Cross-referencing SABER 11 and SABER Pro standardized tests in Antioquia, Colombia: A geographically weighted regression (GWR) approach.

Cruce de las pruebas nacionales Saber 11 y Saber Pro en Antioquia, Colombia: una aproximación desde la regresión geográficamente ponderada (GWR)

Comparação das provas nacionais Saber 11 e Saber Pro em Antioquia, Colômbia: uma aproximação desde a regressão geograficamente ponderada (GWR)

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Abstract

As far as we know, Colombia seems to be the only country in the world where it is possible to assess the same students that took the standardized state tests during their senior year of high school and, subsequently, when culminating studies at a higher education institution (HEI). We describe the performance of the results of 1,806 students who took the Saber 11 test in 2005 and 2006, and then, the Saber Pro test in 2009-2010. Our study is limited to those students who graduated from high school and an HEI in the department of Antioquia. Performance within the sample is slightly lower than that of the sample universe in both tests. We ran an exploratory regression in ArcGIS, a least-squares regression, and a geographically weighted regression (GWR). We found a positive association between both test scores. In the Saber Pro test, individuals with parents that are retired or studying obtained higher scores than those of parents that are wage earners. Surprisingly, there is a negative relationship between school tuition and Saber Pro scores. Students who attended an HEI in Rionegro obtained higher scores in this test compared to an HEI from other municipalities in Antioquia. We conclude that the GWR contributes slightly to measuring the spatial nature of the two tests in the case of Antioquia.

Keywords

Antioquia; quality of education; secondary education; higher education; geographically weighted regression

Resumen

Hasta donde sabemos, Colombia parece ser el único país en el mundo donde se puede evaluar exactamente a los mismos estudiantes que tomaron las pruebas estándar del Estado al terminar la secundaria y luego en una institución de educación superior (IES). Se caracteriza el desempeño de los resultados de los 1,806 estudiantes que tomaron la prueba Saber 11 para los años 2005 y 2006 y luego la prueba Saber Pro 2009-2010. Nuestro estudio se limita a aquellos estudiantes que se graduaron de un colegio y una IES en el departamento de Antioquia. El desempeño en la muestra es ligeramente inferior a la del universo en ambas pruebas. Se llevó a cabo una regresión exploratoria en ArcGis, la regresión de mínimos cuadrados y la regresión geográficamente ponderada (GWR). Se encontró una asociación positiva entre los puntajes de las dos pruebas. Paralelamente, los hijos de padre pensionado o que se encuentra estudiando obtienen mayores puntajes en la prueba Saber Pro, en comparación con los hijos de padre asalariado. Sorprendentemente, hay una relación negativa entre la pensión de los colegios y los puntajes en la prueba Saber Pro. Los estudiantes que asistieron a una IES en Rionegro obtuvieron mayores puntajes en esta prueba en comparación con las IES de otros municipios antioqueños. Se concluye que la GWR contribuye ligeramente a medir el carácter espacial de los datos de estas dos pruebas en el caso de Antioquia.

Palabras clave

Antioquia; calidad de la educación; educación media; educación superior; regresión geográficamente ponderada

Resumo

Até onde é sabido, Colômbia parece ser o único país no mundo onde é possível avaliar exatamente os mesmos estudantes que prestaram as provas standard do Estado ao concluir a média e após em uma instituição de educação superior (IES). Será descrito o desempenho dos resultados dos 1,806 estudantes que prestaram a prova Saber 11 nos anos 2005 e 2006, e posteriormente, a prova Saber Pro 2009-2010. Este estudo limita-se a esses estudantes que concluíram seus estudos no departamento de Antioquia. O desempenho na amostra é ligeiramente inferior ao desempenho geral nas duas provas. Foi elaborada uma regressão exploratória em Arcgis, a regressão de mínimos quadrados e a regressão geograficamente ponderada (GWR). Evidenciou-se uma associação positiva entre as pontuações das duas provas. Paralelamente, os filhos de pais aposentados ou que ainda estão estudando obtém maiores pontuações na prova Saber Pro, em comparação com os filhos de pais assalariados. Surpreendentemente, existe uma relação negativa entre o custo das escolas e as pontuações obtidas na prova Saber Pro. Os estudantes de uma IES em Rionegro obtiveram uma pontuação maior nesta prova em comparação com as IES de outros municípios de Antioquia. Em conclusão, a GWR contribui parcialmente na medição do caráter espacial dos dados das provas no caso de Antioquia.

Palavras-chave

Antioquia; qualidade da educação; educação média; educação superior; regressão geograficamente ponderada

Introduction

The fourth goal of the 2030 Sustainable Development Agenda, adopted by the United Nations in 2015, underlines the importance of inclusive and quality education (United Nations Educational, Scientific, and Cultural Organization [UNESCO], 2017). To achieve sustainable development, countries require professionals in technology, mathematics, science, and engineering; however, in 2013, less than one in three women in the world opted for this clear path (International Bureau of Education [IBE]-UNESCO, 2017). Colombia is not an exception.

Despite progress in coverage in official schools in Colombia, associated with financial decentralization (Faguet & Sánchez, 2008), the World Bank (2009) believes that the country needs to increase education quality and equity. For decades, differences in wealth between departments are evidenced, and among these, the urban/rural differential is associated with secondary education achievement and completion rates (Gaviria & Barrientos, 2001). Even the Colombian agricultural sector is caught in the poverty cycle, among others, because it lacks access to education (Rodríguez, Sánchez, & Armenta, 2010).

In this order of ideas, it is impossible to ignore that the armed conflict contributed to compromising national education (Gómez, 2016). Some Colombian municipalities live in peace bubbles; hence, it is not strange that there is ample evidence supporting that access to HEIs in the country suffers from enormous socioeconomic disparities and per region (Melguizo, Sánchez, &Velasco, 2016) and even at the municipal level (Loaiza & Hincapié, 2016).

Saavedra (2012) emphasizes that few governments have been able to increase coverage and quality in education simultaneously. Evidence suggests that the rapid expansion of professional programs in Colombia deteriorated its quality (Barrera-Osorio, Maldonado, & Rodríguez, 2012; Camacho, Messina, & Uribe, 2016). The foregoing can be explained, since standard state tests, such as Saber tests, allow assessing progress in the quality of education and documenting socioeconomic and spatial differentials.

This study is justified because after conducting the academic literature review and consulting with experts, we did not find articles in peer-reviewed journals on cross-referencing Saber 11 and Saber Pro test databases taken by the same students. In other words, their performance in high school and then at the end of their higher education studies. Colombia seems to be the only country in the world where it is possible to link the same students that took the standard state tests at the end of high school and the end of their undergraduate education.

The Saber tests not only allow assessing quality in education but also offer the possibility of adjusting the educational policy in public and private institutions. According to the World Bank (2012), used together, these two tests can position Colombia as a leader in the assessment of the added value of higher education.

In Brazil, there is a state test, ENADE, but it is applied during the first and last year of undergraduate education and used to assess performance (Zoghbi, Rocha, & Mattos, 2013). In the United States, there is a test similar to the Brazilian one. Still, exclusively for the case of nursing schools, indeed, Hinderer, Dibartolo, and Walsh (2014) underline that nursing programs wish to accept the best applicants and assess them with an exam before admission and another once they have registered professionally. Even for the nursing exam, named the National Council Licensure Examination (NCLEX), there are several previous standardized tests, without there being much literature to help teachers in those nursing schools prepare their students to pass the national test (Mee & Hallenbeck, 2015).

Statistics, particularly spatial statistics, can help in interpreting data in standard tests for the straightforward reason that location matters. Local data analyses gain importance in comparison with global analyses because statistics in the vast majority of disciplines have spatial biases. Thus, a central element in spatial thinking is recognizing that the result of variable changes depending on where it is measured; this also allows for the spatial explanation of said variation (Waller, 2014). There are many examples from the exact and social sciences that show said spatial variability behavior. For instance, per capita income or average annual rainfall vary greatly throughout Colombian geography. A national figure of these indicators would be deplorable and useless; even its validity at the departmental level is questionable. What is the use of knowing that the average annual rainfall in Boyacá is 1384 mm when one knows that in the municipality of Santa María, it is of a greater magnitude than in Tasco? It is paradoxical that whereas average statistics are not accepted, there is a tendency to accept global regression models (Fotheringham, Brunsdon, & Charlton, 2002).

Additionally, for decades, in statistics, especially since the creation of regression models to explain by means of explanatory or independent variables, a dependent variable, the spatiality of data has been omitted, even if it exists. As highlighted by Gelfand, Diggle, Fuentes, and Guttorp (2010), for many years, spatial statistics worked on the periphery of mainstream statistics.

Not contemplating the spatiality of data indeed leads to erroneous conclusions from a regression analysis and specification problems arise in the models when spatial dependence is present in the data. It is a common practice to formulate complex econometric models ignoring spatial issues and assuming the model is robust in the entire study area.

One of the underlying assumptions of traditional statistics is that it assumes that the data are independent. However, if there is spatial or temporal autocorrelation, the model is compromised (Griffith, 1987). In this order of ideas, the Moran statistic (Moran's I) is the test that measures whether the data exhibit spatial autocorrelation (Moran, 1950).

Hence, the importance of statistical techniques such as the Geographically Weighted Regression (GWR), which has its genesis in the mid-90s and addresses this type of problem. The GWR is a novel type of regression that allows a better understanding of the models, provided there is a spatial variable. The GWR allows addressing the models locally and assessing them vis-à-vis the global model. It also contributes to developing an appropriate regression analysis on a dataset, primarily based on spatial dependence and assuming the data's local nature (Brunsdon, Fotheringham, & Charlton, 1996).

The GWR mainly allows observing spatial variations of estimated parameters and thereby learn the location and magnitude of the effect of an explanatory variable on the dependent one. It involves adjusting as many regressions as observations (spatial units) considered in the analysis. This, in turn, is its main sin: too many equations hinder the analysis. In other words, unlike a global equation, local models are obtained; one per observation, this is the price to pay. These models are estimated based on the concept of data decay, as long as more weight is given to the closest observations and less to those farthest away. The preceding is nothing other than the application of the first law of geography (Tobler, 1970): The results of nearby measurements tend to be more similar between each other than distant measurements. This concept is operationalized through a Kernel function, which simulates the effect of the fall as the distance increases. Consequently, it is possible to make an estimate adjusted to each observation by applying its corresponding equation.

The global Ordinary Least Squares (OLS) model is proposed as:

$$y_i = \beta_0 + \beta_1 x_{1,k} + \cdots + \beta_k x_{k,i} + \varepsilon_i, \quad (1)$$

where, y_i is the dependent variable, β_k are the parameters to be estimated, $x_{k,i}$ is the $k^{th.}$ explanatory variable, and ε_i, is the error.

The GWR is given by the following equation:

$$y_i = \beta_0(u_i, v_i) + \sum_k \beta_k(u_i, v_i)x_{k,i} + \varepsilon_i, \quad (2)$$

Where,

y_i is the dependent variable and $x_{k,i}$ is the kth explanatory variable ε_i, is the error in the location, (u_i, v_i) are the coordinates of the kth location and are conditional on various site and $\beta_k(u_i, v_i)$ are the diverse conditions on the location

Materials and methods

The unit of analysis of this study is defined by those students who graduated from a school in Antioquia and additionally completed their undergraduate degree in a HEI the same department. The databases used were downloaded from the website of the Colombian Institute for the Evaluation of Education (Icfes), and include the results of the Saber 11 tests for the years 2005 and 2006 in both semesters, and the Saber Pro test results for these same students in 2009 and the second half of 2010. In other words, there were four Saber, 11 tests, and three Saber Pro tests. In these, the same student is monitored with the results of both Saber tests aforementioned with a time difference between 10 and 13 semesters. These dates are chosen because very few students complete their undergraduate degree in less than five years; it takes them longer because of, among other things, the research work for their dissertation. Furthermore, at the time this study was conducted, these were the most recent and available dates on the ICFES website.

This sample is not generalizable for several reasons. First, we considered those students who were successful; in other words, they completed high school and higher education. Equally important is the filter applied: We only used the data of those individuals that took the Saber Pro test 5 to 6.5 years after taking the Saber 11 test. Second, the 10 to 13-semester window set between both tests excluded those that took the Saber 11 test and did not take the Saber Pro test and vice versa, or, on the contrary, those that took both tests, but that registered less than five or more than six and a half years between tests. Other individuals who were not included in our study, are those who graduated from any school in Antioquia but that completed their higher education somewhere other than in this department, or vice versa. We assume we gathered most of the best students; in other words, the results of the Saber 11 and Saber Pro tests outside of our window are most likely lower, a hypothesis which is tested below. Subsequently, a first filter was applied to the databases since not all had complete information nor matching variables. In other words, the purpose was to obtain a homogeneous database, which had the same exact variables from the list below.

In the case of the databases of the Saber 11 tests, the following variables were considered:

1. Age the Saber 11 test was taken (Julian age), obtained based on the student's date of birth, and the date the test was taken. Using Julian age solves the problem of a fraction of a year.
2. Student's gender.
3. Schooling hours (e.g., morning, afternoon, night, weekends).
4. School calendar (A, starting in February and ending in November. And B, starting in September and ending in June of the following year).
5. The school's academic nature (e.g., Academic or other, e. g. technical).
6. Monthly tuition fee paid at the school.
7. Municipality of the school.
8. Saber 11 test score, which is estimated according to Icfes Resolution 569 of October 18, 2011.

In the case of the databases of the Saber Pro test, the following variables are considered:

1. Student's socioeconomic stratum (1-6 according to utilities paid).
2. Student's marital status.
3. Age, the Saber Pro test, was taken (Julian years), obtained based on the student's date of birth, and the date the test was taken.
4. Time elapsed between taking the Saber 11 test and the Saber Pro test. It is obtained by subtracting the first age in Julian years from the second one.
5. HEI's annual tuition fee (e.g., college or university).
6. HEI's hours (daytime or nighttime).
7. HEI's sector, e.g., public or private.
8. HEI's academic nature, e. g. university or technical.
9. Saber Pro test score (This was the models' dependent variable).
10. Highest educational level attained by the mother.
11. Highest educational level attained by the father.
12. Mother's occupation (retired, working, studying, unemployed).
13. Father's occupation.

14. HEI's municipality.
15. The Euclidean distance between the city of the school where the student took the Saber 11 test and the city where Saber Pro was taken.

The databases were downloaded in a Microsoft Access template. We debugged the data in that same program by removing outliers. For example, in some cases, students below the age of 14 years took the Saber 11 test, which is an outlier; these cases are excluded. Then, the data were exported from Access to Excel to perform the cross-referencing with the common key and obtain a unified row with the information from both tests for the same student. Additionally, in the ArcGIS 10.2 software, the Cartesian coordinates were added in the National Geocentric Reference Framework (Magna-Sirgas), the official datum of Colombia (www.igac.gov.co), corresponding to the city where the school and HEI are located. We estimated, with these two points, the linear or Euclidean distance between both cities, where it is zero if the student attended high school and HEI in the same town.

For the period in question, a total of 94,180 students graduated high school and took the Saber 11 test in Antioquia. Between 5 and 6.5 years later, 33,368 students took the Saber Pro test, for a ratio of approximately one to three (see table 1). Only 14.4% of students who took the Saber 11 test between 2005 and 2006, took the Saber Pro test between 2009 and 2010. Then, after applying various filters, a database was obtained with 1,806 students who had taken both tests in the department of Antioquia (see table 1).

Table 1.

Universe and sample, after all, filters were applied of the students that took the Saber 11 in 2005 and 2006 and SABER PRO in 2009 and 2010 in Antioquia.

	Saber 11	SABER PRO
Total number of students who took the test	94,180	33,368
Total number of students that took both tests	13,540	
Number of students after cleaning the data and removing outliers	1,806	

There is a slight difference between the relative frequency in the sample universe and the sample of students who took both tests by the HEI's nature, e.g., public or private. In the sample, there is a slightly higher frequency of private HEIs, and the opposite is true for public HEIs. Nevertheless, this difference is not large enough to compromise the results (see Table 2).

Table 2.

Absolute and relative frequencies of the universe and the sample regarding the character of the HEI for the same students who took the Saber 11 test in 2005 and 2006 and the Saber Pro test in 2009 and 2010 in Antioquia.

	The character of the HEI			
	Private		Public	
	Frequency		Frequency	
	Absolute	Relative in %	Absolute	Relative in %
Universe	6902	60.9	6548	39.1
"Sample"	1099	61.5	707	38.5

To perform the GWR, the ArcGIS 10.2 software was chosen instead of the public domain GWR 4.0 software (Nakaya, 2009.). Although the latter can be downloaded for free for the Windows operating system (https://geodacenter.asu.edu/software/downloads/gwr_downloads), it has two limitations. First, ArcGIS allows running the exploratory regression with six evaluation rules before processing the GWR , as will be shown below. Second, the output files in ArcGIS can be mapped immediately without requiring intermediate steps, as needed by GWR 4.0.

We performed an Exploratory Regression in ArcGIS. This routine executes an OLS model with all independent variables, where the dependent variable is the Saber Pro score. The above allows evaluating the performance of the explanatory variables and appropriately specifying the model. Then, the best model in terms of R^2 was running in the GWR extension of the same software. Afterward, the best GWR model is compared with the global OLS model.

The GWR routine in ArcGIS calculates thousands of possible combinations with one or more explanatory variables to obtain an appropriate model, indicating why a model is not satisfactory. The six rules considered, according to Rosenshein and Rose (2013), were:

1. The sign (+/-) of the coefficients must be as expected. For example, the coefficient of the variable Saber 11 score must have a positive association with the dependent variable, the Saber Pro score. In other words, students who achieved good scores in their Saber 11 test are more likely to obtain good Saber Pro test scores.

2. The model, as a whole, as well as each variable in the model, must be statistically significant with an alpha level of 5%.
3. The variance inflation factor (VIF) measures the severity of multicollinearity; in other words, the redundancy between explanatory variables. This means that it prevents two or more variables from explaining the same thing. In that sense, what amount of the variance inflation is due to multicollinearity is measured; in an OLS regression, it must be less than 7.5.
4. Moran's I (SA), which measures spatial autocorrelation, must indicate that the under- and over-prediction residuals do not display clustering. If they do, this would suggest that at least one more variable is needed to ensure random residuals.
5. The Jarque-Bera test (JB) measures whether residuals exhibit a normal distribution. If SA and JB are significant, this is indicative of flaws attributable to residuals in the model.
6. The Adjusted R^2 must be greater than 50%. This indicator reflects the model's parsimony regarding the number of independent variables. Additionally, it seeks to reduce the Akaike Information Criterion (AIC). The latter is a measure of the relative quality of the model's fit, considering its fit and complexity. In other words, between two models with similar Adjusted R^2, the one with the lower AIC is preferred. This point gains much relevance when the program's output yields a dozen models that passed the evaluation tests.

Finally, the linear models discussed herein are justified considering that Kobrin, Sinharay, Haberman, and Chajewski (2011) found that linear models are appropriate for academic tests since more complex models did not provide a significant improvement.

Results

Just one model of the thousands of combinations obtained from the exploratory regression passed the six rules, with four explanatory variables, namely: School's tuition fee, SABER 11 test result, the school's academic nature, and father's occupation. Adjusted R^2 was 50.3%, the JB test and SA were not significant, e.g., greater than 0.05. This means the model's residuals are normally distributed, and in addition, there is no evidence of spatial autocorrelation. The Koenker test (Breusch & Pagan, 1979) was not significant at 5%, but it was at 10%, which suggests that the model is marginally seasonal. The coefficient and each explanatory variable is significant at an alpha level of 5%, and finally, the VIF is less than 7.5 (see tables 3 and 4).

Table 3.

Ordinary Least Squares (OLS) Model statistics that passed the Exploratory Regression diagnostics in ARCGIS.

Statistic	Adjusted R2	AIC	JB	k(bp)	VIF	SA
Value	0.503	1382.94	0.369	0.0822	1.2353	0.505

The global model suggests that there is a negative relationship between the student's high school tuition fee and their Saber Pro test score. In other words, the lower the value of the school's tuition fee, the higher the Saber Pro test score. This result is surprising because this finding indicates substantial progress in the quality of education in public schools with lower tuition fees for the years when the test Saber 11 test is taken. It also possible that we captured the best students, e.g., those with scholarships that pay little or no tuition fees. As expected, there is a positive relationship between the Saber 11 and Saber Pro test scores; in other words: The higher the Saber 11 test score, the higher the Saber Pro test score. Thus, good students in high school continue being good students in the HEI (see table 4). Besides, HEI's academic nature is essential. Students that attend a university have higher scores compared to those that graduated from a technical HEI (see table 4). Finally, the father's occupation also appears to be an essential driver. In that sense, the offspring of parents that are retired or studying obtain higher scores in the Saber Pro test compared to those whose parents are wage earners (see table 4).

Table 4.

Coefficients of the global model, test "t" and least-squares significance obtained with the dependent variable test score SABER PRO and four explanatory variables, the value of the school´s fee, Saber 11 test scores, the character of the institution of higher education and finally the father's occupation.

Explanatory variable	Unstandardized coefficients		Standardized Beta coefficients	t	Significance
	B	Typical error			p =
Constant	106.332	3.626		29.323	0,000
School´´s fee	-0.455	0.220	-0.112	-2.064	0.040
SaberABER 11 test results	9.698	0.792	0.680	12.252	0,000

Explanatory variable	Unstandardized coefficients		Standardized Beta coefficients	t	Significance *p* =
	ß	Typical error			
Academic character of the HEI	3.055	1.242	-0.131	-2.460	0.015
Father's occupation	0.310	0.152	0.106	2.037	0.043

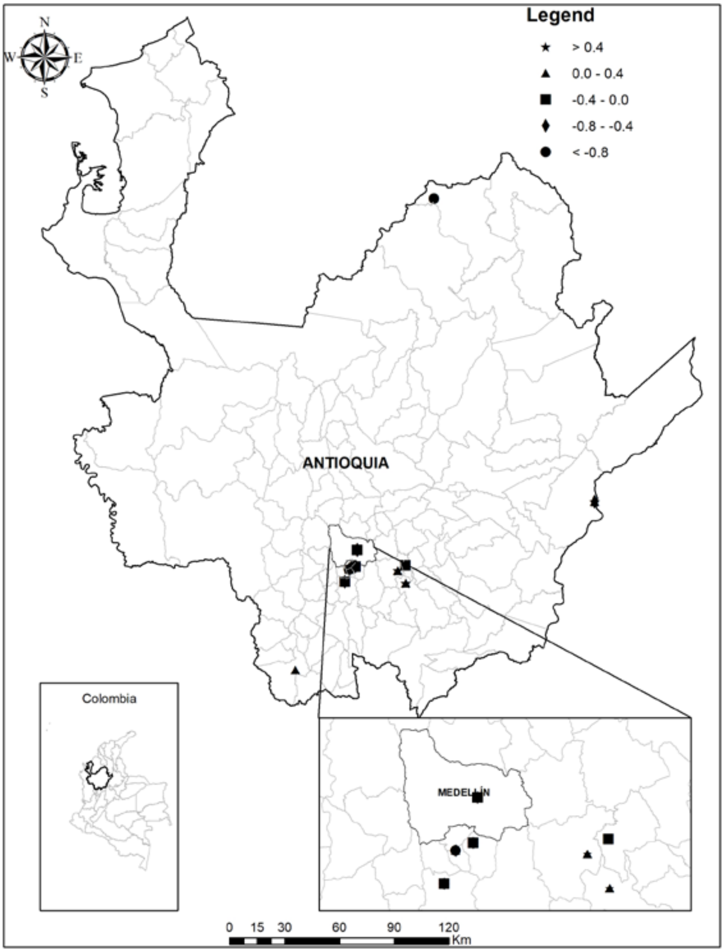

Figure 1: GWR Standard residuals of the GWR, which are explaining Saber Pro (2009 and 2010) test scores in Antioquia.

With a model that passed the six evaluation tests, we proceeded to run the GWR for this model in ArcGIS using a Gaussian-type model and an adaptive Gaussian Kernel, with the option of Golden Section Search.

One way to generalize the results is by mapping the residuals. This allows identifying areas where the effect of certain variables is outstanding. Based on the GWR results by averaging residuals for ten cities in Antioquia, it is possible to identify that the municipality of Rionegro exhibits high standard residuals, indicating that students who attend a HEI in that city achieve better Saber Pro scores compared to those studying in HEI's in other municipalities in Antioquia. In contrast, it is possible to identify that the municipality of Caucasia exhibits low standard residuals, indicating that students attending HEI's in that city obtain low scores on the Saber PRO test (see figure 1).

The performance of the OLS or global model compared to the GWR model is shown in Table 5. A slight improvement in the Adjusted R^2 and a slight reduction in AIC is appreciated. The above could be explained because K(BP) was not significant, indicating the good performance of the model in the department of Antioquia (Table 5).

Table 5.

Comparison of the Ordinary Least Squares (OLS) global model with GWR with the same independent variables to predict the test score Saber Pro in the department of Antioquia.

Statistic	Model	
	OLS	GWR
Adjusted R2	0,500	0.506
AICC	1382.948	1382.318

Our null hypothesis regarding the differential of the Saber 11 and Saber Pro scores between the universe sample and the sample proved to be false. Students in the sample exhibited slightly lower scores, particularly for Saber 11, a statistically significant result (see table 6).

Table 6.

Comparison of the results of the Saber 11 and Saber Pro mean test scores between the universe and the "sample".

	Saber 11**	Saber Pro**
Universe	-0.13	105.10
Sample	-0.17	105.09

**Statistical difference between two means *p*<0,01

Discussion

Using the exploratory regression tool bestows an appropriately specified model. This tool allows a rapid and better spatial understanding of variable performance. Ultimately, there is no substitute for common sense.

Consequently, a model should ideally contain variables that are subject to the public policy change, or that can be modified by decisions made by parents when choosing their children's school. In our case, of the model's four variables, only the father's occupation is not likely to change by choice. In contrast, the other three, the Saber 11 test score, the HEI's nature (university versus technical), and the school's tuition fee are susceptible to change by the student and or their parents.

The shortcomings and benefits of secondary education are perpetuated in higher education. Unfortunately, the amount of evidence pointing at the poor quality of secondary education in Colombia is overwhelming. That is why underperforming students in high school continue underperforming in the HEI. In the Colombian case, this finding had already been documented by Melo, Ramos, and Hernández (2014). In other words, our study supports the predictive validity of admission exams to higher education posited by Zwick (2010).

Primary and secondary education in Colombia moved toward greater coverage and gratuity. This study suggests that schools with low or no tuition fee also offer quality education, which is not exclusive to expensive schools. It is abnormal that the program *Ser Pilo Paga* [Being a Nerd is Worth It], established in 2014, but now abolished, sponsored students in private universities despite the Ministry of Education's enormous efforts to improve education in public schools. Our evidence suggests that in Antioquia; public secondary education has been fruitful.

Finally, our study argues there are mediocre HEIS. These institutions deserve more attention from the Ministry of Education since many of them offer a deficient quality of education. To summarize: What high school or HEI should parents send their offspring to in Antioquia to develop a competent professional? At a school with little or no tuition fee, most likely a public high school, and subsequently to a university in or near the municipality of Rionegro.

To date, no research have been published in the academic literature cross-referencing both tests, Saber 11 and Saber Pro, and that analyze them together for the same student. Regarding gender, according to our findings, unlike Guhl's study (2005) regarding the geography of admissions at the *Universidad Nacional de Colombia*, there was no significant gender differential in the Saber Pro test.

The GWR model experienced a slight improvement compared to the global OLS model. There were few benefits from using the GWR, except in the case of the municipality of Rionegro, where the residuals obtained were the highest. In other words, the Saber Pro test results seem stationary for students who attended HEIs outside of Rionegro. The Koenker statistic K(BP) was not significant at 5%. This means that the global model performs well in the area of study, the department of Antioquia. A significant K(BP) would have indicated a bigger improvement in Adjusted R^2, provided it is a well-specified model, but in contrast to our findings here, its performance varies in the area of study as aforementioned.

The mapping of the residuals is a handy tool to observe the dynamics of the model. However, the copious amount of regressions yielded by the GWR, one per observation, limit generalizations or predictions (Fortin, James, Mackenzie, Melles, & Rayfield, 2012). This is why we mapped 10 cities with the average standard residuals.

It is important to observe the aforementioned modeling rules to achieve an appropriately specified model. In other words, the GWR is not a panacea, the reason why we do not recommend applying it without having performed an exploratory regression in ArcGIS. One of the advantages of ArcGIS over GWR 4.0 is that in the former, if the model is in violation of the rules, it does not run, whereas in the latter, it does. In addition, ArcGIS can be used to map the resulting coefficients, as well as normalized residuals once the routine is executed. On the other hand, the GWR 4.0 offers neither this evaluation option nor the cartographic possibility. Notwithstanding, the GWR 4.0 software offers more freedom in handling the parameters of the GWR model versus ArcGIS 10.2. The latter is not appropriate for all types of data (Charlton & Fotheringham, 2009), such is the case of a dichotomous variable, which is impossible to model in ArcGIS. Indeed, GWR 4.0 offers a Gaussian logistic modeling when the dependent variable is dichotomous.

Additionally, in the GWR 4.0, semi-parametric models can be carried out. The above is achieved by leaving one or more fixed variables and others subject to local GWR coefficients. To summarize, the GWR 4.0 offers three local and three semi-parametric models, for a total of six. Whereas this is impossible in ArcGIS 10.2.

Finally, GWR is a technique that allows moving from a global analysis of the data to a local analysis, whereby a greater degree of detail and accuracy is obtained from the data under analysis.

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