the empirical strategy of combining a probit-AHP model is novel and allows us to contrast the perceptions of decision-makers with the data found.

The human development framework will support decision-making processes addressing factors that affect differences in performance in contexts characterized by severe inequalities. The findings demonstrate the importance of valuing students as subjects located within societies, communities, families and groups, who may face multiple forms of disadvantage resulting from the way in which issues such as gender, rurality or ethnicity intersect.

8. Key References

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9. Appendices

9.1 Results of the ordered probit model in the area of Mathematics

Variables	Coefficient	Marginal Effects			
		P(y)= Insufficient	P(Y)= Regular	P(y)= Satisfactory	P(y)= Advanced
Gender	0,270**	-0,058	-0,030	0,074	0,015
Ethnic minority group	-0,065	0,014	0,007	-0,018	-0,004
Socioeconomic status					
Level 2	-0,068**	0,014	0,008	-0,018	-0,004
Level 3	-0,098**	0,021	0,011	-0,026	-0,006
Level 4	-0,325**	0,076	0,027	-0,087	-0,016
Level 5	-0,200**	0,045	0,020	-0,054	-0,011
Level 6	-0,266**	0,061	0,024	-0,071	-0,014
Father's education					
Incomplete primary school	0,313**	-0,081	-0,015	0,085	0,011
Primary school complete	0,328**	-0,085	-0,016	0,090	0,011
Secondary (High School) incomplete	0,325**	-0,084	-0,016	0,089	0,011
Secondary (High School) complete	0,381**	-0,097	-0,022	0,105	0,014
Technical or technological incomplete	0,463**	-0,114	-0,032	0,128	0,018
Technical or technological complete	0,519**	-0,125	-0,041	0,144	0,022
Professional education incomplete	0,457**	-0,113	-0,032	0,126	0,018
Professional education complete	0,461**	-0,114	-0,032	0,127	0,018
Postgraduate	0,784**	-0,169	-0,089	0,216	0,043
Mother's education					
Incomplete primary school	0,121	-0,032	-0,005	0,033	0,004
Primary school complete	0,120	-0,032	-0,005	0,033	0,004
Secondary (High School) incomplete	0,210**	-0,054	-0,012	0,059	0,007
Secondary (High School) complete	0,283**	-0,071	-0,019	0,080	0,010
Technical or technological incomplete	0,353**	-0,086	-0,028	0,100	0,014

Technical or technological complete	0,477**	-0,110	-0,046	0,136	0,021
Professional education incomplete	0,391**	-0,094	-0,033	0,111	0,016
Professional education complete	0,476**	-0,110	-0,046	0,135	0,021
Postgraduate	0,719**	-0,150	-0,093	0,202	0,040
Internet	0,211**	-0,046	-0,024	0,058	0,012
Computer	0,148**	-0,032	-0,017	0,040	0,008
Number of books					
11 to 25 Books	0,062**	-0,014	-0,007	0,017	0,003
26 to 100 Books	0,228**	-0,047	-0,030	0,063	0,013
More than 100 books	0,145**	-0,031	-0,017	0,040	0,008
Job	-0,298**	0,064	0,033	-0,081	-0,016
Nature of school	-0,512**	0,111	0,058	-0,140	-0,028
Location of school	0,291**	-0,063	-0,033	0,080	0,016
Reading time					
30 minutes or less	0,091**	-0,022	-0,007	0,025	0,004
Between 30 and 60 minutes	0,287**	-0,063	-0,031	0,080	0,015
Between 1 and 2 hours	0,276**	-0,061	-0,030	0,077	0,014
More than 2 hours	0,427**	-0,088	-0,054	0,118	0,025
No. of observations	10.592				
LR chi2(32)	2250,23				
Prob > chi2	0,000				
Pseudo R2	0,1029				

Note: Significance level **$p<0.05$

9.2 Results of the ordered probit model in the critical reading

		Marginal Effects			
Variables	**Coefficient**	**P(y)= Insufficient**	**P(Y)= Regular**	**P(y)= Satisfactory**	**P(y)= Advanced**
Gender	0,041	-0,005	-0,009	0,008	0,006
Ethnic minority group	-0,110**	0,014	0,023	-0,020	-0,017
Socioeconomic status					
Level 2	-0,024	0,003	0,005	-0,004	-0,004
Level 3	-0,070**	0,009	0,015	-0,013	-0,011
Level 4	-0,243**	0,033	0,048	-0,047	-0,034
Level 5	-0,203**	0,027	0,041	-0,039	-0,029
Level 6	-0,326**	0,047	0,061	-0,065	-0,044
Father's education					
Incomplete primary school	0,203**	-0,030	-0,039	0,044	0,025
Primary school complete	0,169**	-0,025	-0,032	0,037	0,020
Secondary (High School) incomplete	0,189**	-0,028	-0,036	0,041	0,023
Secondary (High School) complete	0,259**	-0,037	-0,051	0,055	0,033
Technical or technological incomplete	0,274**	-0,039	-0,055	0,058	0,035
Technical or technological complete	0,376**	-0,050	-0,078	0,077	0,052
Professional education incomplete	0,370**	-0,050	-0,077	0,076	0,051
Professional education complete	0,344**	-0,047	-0,071	0,071	0,046

Variables	Coefficient	Marginal Effects			
		P(y)= Insufficient	P(Y)= Regular	P(y)= Satisfactory	P(y)= Advanced
Postgraduate	0,674**	-0,075	-0,154	0,120	0,109
Mother's education					
Incomplete primary school	0,100	-0,016	-0,018	0,023	0,011
Primary school complete	0,102	-0,016	-0,018	0,023	0,011
Secondary (High School) incomplete	0,172	-0,027	-0,032	0,039	0,020
Secondary (High School) complete	0,274**	-0,040	-0,054	0,061	0,033
Technical or technological incomplete	0,388**	-0,053	-0,081	0,083	0,051
Technical or technological complete	0,431**	-0,057	-0,092	0,091	0,058
Professional education incomplete	0,416**	-0,056	-0,088	0,089	0,055
Professional education complete	0,457**	-0,060	-0,098	0,096	0,062
Postgraduate	0,675**	-0,078	-0,155	0,128	0,105
Internet	0,273**	-0,034	-0,058	0,051	0,041
Computer	0,177**	-0,022	-0,038	0,033	0,027
Number of books					
11 to 25 Books	0,098**	-0,012	-0,021	0,019	0,014
26 to 100 Books	0,307**	-0,034	-0,071	0,055	0,050
More than 100 books	0,103	-0,013	-0,023	0,020	0,015
Job	-0,347**	0,043	0,074	-0,065	-0,052
Nature of school	-0,525**	0,065	0,112	-0,098	-0,079
Location of school	0,211**	-0,026	-0,045	0,039	0,032
Reading time					
30 minutes or less	0,110**	-0,016	-0,021	0,024	0,014
Between 30 and 60 minutes	0,317**	-0,041	-0,068	0,064	0,045
Between 1 and 2 hours	0,424**	-0,051	-0,094	0,082	0,064
More than 2 hours	0,688**	-0,071	-0,162	0,114	0,119
No. of observations	10.592				
LR chi2(32)	2686,3				
Prob > chi2	0,000				
Pseudo R2	0,1167				

Note: Significance level **$p<0.05$