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Peer Effects on First-Year University Students' Results: The Role of Classmates' Academic Performance and Socioeconomic Status

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Abstract: Peer effects in the context of higher education have lately received increased attention. Higher diversity in the composition of new cohorts of students, generated mainly in countries where public and institutional policies have enabled access to students from low socioeconomic conditions and races who unusually attend postsecondary education, make these effects even more relevant. This research estimates and analyzes the effect of peers' academic performance and course composition by socioeconomic origin on students' academic achievement at a private Colombian university between 2008 and 2019. The estimates, by Ordinary Least Squares and Multilevel models, support the existence of significant peer effects. There was a positive effect of peers' performance on Calculus I academic results, principally of medium and high-performance peers, and a null effect of the socioeconomic level in Calculus I, but a significant effect in Communication Skills I, although with a limited impact. By introducing heterogeneities, it is evident that students perceived a greater benefit from performance improvements from peers who are in the same performance category or socioeconomic level. These results provide evidence of the existence, direction, and magnitude of peer effects in Colombian higher education. Additionally, they suggest that the most relevant characteristic of classmates is their academic performance and not their socioeconomic origin.

Keywords: peer effects; academic performance; socioeconomic status; linear model; multilevel or hierarchical model; heterogeneity

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1. Introduction

In recent years, great progress has been made in identifying peer effects. Several studies show that the influence of classmates, study or neighborhood peers is an important factor in individual results such as test scores, career choice, drug use, smoking probability, and teenage pregnancy [1–4]. These effects are often externalities in which the background, current behavior or peers' results impact a person's result who is part of the group. For example, this happens when classmates are more skilled and, therefore, the professor can teach better or at a more demanding pace. When a student is disruptive and consumes more of the professors' attention, this affects the rest of his/her classmates, and when peers have more skills other students learn from them [5]. In general, there are many channels through which this influence operates, and various results are recorded in the literature that include both positive and negative peer effects, as well as large, medium, small, and null effects [6].

Peer effects are especially important in determining the impact of certain educational policies in which, directly or indirectly, class group composition is modified. In Colombia, as in other developing countries, private school education generally performs better than public education. In addition, the high cost of quality private universities and the scarce resources available to public universities, limits the alternatives for most students to enroll in low-quality private institutions or be left out of the system. This results in severe social segregation in both schools and universities. For this reason, policies that promote the access of low-income students to quality institutions through demand subsidies or education fellowships are often discussed [7–9]. These policies are aimed at increasing access to quality education, but also reducing segregation between social classes. Therefore, an appropriate evaluation of direct and indirect results should consider the effect of the greater interaction between students from different socioeconomic backgrounds.

In line with this, Being Smart Pays Off (Ser Pilo Paga—SPP for its acronym in Spanish) was a program implemented by the National Colombian Government from 2015 to 2018, which granted financial aid to facilitate the entry of 40,000 low-income students with good academic performance to quality higher education institutions [10]. (The granted SPP benefit corresponded to a condonable credit that covered tuition costs in a high-quality accredited higher education institution in the country, and semester aid between one and four minimum wages. High school students who could apply to this program had to meet certain conditions, including belonging to an economically disadvantaged household and being registered in the System for Beneficiaries Selection for Social Programs (Sisbén). The program worked as a condonable credit that covered the entire tuition cost at any accredited university, public or private, of high quality, and provided support to students who chose an institution outside their residence municipality. This program enabled an unprecedented number of high-performing students from the lowest socioeconomic levels to enter some high-tuition private universities. Álvarez [11] argues that in a society as unequal as the Colombian society, where people from different social classes do not meet and empathy for the other is low, SPP allows an interaction in which prejudices are reduced and pro social attitudes are forged. Londoño [12] used data from a private Colombian university in which 2015 students were exogenously exposed to a higher proportion of classmates from low socioeconomic levels as a result of SPP and analyzed whether this socioeconomic diversity affected individual preferences towards income redistribution. The author found that greater diversity had a considerable impact on with whom high-income students interacted and, consequently, how unevenly they perceived income to be distributed across the country and how supportive they turned towards redistribution. Londoño also explored the effect of socioeconomic diversity on academic achievement and did not find a significant effect.

Hoxby and Weingarth [13] argue that the evidence for greater diversity benefits, by race and income, within classrooms is often anecdotal. In fact, they argue that desegregation policies in the United States, until then, had been based on theories rather than evidence about peer effects. In the Colombian case, there are few studies on the existence of peer effects, and even fewer on their structure and the mechanisms through which they take place. This research aims to fill this gap through a case study of a Colombian university that offers a favorable environment to identify and disaggregate the influence of peer characteristics, in particular their academic performance and socioeconomic origin, on the individual academic performance of first semester students. Since 2002, this university has progressively increased its scholarship program for students of low socioeconomic status and, additionally, with the SPP program, it had a historic increase in the volume of low-income students. These results can increase efficiency in decision-making within universities, but also provide evidence of the impact in terms of academic performance of educational policies that reduce social segregation in universities.

Since Coleman's study [14], in which the importance of the student's background in their school performance is emphasized, the identification and disaggregation of peer effects has taken on great relevance in understanding educational production function. Sacerdote [6] displays the results of an extensive review of the literature on peer effects on the outcome variables, both academic (scores, student dropout or career choice) and social (probability of drinking, smoking or consuming drugs), in primary, secondary, and higher education. As mentioned before, the results, under different contexts and methodological approaches, are very diverse.

Regarding higher education, peers are generally defined as residence partners or roommates, and the effect of their characteristics on students' academic achievement has been analyzed. Some authors find significant peer effects [15–17], while others such as

Foster [18] and Lyle [19] argue that roommates' habits and characteristics do not have an impact on the student's overall Grade Point Average (GPA). According to Foster, this result is valid even for peers who are socially closer, while Lyle, argues that peer influence is considered significant on career choice and the decision to remain in the army. In another aspect of this literature, the relevance of peers on social behavior was explored in which there was, with greater consensus, a significant effect on the frequency of alcohol or cigarette consumption, drug use and certain sexual behaviors [20–22].

These peer effects are often externalities that are not considered in schools, universities, and other settings in which people interact. Therefore, there is the possibility of increasing social welfare through interventions that incorporate such effects. However, in practice, there are some empirical difficulties in identifying peer effects properly. In the basic model, linear in means, the individual result variable is a function of the average result of their partners. This model has been widely used, at least as a starting point, by different authors [1,23–25]. However, given that the estimation by ordinary least squares is biased by the presence of reflection, correlation, and self-selection problems (which are discussed in the methodological section), the authors used different empirical strategies [26]. Some studies have solved these problems by making use of randomized controlled experiments in group assignments [15,17,27,28], instrumental variables techniques [4,13,26,29,30], and other quasi-experimental methods [1,31].

Despite its usefulness, the linear model in means may not be the most appropriate or the most interesting because the assumption of linearity implies homogeneity in the peer effects, i.e., each student has the same effect on his/her classmates. If so, any policy based on these results would have a distributive effect, but not on efficiency. If we assume that a high-performing student in course A is exchanged for a low-performing student in B, with courses A and B being equal in size, the gains from reassignment for students in A are eliminated by losses from students in B. So, although the linear model can be useful to solve some distributional dilemmas, such as the disparity of educational opportunities, a less restrictive estimate allows us to identify the structure of these peer effects and increase the efficiency of certain educational models [13]; for example, programs that assign young people to schools outside their locality, or policies such as SPP, which promote desegregation by income level.

In this way, recent literature has focused on disaggregating peer effects, allowing different reference groups to act with greater or lesser incidence on the different types of students. Lavy, Silva and Weinhardt [25] found a significant negative effect of the lowest performing peers on individual results in the national Key Stage 3 test conducted in ninth grade in England. Burke and Sass [23] analyzed the determinants of reading and math test scores in Florida public school students and argue that high-achieving students benefit more from having peers with outstanding academic performance. Likewise, Hoxby and Weingarth [13] explored the results of a student reassignment policy in schools in a North Carolina County (Wake County) and indicate that once it was organized by academic achievement, characteristics such as race, income, parental education, and ethnicity had little or no effect on the state end-of-course test score. Stinebrickner and Stinebrickner [17] used data from 1295 students at Berea College in Kentucky, United States, to examine the effect of roommate characteristics on student achievement. The authors found that the peer effects acted only for women and not for men, and when examining the role of income, they found that low-income students who were assigned to high-income roommates performed academically significantly better than low-income students who were assigned to other low-income students.

In this sense, the nonlinear models in peer's average achievement allow identification of the structure of these relationships. The "*bad apple*" and "*Shining light*" models are the most popular. In the first, the most relevant peer effects come from the student with the worst academic performance or being the least disciplined. If the result of low-achieving students having a disproportionate negative effect is found (greater than in the linear model on means), then it is evidence of this type of behavior. The brilliant student model is the opposite in that an outstanding student can significantly increase his/her classmates' achievement so that they increase their performance, and the number of such students, would have a disproportionate positive effect on the achievement of other students [13]).

There are other models that represent possible structures in which the peer effects work. In the *Invidious Comparison* model, the results are negatively affected by the presence of better performing students. The *boutique model* suggests that students improve their performance when they have peers with similar characteristics. Similarly, the *focus model* maintains that homogeneity among peers is good regardless of the characteristics of the i-th student. Finally, and contrary to the latter, in the *rainbow model* all students are better when they are forced to deal with all other types of students. That is, heterogeneity has a positive effect [6].

Based on this, the purpose of the following sections is to estimate and analyze the effect of academic performance and socioeconomic origin of peers on the academic achievement of students. For this analysis we used a database in which students were randomly assigned to their courses and then we identified the structure of these effects (if they existed) without the assumption of linearity.

2. Data

The data for this analysis were obtained from two sources. The administrative records of Universidad del Norte, a private, high quality accredited university, considered one of the top ten universities in Colombia, located in Barranquilla, were used. These records have detailed information on the grades in each course, the study program, the faculty, and socioeconomic information of the freshmen students at the Universidad del Norte who enrolled between 2008 and 2019, and who took Calculus I and/or Communication Skills I. The second source of information came from the records of the Colombian Institute for Education Evaluation (Icfes) [32], in charge of applying the *Saber 11* test to students close to finishing their secondary education as a requirement for college admission. This base provides information on scores by test components and broader information on the socioeconomic origin of the students, such as education and parents' occupation, family income, housing stratum, assets possession, among others.

The cross database provides information on the student's performance in Calculus I and Communication Skills I in their freshmen semester, as well as in the components of mathematics and critical reading in the admission exam to higher education—Saber 11. Additionally, the course to which each student was randomly enrolled is known, and therefore, it is possible to identify their classmates. The university's registration office assigns freshmen students to its classes without any criteria related to their characteristics of origin or performance, only considering the places available in each course and the mandatory subjects for the student according to their study plans. This feature is useful in overcoming the auto selection problem, as explained in the next section.

As can be seen in Table 1, there were 9771 freshmen students enrolled in Calculus I (Those courses for which there is no complete information on the socioeconomic characteristics of the total enrolled students were eliminated from the sample if the missing data included more than 40% of the students). Thirty-eight percent of the students were women, the average age being 17.7 years, 72% finished their school education in the Department of Atlántico (state where Universidad del Norte is located), 41% had some type of scholarship, and 72% studied an engineering school program. It is important to highlight that the Saber 11 test scores are standardized in deviation numbers with respect to the national average in each period, so that they are comparable over time despite methodological changes. In this sense, on average, the score in mathematics on the Saber 11 test was 1.72 standard deviations above the national average. Similarly, there were 21,397 students enrolled in Communication Skills, 52% of them were women, only 28% had some type of scholarship, the distribution was less concentrated among academic divisions, and the average standardized score in critical reading was 1.15.

Table 1. Descriptive Statistics.

	Calculus I		Communication Skills I	
	Mean	**Deviation**	**Mean**	**Deviation**
Women *	0.38	0.48	0.52	0.50
Age	17.7	0.99	17.9	1.28
Student origin *				
Atlántico	0.72	0.45	0.73	0.45
Caribe	0.26	0.44	0.25	0.43
Rest	0.02	0.14	0.02	0.16
Student with *				
Institutional Scholarship	0.15	0.04	0.10	0.05
Corporate Scholarship	0.03	0.36	0.02	0.30
SPP Scholarship	0.20	0.18	0.15	0.15
Gen E Scholarship	0.02	0.40	0.01	0.35
Faculty *				
Business	0.23	0.42	0.21	0.41
Basic Sciences	0.03	0.16	0.05	0.22
Hum. and Social Sciences	0.02	0.14	0.02	0.12
Engineering	0.72	0.45	0.04	0.20
Other faculty	0	0	0.68	0.46
Average score **	3.50	0.77	3.88	0.62
Icfes score	1.72	1.06	1.15	0.98

Source: Authors' preparation. Note: There are four types of scholarships: institutional, financed with resources from the Universidad del Norte; Corporate, financed with external resources from the private sector; and scholarships from two national government programs: *Ser Pilo Paga* (SPP-2014–2018) and Generación E (2019). (*) They correspond to dichotomous variables; in these cases, the mean indicates the percentage that the category represents in the total of observations. (**) The grade ranges between 0 and 5 (maximum grade). There are 9971 observations in Calculus I and 21,397 in Communication Skills I.

Regarding the students' socioeconomic origin, between 54 and 56% came from households with a low socioeconomic level, in stratum 1, 2 or 3. The stratum is a measure of the socioeconomic level in Colombia. They are classified into six strata (where 1 is the poorest) according to the physical and environmental characteristics of the house. Although the correlation with income is imperfect, its simplicity is an advantage since most Colombians are aware of their stratum [12]. Although the information on family income was more limited, around 40% of the students belonged to a family with an income of less than three current legal minimum wages, and 52% of the parents registered as maximum educational level achieved being professional or having a postgraduate degree (Table 2). It should be noted that this information was taken from the Saber 11 form, which corresponds to the student's situation at the time of taking the test. Around 90% of students enter university in the year following the Saber 11 test, so it is unlikely that their socioeconomic conditions have changed substantially.

If the evolution over time of the total number of students by socioeconomic level is examined, it is observed that from 2008 to 2014 the number of students enrolled in Calculus I is increasing and is distributed equally by stratum group. However, as of 2015, the number of students taking Calculus I doubled and they came from stratum 1, 2 and 3. Later, in 2019, the number of enrolled students fell (Figure 1). At the same time, in the case of Communication Skills, the total number of students of high socioeconomic level remained stable and began to decrease as of 2016. In contrast, the total of students of low stratum showed an increasing trend, with an increase in 2015 that doubled the students coming from these strata, and then began to fall from the following year (Figure 1).

The observed growth in 2015 was due to the Ser Pilo Paga program. Between 2014 and 2015, Universidad del Norte registered an undergraduate enrollment growth of 11.7%, while the figure in the last two years had been around 4% [33] (Universidad del Norte, 2020). This exponential growth was due to 1040 students of the SPP program who were admitted and enrolled at the University in 2015. This dynamic was maintained during the four years of the program, and for 2018 Universidad del Norte ended with 3918 undergraduates enrolled SPP beneficiary students. These students represented 29% of the student population in that year and positioned the University with the highest number of SPP students in the country (Universidad del Norte, 2020).

Table 2. Students' socioeconomic origin statistics.

	Calculus I	Communications Skills I
	Mean	Mean
Stratum 1	0.14	0.13
Stratum 2	0.20	0.19
Stratum 3	0.22	0.22
Stratum 4	0.21	0.21
Stratum 5	0.11	0.13
Stratum 6	0.11	0.12
Less than 3 smlv *	0.41	0.40
Between 4 and 9 smlv	0.45	0.46
More than 10 smlv	0.14	0.14
Mothers with high school or less	0.24	0.25
Professional mothers	0.47	0.46
Mothers with a postgraduate degree	0.06	0.07
Father with high school or less	0.25	0.25
Professional fathers	0.45	0.45
Fathers with a postgraduate degree	0.07	0.08

Source: Authors' preparation. Note: All variables are dichotomous, and the mean indicates the percentage that the category represents in the total of observations. There were 9710 students with stratum information in Calculus and 19,840 in Communication skills I (*) Current legal minimum wage (smlv for its acronym in Spanish).

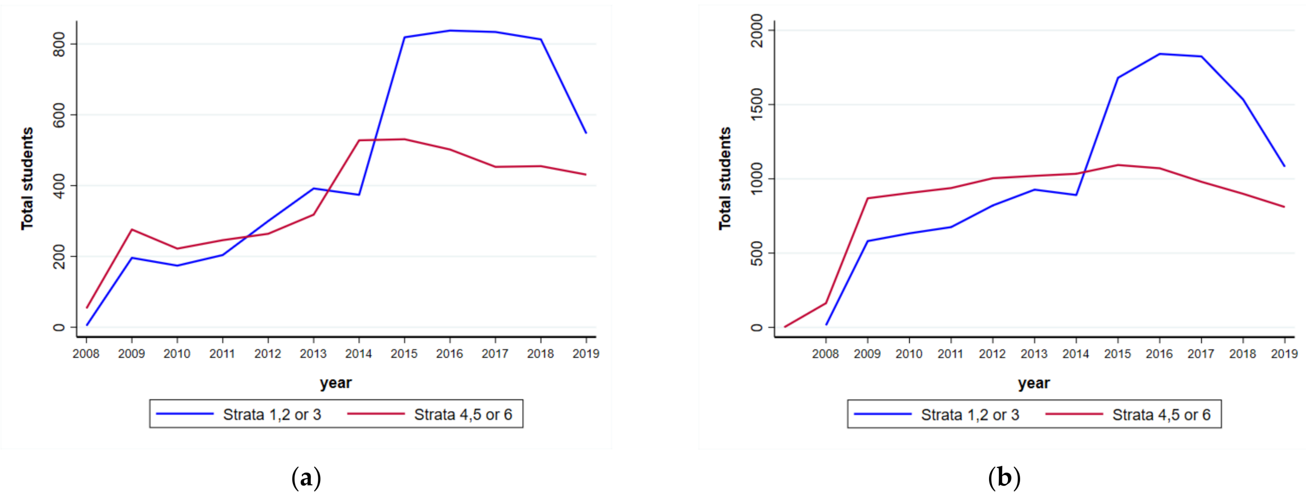
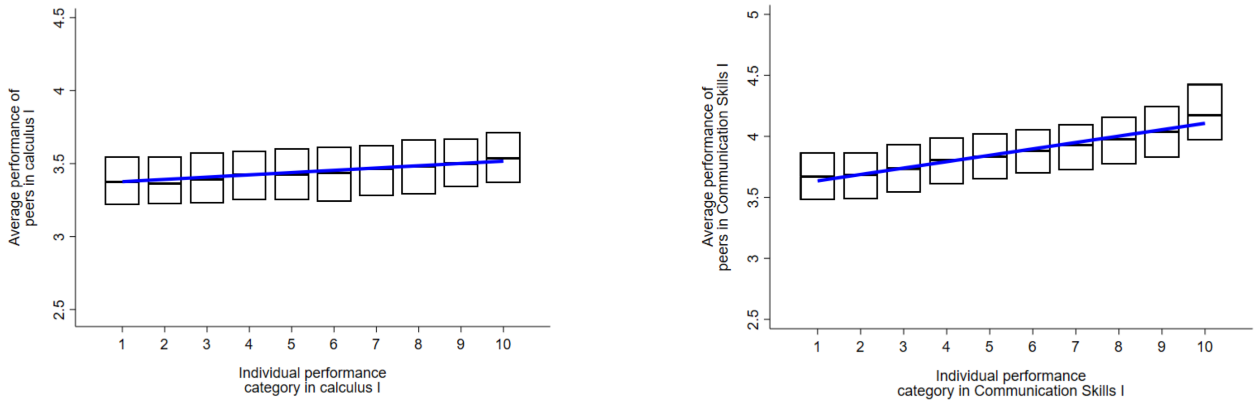


Figure 1. Distribution of total students according to stratum and year: (**a**) Calculus I; (**b**) Communication Skills I. Source: Authors' preparation.

The evolution of these indicators shows the growing participation of the lower stratum in the student population of Universidad del Norte, even before the SPP program. This allows exploiting the variations in course composition by socioeconomic level and identifying if this has an impact on their academic performance. These variations are considered exogenous to students for two reasons. First, there is no evidence that students changed their preferences for Universidad del Norte due to its growing low-income student population. Second, they are randomly assigned to their courses so they cannot choose their peers. However, since individual performance may be related to socioeconomic level, it is important to separate these effects.

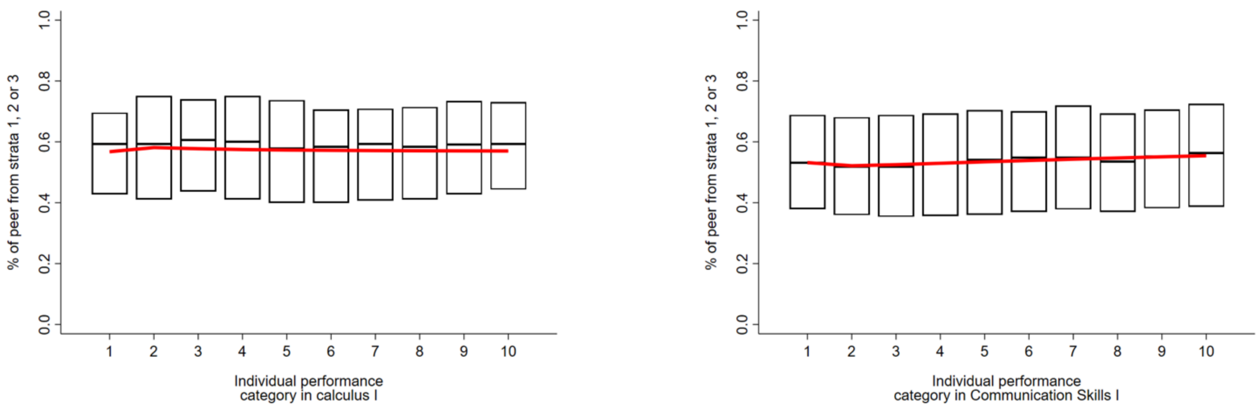
Each student was related to the average final grade of his/her classmates (hereafter his/her peers) and the percentage of classmates who came from lower stratum. Figure 2 shows the distribution (between the upper and lower quartiles) of the peers' average grade (y-axis) for each type of student according to their academic performance (x-axis), where 1 represents the lowest academic performance and 10 the highest performance. Both in Calculus I and in Communication Skills I, a positive relationship was observed between the category of the student's academic performance and the average grade of his/her classmates. This suggests that students with higher academic achievement also have higher performing peers. However, this is only a correlation so far, with no evidence of causality.



(**a**) (**b**)

Figure 2. Peer performance distribution by student performance category: (**a**) Calculus I; (**b**) Communication Skills I. Source: Authors' preparation.

Equivalently, the relationship between the student's academic performance and the percentage distribution of classmates who came from stratum 1, 2, or 3 was examined. Figure 3 shows that between 40% and 80% of the peers came from lower stratum (y-axis), with a median around 60%. However, this does not vary systematically as student performance varies (x-axis). In addition, if the stratum variable is replaced by the socioeconomic level index estimated by Icfes, there is no clear trend either (Figure A1). This is formalized in the next section.



(**a**) (**b**)

Figure 3. Peer percentage distribution in lower stratum by student performance category: (**a**) Calculus I; (**b**) Communication Skills I. Source: Authors' preparation.

3. Methodology

In the linear model on means, frequently cited in the literature on peer effects, the individual student result is a function of the individual student characteristics, average group characteristics, and peers' average result [1,26]. Formally:

$$Y_{ij} = \beta_0 + \beta_1 X_{ij} + \beta_2 \overline{Y}_{j-i} + \beta_3 \overline{X}_{j-i} + \epsilon_i \tag{1}$$

In this analysis, Y_{ij} is student i final grade in group or classroom j, X_{ij} is a vector of individual characteristics of i. The peers of i are all the other students who belong to group j, their classmates. So, $\overline{Y}_{j-i}$ is the average of the final grade of all students in j except i. $\overline{X}_{j-i}$ is a vector of the average characteristics of the group excluding i.

In this specification, a significant coefficient β_2 or β_3 is interpreted as evidence of the existence of peer effects on academic performance. However, in the literature, at least three problems are recognized for which estimating this model by ordinary least squares (OLS) is questionable.

The first problem arises because, generally, belonging to group j is not the result of a random process but is determined by observed and unobserved characteristics that, in turn, are related to the individual's academic performance. Therefore, if it is not possible to control these factors that determine self-selection, the student's result may be misleadingly seen as an effect of the characteristics or performance of his/her peers rather than a reason why he or she belongs to that group. Think, for example, that students are assigned to courses according to their academic performance in the admission test, or according to their country of origin; if the model does not take this into account appropriately, the peer effect estimators would be biased.

The second difficulty is a reflection problem in which the classmates influence the student's grade and, in turn, the student also influences the grade of his/her classmates. Because the mean $(\overline{Y}_{j-i})$ excludes student's i own result, the equation already eliminates the mechanical incorporation of the student's effect on the mean. However, this is included through the results of his/her peers because each of them has an equation parallel to his/hers, thus generating a problem of endogeneity by simultaneity [13]. In these circumstances, the OLS estimators reflect an effect mixture between the different causality directions and are, therefore, not consistent. Finally, there is also a correlation problem that could affect the estimators' efficiency since the peers' characteristics $(\overline{X}_{j-i})$ are related to the academic performance of the same $(\overline{Y}_{j-i})$ [1,13,26,34].

In the used database, freshmen university students were randomly enrolled in their courses according to their study plans and the available places in each course. Given that the characteristics that lead a student to choose a certain career (and therefore a certain study plan) are probably related to their performance in Calculus I and Communication Skills I, it is necessary to add fixed effects of faculty. Once this is controlled, and considering the process of assigning students to their courses, there is no suspicion of selection bias presence.

Regarding the reflection problem, the modern literature has managed to overcome this challenge with instrumental variable techniques [1,13], with the use of specific peer groups for each individual [4,26,30], or through proxy variables of student's abilities; for example, results in courses or tests prior to the current period [25]. On this occasion, we use a proxy of peer performance that is estimated from variables that reflect students' initial abilities and that have not been affected by their peer characteristics. Estimating the following model:

$$Y_{ijt} = \beta_0 + \beta_1 X_{ijt} + \beta_2 \overline{Z}_{j-i,t} + \beta_3 \% EstratoBajo_{j-i,t} + \gamma_f + \varepsilon_t + \epsilon_{ijt} \tag{2}$$

$$\overline{Z}_{j-i,t} = \frac{\sum_{u \in j-i}^{N} (Z_{ut})}{N_{j-i}} \tag{3}$$

where Y_{ijt} is the final grade (in Calculus I or in Communication Skills I) of student i in group or classroom j in year t, and X_{ijt} is a vector of individual characteristics of i (gender, age, stratum, origin and characteristic of home and school origin). $\overline{Z}_{j-i,t}$ is the average of the predicted final grade of all students in j except i. The $\%EstratoBajo_{j-i,\,t}$ is the student proportion who coming from household stratum 1, 2, or 3 of the total student number in group j excluding i in year t. Finally, we include fixed effects of year (ε_t) and the faculty to which the program the individual is studying belongs (γ_f). In this specification, the reflection problem is solved by calculating the peer's academic performance as the average of the expected students' grade based on their mathematics score on the Saber 11 test and their grade in the first term exam, in the case of Calculus, and based on the critical reading score on the Saber 11 test for Communication Skills (there is no information on the exam qualification in the Communication Skills course.) This is:

$$Z_{u,calculo} = \beta_0 + \beta_1 MatSaber11_{u,calculo} + \beta_2 NotaPrimerExamen_{u,calculo} + \epsilon_{u,calculo} \quad (4)$$

$$Z_{u,competencias} = \beta_0 + \beta_1 LecSaber11_{u,competencias} + \epsilon_{u,competencias} \quad (5)$$

Because the Saber 11 test is taken before entering the University, the results in this test are not influenced by current classmates in Calculus I and Communication Skills I classes, and in that sense the predicted grade from these scores is free from the reflection problem. However, the differences between the competencies assessed in the mathematics component of the Saber 11 test and in the Calculus I course suggest that the score on this test does not adequately predict the student's outcome at the end of the Calculus course. Therefore, the first exam grade is also included in Equation (4) so that it better approximates the observed peers' performance. It is important to note that the implicit assumption is that peers have little or no influence on the results on the first term exam that is taken within the first four weeks of the semester. This is plausible if it is considered that they are freshmen university students, so it is likely that they did not know their classmates previously, and it is also supported by the theory of peers under which the transmission of specific knowledge or habits study is not immediate but takes time.

In model estimation (2), a β_2 significant coefficient is evidence that the peers' academic performance affects the students' academic performance. Furthermore, if it is controlled for individual characteristics and group academic performance, a β_3 significant coefficient implies that student academic achievement varies systematically with the peer percentage coming from low socioeconomic stratum. This model, however, is limited to identifying the existence of peer effects.

Following Díaz and Penagos [26], it was explored whether both the lowest and the highest performing students exerted a significant influence on individual academic results. For this, individuals were classified into three categories according to their expected academic performance (C_{ijt}), and then the reference group j of student i was divided among those with low, medium, and high performance. Low-performing students were those with a grade lower than the lower tercil of the distribution, medium-performing students had a grade between the lower and higher tercil, and high-performing students had a grade higher than the highest tercil of the distribution. Subsequently, the average grade of the three subgroups was calculated and the following model was estimated, where the course composition was also disaggregated by level:

$$Y_{ijt} = \beta_0 + \beta_1 X_{ijt} + \beta_2 \overline{Z}^{bajo}_{j-i,t} + \beta_3 \overline{Z}^{medio}_{j-i,t} + \beta_4 \overline{Z}^{alto}_{j-i,t} + \beta_5 \%Estrato1_{j-i,t} + \beta_6 \%Estrato6_{j-i,t} + \gamma_f + \varepsilon_t + \epsilon_{ijt} \quad (6)$$

In addition, interactions were introduced to explore whether results vary based on individual student performance:

$$\begin{aligned} Y_{ijt} = \beta_0 + \beta_1 X_{ijt} \quad & + \beta_2 \overline{Z}^{bajo}_{j-i,t} + \beta_3 \overline{Z}^{medio}_{j-i,t} + \beta_4 \overline{Z}^{alto}_{j-i,t} + \beta_5 C_{ijt} \times \overline{Z}^{\,bajo}_{j-i,t} + \beta_6 C_{ijt} \times \overline{Z}^{medio}_{j-i,t} + \beta_7 C_{ijt} \times \overline{Z}^{alto}_{j-i,t} \\ & + \beta_5 \%Estratos1_{j-i,t} + \beta_6 \%Estratos6_{j-i,t} \\ & + \beta_7\ EstratoBajo_{ijt} \times \%Estratos1_{j-i,t} + \ \beta_8\ EstratoBajo_{ijt} \times \%Estratos6_{j-i,t} + \gamma_f + \varepsilon_t + \epsilon_{ijt} \end{aligned} \quad (7)$$

$$\forall\ C_{ijt} = Category\ of\ low\ performance, medium\ performance, highperformance\ ofstudentiingroupjinyeart$$

Model (6) allows identification of whether the relevant variable is group performance or the performance of a particular student group: the best, the average, or the worst. In addition, by disaggregating the peers' socioeconomic level, it is possible to identify the effect of altering the peers' participation with a lower or higher socioeconomic level in the peer group. In model (7), interactions are added to explore whether these effects, as argued by Hoxby and Weingarth [13], are heterogeneous according to the performance and income level of students *i*.

Finally, additional estimates were made in which the independence assumption of the observations was relaxed and was controlled for the unobserved characteristics of each group such as professor training, class schedule, type of exam, among others. This second part of the study avoided possible shock biases common to all individuals within a class. For this, a hierarchical or multilevel model of random effects was used in which the first level corresponds to the individual characteristics, and the second level to course *j* characteristics in which the individual is enrolled, and which also define his/her group reference. Therefore, models (2), (6) and (7) were adapted to this methodology:

$$Y_{ijt} = \beta_0 + \beta_1 X_{ijt} + \beta_2 \overline{Z}_{j,t} + \beta_3 \% EstratosBajos_{j,t} + \gamma_f + \varepsilon_t + u_j + e_{ijt} \quad (8)$$

To explore the existence of heterogeneous effects, it is estimated:

$$Y_{ijt} = \beta_0 + \beta_1 X_{ijt} + \beta_2 \overline{Z}^{bajo}_{j-1,t} + \beta_3 \overline{Z}^{medio}_{j-1,t} + \beta_4 \overline{Z}^{alto}_{j-1,t} + \beta_5 \% Estratos1_{j-i,t} + \beta_6 \% Estratos6_{j-i,t} + \gamma_f + \varepsilon_t + u_j + \epsilon_{ijt} \quad (9)$$

$$\begin{aligned} Y_{ijt} = \beta_0 + \beta_1 X_{ijt} \quad & + \beta_2 \overline{Z}^{bajo}_{j-1,t} + \beta_3 \overline{Z}^{medio}_{j-1,t} + \beta_4 \overline{Z}^{alto}_{j-1,t} + \beta_5 C_{ijt} \times \overline{Z}^{bajo}_{j-1,t} + \beta_6 C_{ijt} \times \overline{Z}^{medio}_{j-1,t} + \beta_7 C_{ijt} \times \overline{Z}^{alto}_{j-1,t} \\ & + \beta_5 \% Estratos1_{j-i,t} + \beta_6 \% Estratos6_{j-i,t} + \beta_7 \ EstratoBajo_{ijt} \\ & \times \% Estratos1_{j-i,t} \ \beta_6 + \ \beta_8 \ EstratoBajo_{ijt} \times \% Estratos6_{j-i,t} + \gamma_f + \varepsilon_t + u_j + \epsilon_{ijt} \end{aligned} \quad (10)$$

where u_j considers the differences between courses or classes by unobserved characteristics, and the intra-class correlation ρ is an estimator of the variance proportion that is explained by differences between groups.

$$\rho = \frac{\sigma_u}{\sigma_u + \sigma_e} \quad (11)$$

4. Results

4.1. Calculus I

Table 3 shows the results of the ordinary least squares estimates of the linear model (2) and the disaggregated peer effects model (6). Regarding the effect of the student's characteristics on their grade in Calculus I, it was found that better results in the mathematics component of the Saber 11 test increased the final grade. Specifically, an increase of one standard deviation in the math score increased the grade in Calculus I by 0.32 points. Women had, on average, better results than men. Students whose parents had the highest level of basic or secondary education had results slightly below the rest (−0.05). One more year of age decreased the expected grade by 0.03 points. Students of low socioeconomic level (from stratum 1, 2 or 3) had lower results than those from higher strata. Graduating from a high school in the *Atlántico* department and having studied full time had a positive effect, while the high school nature (public or private) was not significant. Regarding classmates, significant results were found in the academic peers' performance, measured as the average of the expected grade in Calculus I, over the student's grade. The results of the expected grade estimation are found in Table A1 in Appendix A. A one-point increase in the peer rating increased the individual's score by 0.23 (30% of a standard deviation).

As a first step to relax the assumptions of the linear model on means, the student's peers were disaggregated into those with low, medium, and high predicted performance and it was found that the performance of the lowest performing students had a negative effect on the individual with a significance of 0.10. A one-point increase in these students' average grade decreased the individual's grade by 0.08 points. Contrary to this, an increase in the grade of medium and high-performance students increased the individual grade by

0.31 and 0.19 points respectively; this is 40% and 25% of the deviation in the grade (Table 3). Such estimates are highly significant.

Table 3. Peer effects on academic performance in Calculus I—OLS.

	OLS	
	Model (2)	**Model (6)**
Mathematics Saber 11	0.321 ***	0.323 ***
	(0.00801)	(0.00815)
Women	0.157 ***	0.156 ***
	(0.0152)	(0.0154)
Age	−0.0363 ***	−0.0375 ***
	(0.0103)	(0.0105)
Public School	0.0273	0.0334
	(0.0205)	(0.0206)
Mother's education basic & middle	−0.0540 ***	−0.0551 ***
	(0.0201)	(0.0203)
Father's education basic & middle	−0.0534 ***	−0.0538 ***
	(0.0197)	(0.0199)
stratum 1,2,3	−0.0756 ***	−0.0715 ***
	(0.0186)	(0.0188)
Full time	0.116 ***	0.117 ***
	(0.0183)	(0.0184)
Atlántico Department	0.0471 ***	0.0511 ***
	(0.0173)	(0.0174)
Second Semester	0.154 ***	0.163 ***
	(0.0217)	(0.0253)
Average peer performance	0.230 ***	
	(0.0345)	
Average low peer performance		−0.0848 *
		(0.0508)
Average medium peer performance		0.310 ***
		(0.0916)
Average high peer performance		0.188 ***
		(0.0664)
%Stratum 1,2,3	0.0364	
	(0.0501)	
%Stratum 1		−0.0582
		(0.0741)
%Stratum 6		0.00557
		(0.0899)
Constant	2.036 ***	1.165 ***
	(0.250)	(0.428)
Year dummy	yes	yes
Faculty dummy	yes	yes
Observations	8344	8176
R^2	0.216	0.216

Robust standard errors in parentheses. *** $p < 0.01$, * $p < 0.1$. Note: "Stratum" is a measure of socio-economic status in Colombia. The system classifies housing from strata 1 (the poorest) to strata 6 (the richest) based on their physical characteristics and those of the neighborhood.

In relation to the peers' socio-economic level, no significant effect was found in any of the specifications. These estimates were replicated by replacing the socioeconomic level variable with the index calculated by Icfes (INSE) for the period from 2015 to 2019 and the results are robust (Table A2). So, until now, what is relevant in the peers' composition is their academic performance and not their socioeconomic origin.

Although in model (6), when disaggregating the group average, the assumption that each student has the same effect on their classmates is relaxed, it still doesn't allow us to identify how these effects vary according to individual characteristics. For this, Equation (7) is estimated, and the results are presented in Table A3. Again, there was no significant effect for the socioeconomic level of the reference group, nor differential effects of the peers' academic performance according to the individual's stratum (Tables A3 and A4). The significant results related to performance are summarized in Table 4. Specifically, it was found that, for low-performing students, an increase of 1 point from their low-performing peers decreased their score by 0.18 points, while having peers as average performer with an average grade 1 point higher increased their score by 0.23. An increase in the score of the high-performance peers lowered their grade by 0.05 points. As evidenced in Table 4, the peers that generated the greatest benefit for all students, except the high performers, were the peers with medium performance. While the result for high-performing students suggests that these students' grades were not affected by the performance of any of their peers, they were good regardless of who their peers were.

Table 4. Effects of heterogeneous peers according to student's academic performance in Calculus I—OLS.

	Low Performance Peers	**Medium Performance Peers**	**High Performance Peers**
Low performance student	−0.18 ***	0.23 **	−0.05 **
Medium performance student	0.00	0.26 **	0.22 **
High performance student	0.00	0.00	0.00
N	8176	8176	8176
Individual characteristics	yes	yes	yes
Year dummies	yes	yes	yes
Faculty dummies	yes	yes	yes

*** $p < 0.01$, ** $p < 0.05$. Note: non-significant coefficients equal zero.These effects are the coefficient sum that accompanies the peers' performance in the corresponding category and the coefficient of the interaction between the category of individual student performance and the average performance of their peers in a certain category. For example, \beta_2+\ \beta_5\ in Equation (7) to estimate the effect of underperforming peers.

Additionally, these three specifications were estimated using hierarchical or multilevel models. In least squares estimation, it is assumed that the observations are independent of each other; however, the students were nested in groups and, therefore, shared class time, evaluation methodology, professor, among other common factors. In this sense, it is important to estimate peers' effects differentiating between the individual characteristics and student's origin (freshmen) and group characteristics (second level). The added value of these models is that they allow control for those unobserved group characteristics that can influence the results, such as a more flexible professor or a more demanding one. However, the intra-class coefficient (ρ) in Table 5 suggests that the differences between groups explain only between 3.5 and 5.1% of the error variance.

Results related to students' characteristics were consistent with what was found in the estimation by ordinary least squares (OLS). However, the magnitude of the peers' average effect was greater; an increase of one point in the average grade for the course increased the student's expected grade by 0.46. When this effect was disaggregated (Table 5) it was found that the low performance peers did not have a significant effect, and similar to what was found before, medium and high-performance peers impacted positively and significantly the student's performance in Calculus I. By allowing heterogeneous effects according to individual student performance, it was found that the most relevant subgroups for each student were those with the same academic performance (Table 6).

Table 5. Peer effects on academic performance in Calculus I—Multilevel.

	Multilevel	
	Model (8)	**Model (9)**
Mathematics Saber 11	0.315 *** (0.00867)	0.324 *** (0.00884)
Women	0.152 *** (0.0165)	0.150 *** (0.0168)
Age	−0.0352 *** (0.0107)	−0.0361 *** (0.0110)
Public School	0.0246 (0.0194)	0.0279 (0.0194)
Mother's education basic & middle	−0.0550 *** (0.0203)	−0.0554 *** (0.0207)
Father's education basic & middle	−0.0521 *** (0.0194)	−0.0544 *** (0.0197)
stratum 1,2,3	−0.0784 *** (0.0190)	−0.0743 *** (0.0188)
Full Time	0.114 *** (0.0172)	0.117 *** (0.0173)
Atlántico Department	0.0453 *** (0.0170)	0.0492 *** (0.0170)
Second Semester	0.160 *** (0.0296)	0.162 *** (0.0335)
Course size	0.00546 *** (0.00148)	0.00631 *** (0.00172)
Average peer performance	0.463 *** (0.0438)	
Average low peer performance		0.0755 (0.0704)
Average medium peer performance		0.325 ** (0.139)
Average high peer performance		0.206 ** (0.0940)
%Stratum 1,2,3	0.0470 (0.0625)	
%Stratum 1		−0.0553 (0.1000)
%Stratum 6		0.0993 (0.115)
Constant	1.153 *** (0.246)	0.533 (0.535)
σ_u	0.0153	0.0229
σ_e	0.4202	0.4208
ρ	0.035	0.051
Year dummies	yes	yes
Faculty dummies	yes	yes
Observations	8344	8208
Number of Groups	464	454

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$.

Table 6. Effects of heterogeneous peers according to student's academic performance in Calculus I—Multilevel.

	Low Performance Peers	**Medium Performance Peers**	**High Performance Peers**
Low performance student	0.67 **	0.03 *	−0.14 ***
Medium performance student	−0.12 **	0.63 ***	−0.02 **
High performance student	−0.01 ***	−0.02 **	0.68 ***
N	8208	8208	8208
Number of groups	454	454	454
Individual characteristics	yes	yes	yes
Year dummies	yes	yes	yes
Faculty dummies	yes	yes	yes

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Note: Non-significant coefficients equal zero.

4.2. Communication Skills I

Similar to the estimated results for Calculus I, a higher score in the critical reading section in the Saber 11 test and being a woman significantly increased the Communication Skills grade in the first semester. Other characteristics such as age, mothers with basic or secondary education, and belonging to a stratum 1, 2 or 3 household had a smaller but significant and negative effect on the grade. Likewise, having finished full-time high school in a municipality in the *Atlántico* Department had a positive effect. Contrary to Calculus I, the father's education was not relevant, and significant differences were found with respect to peer effects. An increase of one point in peers' average increased student's scores by 0.48 points. However, when the peers were disaggregated according to their academic performance, no subgroup had a significant effect on the student's grade (Table 7).

Table 7. Peer effects on academic performance in Communication Skills I—OLS.

	OLS	
	Model (2)	**Model (6)**
Reading Saber 11	0.146 ***	0.150 ***
	(0.00516)	(0.00511)
Women	0.165 ***	0.165 ***
	(0.00919)	(0.00923)
Age	−0.0472 ***	−0.0480 ***
	(0.00648)	(0.00654)
Public School	0.00601	0.0103
	(0.0120)	(0.0121)
Mother's education basic & middle	−0.0339 ***	−0.0342 ***
	(0.0118)	(0.0118)
Father's education basic & middle	−0.00147	−0.00114
	(0.0116)	(0.0117)
Stratum 1,2,3	−0.0257 **	−0.0253 **
	(0.0109)	(0.0109)
Full-time	0.0543 ***	0.0541 ***
	(0.0101)	(0.0102)
Atlántico department	0.0161	0.0146
	(0.0102)	(0.0102)
Second semester	0.0371 ***	0.0431 **
	(0.0126)	(0.0195)
Average peer performance	0.477 ***	
	(0.0945)	
Average low peer performance		−0.0781
		(0.125)
Average medium peer performance		0.190
		(0.247)
Average high peer performance		0.115
		(0.131)
%Stratum 1,2,3	0.0651 **	
	(0.0301)	
%Stratum 1		−0.0441
		(0.0451)
%Stratum 6		−0.204 ***
		(0.0532)
Constant	2.611 ***	3.608 ***
	(0.383)	(0.972)
Year dummies	yes	yes
Faculty dummies	yes	yes
Observations	17,554	17,447
R^2	0.157	0.154

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$.

While in Calculus I peers composition by socioeconomic origin was not relevant, in Communication Skills increasing peers' participation of low socioeconomic level had a positive and significant effect. (When the INSE was used as a variable of socioeconomic level, the results were robust. An increase in the socio-economic level index in peers was related to a lower grade in Communicative Skills (Table A6)) If this effect was disaggregated between the students' percentage in the lowest and highest stratum, increasing the classmate proportion in stratum six had a negative and significant effect, although a small one. Specifically, a 10% increase in stratum six peers decreased the expected score by 0.02 points (3.2% of a standard deviation).

Tables A7 and A8 from Appendix A show the results of disaggregating these peer effects according to students' individual characteristics. Again, there were no significant differences between students according to their academic performance, but according to their social stratum. These last results are synthesized in Table 8. It was observed that increasing the students' percentage from stratum six affected negatively the grade for both high and low socioeconomic level students. However, the effect on the latter was almost double. A 10% increase in stratum six peers decreased the students score in the lower strata by 0.037 points. Similarly, increasing students' participation from the lowest stratum had a negative effect on high socioeconomic status students, and almost zero for those of low socioeconomic status. A 10% increase in stratum one peers decreased the achievement of high social stratum students by 0.029 points.

Table 8. Effects of heterogeneous peers according to student's socioeconomic level in Communication Skills I—OLS.

	Stratum 1 Peers %	**Stratum 6 Peers %**
Low socioeconomic level student	0.007 ***	−0.376 **
High socioeconomic level student	−0.291 ***	−0.154 ***
N	17,447	17,447
Individual characteristics	yes	yes
Year dummies	yes	yes
Faculty dummies	yes	yes

*** $p < 0.01$, ** $p < 0.05$. Note: (1) non-significant coefficients equal zero. (2) Low socioeconomic level are students who belong to a household stratum 1, 2 or 3, and those with a high socioeconomic level are those of stratum 4, 5 or 6.

The multilevel estimates of random effects show results that are mostly consistent with what was found by OLS. It should be noted that the socioeconomic composition effect of the course was not significant when added in a dummy of low or high strata (stratums 1, 2, or 3), but the percentage of stratum six peers was significant and negative (Table 9). When heterogeneities are examined according to student's socioeconomic level, it is again observed that increasing the composition of the peers at the extremes of the distribution by socioeconomic level (SEL) had a negative effect for both types of students (those of low and high SEL). However, students were less affected in their academic achievement when this increase was in peers close to their socioeconomic level (Table 10). Finally, it should be noted that the differences between groups explain 21% of the variance, which was significantly higher than in Calculus I.

Table 9. Peer effects on academic performance in Communication Skills I—Multilevel.

	Multilevel	
	Model (8)	**Model (9)**
Reading Saber 11	0.141 ***	0.142 ***
	(0.00525)	(0.00520)
Women	0.148 ***	0.148 ***
	(0.00946)	(0.00950)
Age	−0.0482 ***	−0.0482 ***
	(0.00615)	(0.00617)
Public School	0.00799	0.00998
	(0.0116)	(0.0116)
Mother's education basic & middle	−0.0259 **	−0.0261 **
	(0.0106)	(0.0106)
Father's education basic & middle	−0.0129	−0.0130
	(0.0109)	(0.0109)
stratum 1,2,3	−0.0292 ***	−0.0292 ***
	(0.0102)	(0.0101)
Fulltime	0.0508 ***	0.0507 ***
	(0.00933)	(0.00941)
Atlántico Department	0.0156	0.0152
	(0.00952)	(0.00954)
Second Semester	0.0689 **	0.153 ***
	(0.0293)	(0.0518)
Course size	0.00954 ***	0.0107 ***
	(0.00306)	(0.00312)
Average peer performance	0.468 **	
	(0.213)	
Average peer low performance		0.0544
		(0.328)
Average peer medium performance		1.162 *
		(0.614)
Average peer high performance		0.361
		(0.330)
%Stratum 1,2,3	0.0478	
	(0.0607)	
%Stratum 1		−0.0873
		(0.0999)
%Stratum 6		−0.228 *
		(0.118)
Constant	2.348 ***	−1.950
	(0.831)	(2.473)
σ_u	0.0634	0.0643
σ_e	0.2453	0.2455
ρ	0.21	0.21
Year dummies	Yes	yes
Faculty dummies	yes	yes
Observations	17,554	17,467
Number of Groups	759	753

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 10. Effects of heterogeneous peers according to student's academic performance in Communication Skills I—Multilevel.

	Stratum 1 Peers %	**Stratum 6 Peers %**
Low socioeconomic level student	−0.06 **	−0.39 *
High socioeconomic level student	−0.27 **	−0.21 *
N	8208	8208
Number of Groups	454	454
Individual characteristics	yes	yes
Year dummies	yes	yes
Faculty dummies	yes	yes

** $p < 0.05$, * $p < 0.1$. Note: Non-significant coefficients equal zero.

5. Discussion

In recent decades, the existence of peer effects has been widely studied, and in more recent years the structure and mechanisms under which they operate have also been studied. However, the results are far from homogeneous and there is evidence of negative, positive, null, large, or small effects of peer characteristics on individual results such as test scores, dropout, career choice, and other social behaviors [1–4]. This research estimated and analyzed the effect of peers' academic performance and course composition by socioeconomic origin on the final grade in Calculus I and Communication Skills I of Universidad del Norte's freshmen students between 2008 and 2019 with Ordinary Least Squares Estimates and Multilevel Models.

The results in the previous section provide evidence on the existence and direction of the peer characteristics effect on individual student performance. Once the characteristics of the student and the unobserved characteristics of the group were controlled for, a positive effect of peers' academic performance was found on the individual grade in Calculus I. In particular, medium and high-performance peers were those that had greater influence, whereas the peers' socioeconomic origin was not a significant variable. Contrary to this, in Communication Skills, the peers' achievement was not significant, and in contrast, the peers' percentage from stratum one and six had a negative and significant effect, although moderate. Increasing the peer predicted grade by one point increased the expected grade in Calculus I by 0.23 to 0.46 points. Mid-performing peers were the most influential subgroup. Higher performing classmates had a positive but less than average effect, while lower-performing classmates had a less than average (absolute value) or no negative effect. In this sense, little evidence was found for the model of the *Shining light* or the *bad apple*, since increases in the scores of the best or worst students did not have a disproportionate effect (greater than in the linear model in means) on the student's grade in Calculus and Skills.

These results are in line with what was found by Díaz and Penagos [26], who analyzed peer effects in an economics course at a Colombian university and found that low-performing peers decreased the grade by 0.29 points, while medium and high-performance peers increased the grade by 0.39 and 0.21 points, respectively. As argued by Brady, Insler and Rahman [35], it is possible that having peers with better performance negatively affects the individual score, either because of the *harmful comparison* model suggested by Hoxby and Weingarth [13], or in the case of underperforming students, because the *bad apple* can degrade performance even as that apple does better, given its disruptive behavior that affects the rest of the class.

The most interesting results came from the non-linear estimations, in which the variations in peers' effects were examined according to students' individual characteristics. These results reaffirm that the socioeconomic level was not relevant for peer effects in the academic achievement in Calculus I, because the results did not vary according to a student's stratum. In contrast, when peers' effects were disaggregated by the individual's level of academic performance, it was found that the greatest benefit for students came from an improvement in peer performance in the same category or at least in the closest category to them (Tables 4 and 6). On the contrary, an improvement in peer performance in a different category, or in the most distant category from their performance had a negative effect. These results suggest two preliminary conclusions. On the one hand, they provide evidence of the validity of the *harmful comparison* model between students with different academic performance, in which the results are negatively affected by better peers' performance in a different performance category. On the other hand, they reveal that high and low ability students were separated into different study or social networks, decreasing beneficial social interaction between members of different academic performance, which is in line with experiment findings by Carrell, Sacerdote, and Wells [36].

The results in Communication Skills, once again, differed from the findings in Calculus I. Effects of heterogeneous peers were evidenced according to the student's socioeconomic level, but not according to their academic performance. However, it is important to note that an increase of 10% in the peers of either low strata, stratum 1, or stratum 6 had a limited impact on the student's final grade that varied between ± 0.02 and ± 0.04 (between 3.2% and 6.5% of a standard deviation). Regarding the heterogeneous effects, the results suggest that students benefit more from having classmates of a medium socioeconomic level, since increasing the course composition with low-income students or with high-income students had a negative effect on individual achievement. Nevertheless, within this negative effect, students obtained better results when being with peers of a socioeconomic level more like theirs, which is evidence of a version of the *boutique model* in which students improve their performance when they have peers with similar characteristics.

The result in Communication Skills supports the conclusions of Hoxby and Weingarth [13], who analyzed the policy effect of students' reassignment between schools in Wake County in North Carolina, United States. Using a data panel of students in eight grades between 1994 and 2003, the authors support that race and income are not significant in most cases, and in the few cases where they are, they have a very small effect. The authors found that if a poor black student experienced a ten percent increase in their class proportion that is black and poor, their achievement fell by 0.6 points (about 2.5% of a standard deviation).

There are two hypotheses that explain the different results in Skills and Calculus. On the one hand, Communication Skills is a mandatory first semester course for a greater number of programs and, therefore, the classes are more heterogeneous. This can limit interactions between students and, consequently, peer effects. On the other hand, as evidenced in the multilevel estimates, the variance percentage that is explained by the characteristics not observed at the course level was higher in Communication Skills case than in Calculus case. This means that group factors (other than peer performance and SEL) such as the professor, the type of exam or the class schedule explain the differences in grades in Skills to a greater extent. So, these unobserved characteristics downplay the peers' performance.

6. Conclusions

In essence, three general conclusions derived from these findings are worth highlighting. First, the evidence on the negative effects, in terms of academic achievement, of increasing heterogeneity in classrooms based on students' socioeconomic origin is limited, and if it exists it has very modest effects. Second, the positive and significant peer effects suggest that students benefit from having better performing classmates, for which there is a social multiplier effect in which students not only benefit (or not) from education received but also from their classmates. Evidence of these effects has been found in the literature not only on academic achievement [1,15–17] but also on other social attitudes such as the perception of inequality and poverty, the probability of using drugs, and political positions [2–4,12,20]. The third conclusion is related to the importance of distinguishing the type of knowledge for which peer academic performance is relevant. As evidenced in this study, there were clear differences in the results in Calculus I and in Communication Skills I. This suggests that those studies that examine peer effects aggregating greater diversity of programs and courses may find different, and even opposite results, distinguishing between them.

Finally, these results cannot be interpreted as efficient social interactions for the students. Since the peers refer to all classmates, it is impossible to examine the variation of the results based on the peers with whom there was a more significant interaction (specific peers to the student). Instead, it can only be deduced how these interactions were with the reference groups most important to determine the student's grade. In this sense, an analysis of the social interactions that are most beneficial to the student requires the study of specific peer groups, which is an aspect to be developed in future research.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

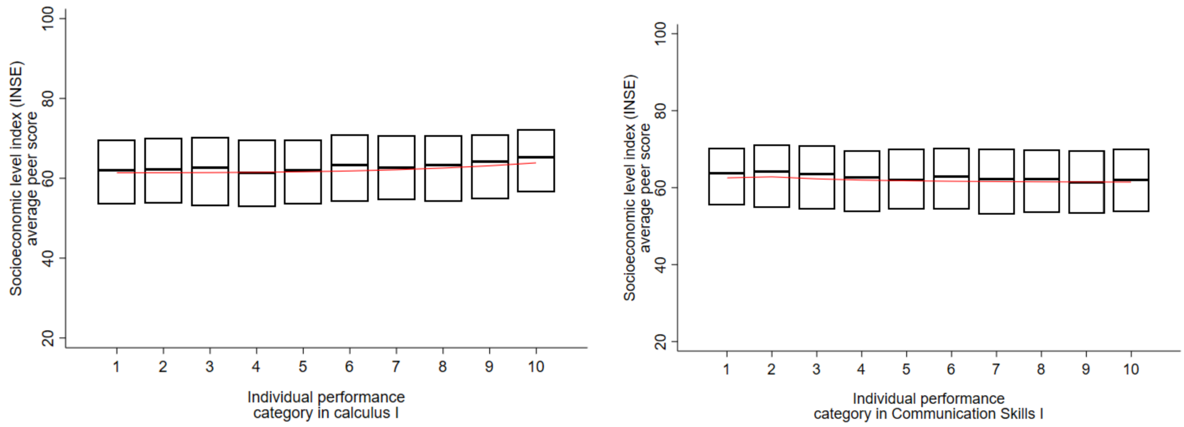

Figure A1. Distribution of the socioeconomic level index by student category. This is a calculation carried out by Icfes that brings together different factors, generally related to education, occupation and income, which interact for an adequate measurement of an individual's well-being. Source: Authors' preparation.

Table A1. Final grade determinants.

	Final Grade	**Final Grade**
	Calculus I	**Communication Skills I**
First Term Grade	0.531 ***	
	(0.00429)	
Saber 11 Score	0.103 ***	0.164 ***
	(0.00393)	(0.00400)
Constant	1.477 ***	3.694 ***
	(0.0141)	(0.00603)
Observations	15,534	24,340
R^2	0.570	0.064

Standard errors in parentheses. *** $p < 0.01$. Note: The Saber 11 score in mathematics is used for Calculus I and in critical reading for Communication Skills I.

Table A2. Peer effects on academic performance in Calculus I—INSE.

	OLS	
	Model (2)	**Model (6)**
Mathematics Saber 11	0.377 ***	0.380 ***
	(0.0118)	(0.0119)
Women	0.133 ***	0.136 ***
	(0.0194)	(0.0194)
Age	−0.0503 ***	−0.0478 ***
	(0.0148)	(0.0149)
Public School	0.0310	0.0339
	(0.0245)	(0.0245)
Mother's education basic & middle	−0.0120	−0.0153
	(0.0246)	(0.0246)
Father's education basic & middle	−0.0138	−0.0165
	(0.0241)	(0.0241)
INSE	0.00427 ***	0.00410 ***
	(0.00149)	(0.00148)
Full-time	0.119 ***	0.120 ***
	(0.0230)	(0.0230)
Atlántico Department	0.0513 **	0.0507 **
	(0.0215)	(0.0216)
Second semester	0.224 ***	0.247 ***
	(0.0269)	(0.0283)
Average peer performance	0.258 ***	
Average peer low performance		−0.0654
		(0.0661)
Average peer medium performance		0.0678
		(0.127)
Average peer high performance		0.441 ***
		(0.0919)
INSE peers	0.00201	0.00294
	(0.00244)	(0.00245)
Constant	2.322 ***	1.221 **
	(0.332)	(0.572)
Year dummies	yes	Yes
Faculty dummies	yes	yes
Observations	4800	4752
R^2	0.222	0.223

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$.

Table A3. Effects of heterogeneous peers according to the student's academic performance in Calculus I.

	OLS		
	(7.A)	**(7.B)**	**(7.C)**
%stratum 1	0.00141	−0.0810	−0.0886
	(0.120)	(0.134)	(0.115)
%stratum 6	−0.0389	0.0528	−0.00724
	(0.0869)	(0.0943)	(0.0843)
Stratum bajo * %stratum 1	−0.124	0.0209	0.0416
	(0.134)	(0.149)	(0.127)
Stratum bajo * %stratum 6	−0.0156	−0.181	−0.117
	(0.143)	(0.161)	(0.142)
Average peer low performance	−0.175 ***	−0.0590	−0.0499
	(0.0492)	(0.0653)	(0.0559)
Average peer medium performance	0.225 **	0.255 **	0.135
	(0.0890)	(0.113)	(0.0936)
Average peer high performance	0.194 ***	0.222 **	−0.00796
	(0.0651)	(0.0870)	(0.0701)

Table A3. *Cont.*

	OLS		
	(7.A)	**(7.B)**	**(7.C)**
Low performance * Average peer low performance	0.115		
	(0.0940)		
Low performance * Average peer medium performance	−0.00955		
	(0.143)		
Low performance * Average peer high performance	−0.247 **		
	(0.117)		
Medium performance * Average peer low performance		−0.0429	
		(0.0821)	
Medium performance * Average peer medium performance		0.156	
		(0.129)	
Medium performance * Average peer high performance		−0.119	
		(0.106)	
High performance * Average peer low performance			0.0256
			(0.0783)
High performance * Average peer medium performance			0.0654
			(0.125)
High performance * Average peer high performance			0.118
			(0.104)
Constant	2.047 ***	1.176 ***	2.708 ***
	(0.394)	(0.427)	(0.384)
Individual characteristics	yes	yes	yes
Year dummies	yes	yes	yes
Faculty dummies	yes	yes	yes
Observations	8176	8176	8176
R^2	0.379	0.218	0.413

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A4. Effects of heterogeneous peers according to the students' socioeconomic level in Calculus I.

	OLS
	Model 8.D
%stratum 1	−0.0645
	(0.134)
%stratum 6	0.0370
	(0.0962)
Stratum bajo * %stratum 1	−0.00123
	(0.150)
Stratum bajo * %stratum 6	−0.150
	(0.164)
Average peer low performance	−0.0677
	(0.0739)
Average peer medium performance	0.417 ***
	(0.126)
Average peer high performance	0.0876
	(0.104)
Low performance * Average peer low performance	−0.0322
	(0.0963)
Low performance * Average peer medium performance	−0.174
	(0.159)
Low performance * Average peer high performance	0.168
	(0.131)
Constant	1.156 **
	(0.548)
Individual characteristic	Yes
Year dummies	Yes
Faculty dummies	yes
Observations	8176
R^2	0.216

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A5. Effects of heterogeneous peers according to student's academic performance in Calculus I.

	Multilevel		
	(10.A)	**(10.B)**	**(10.C)**
%stratum 1	0.0275	−0.0668	−0.0598
	(0.143)	(0.160)	(0.141)
%stratum 6	0.0918	0.176	0.0947
	(0.108)	(0.120)	(0.101)
Stratum bajo * %stratum 1	−0.142	−0.0116	0.0292
	(0.136)	(0.157)	(0.134)
Stratum bajo * %stratum 6	−0.178	−0.362 **	−0.251 *
	(0.143)	(0.168)	(0.149)
Average peer low performance	−0.157 **	0.196 **	0.263 ***
	(0.0727)	(0.0860)	(0.0668)
Average peer medium performance	0.321 **	0.128	0.335 **
	(0.145)	(0.163)	(0.133)
Average peer high performance	0.353 ***	0.308 ***	−0.0849
	(0.101)	(0.118)	(0.0896)
Low performance * Average peer low performance	0.823 ***		
	(0.129)		
Low performance * Average peer medium performance	−0.293 *		
	(0.166)		
Low performance * Average peer high performance	−0.490 ***		
	(0.138)		
Medium performance * Average peer low performance		−0.315 ***	
		(0.0936)	
Medium performance * Average peer medium performance		0.625 ***	
		(0.176)	
Medium performance * Average peer high performance		−0.328 **	
		(0.141)	
High performance * Average peer low performance			−0.271 ***
			(0.0826)
High performance * Average peer medium performance			−0.359 ***
			(0.129)
High performance * Average peer high performance			0.676 ***
			(0.111)
Constant	0.879 *	0.459	1.437 ***
	(0.520)	(0.541)	(0.481)
Individual characteristics	yes	yes	yes
Year dummies	yes	yes	yes
Faculty dummies	yes	yes	yes
Observations	8208	8208	8208
Number of groups	454	454	454

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A6. Peer effects on academic performance in Communication Skills I—INSE.

	OLS	
	Model (2)	**Model (6)**
Reading Saber 11	0.126 ***	0.131 ***
	(0.00788)	(0.00774)
Women	0.175 ***	0.174 ***
	(0.0123)	(0.0124)
Age	−0.0536 ***	−0.0540 ***
	(0.00917)	(0.00924)
Public School	0.000434	0.000636
	(0.0145)	(0.0147)

Table A6. *Cont.*

	OLS	
	Model (2)	**Model (6)**
Mother's education basic & middle	−0.0164	−0.0175
	(0.0148)	(0.0149)
Father's education basic & middle	0.00260	0.00236
	(0.0143)	(0.0144)
INSE	−0.000817	−0.000893
	(0.000905)	(0.000912)
Full-time	0.0526 ***	0.0521 ***
	(0.0138)	(0.0140)
Atlántico Department	0.0123	0.0103
	(0.0132)	(0.0133)
Second semester	0.0862 ***	0.114 ***
	(0.0175)	(0.0342)
Average peer performance	0.503 ***	
	(0.126)	
Average peer low performance		0.184
		(0.153)
Average peer medium performance		0.389
		(0.392)
Average peer high performance		0.166
		(0.199)
INSE peers	−0.00363 **	−0.00532 ***
	(0.00157)	(0.00151)
Constant	2.768 ***	1.957
	(0.568)	(1.695)
Year dummies	Yes	yes
Faculty dummies	yes	Yes
Observations	8275	8179
R^2	0.156	0.152

Standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$.

Table A7. Effects of heterogeneous peers according to student's academic performance in Communication Skills I—OLS.

	MCO		
	(7.A)	**(7.B)**	**(7.C)**
%stratum 1	−0.297 ***	−0.295 ***	−0.299 ***
	(0.0829)	(0.0829)	(0.0829)
%stratum 6	−0.135 **	−0.136 **	−0.135 **
	(0.0576)	(0.0577)	(0.0577)
Stratum bajo * %stratum 1	0.297 ***	0.302 ***	0.310 ***
	(0.0921)	(0.0920)	(0.0921)
Stratum bajo * %stratum 6	−0.262 ***	−0.262 ***	−0.262 ***
	(0.0872)	(0.0872)	(0.0872)
Average peer low performance	−0.0548	−0.186	−0.159
	(0.134)	(0.144)	(0.162)
Average peer medium performance	0.0827	0.171	0.167
	(0.255)	(0.271)	(0.280)
Average peer high performance	0.175	0.160	0.135
	(0.134)	(0.151)	(0.152)
Low performance * Average peer low performance	−0.243		
	(0.246)		
Low performance * Average peer medium performance	0.275		
	(0.352)		
Low performance * Average peer high performance	−0.0518		
	(0.230)		

Table A7. *Cont.*

	MCO		
	(7.A)	**(7.B)**	**(7.C)**
Medium performance * Average peer low performance		0.171	
		(0.232)	
Medium performance * Average peer medium performance		−0.119	
		(0.308)	
Medium performance * Average peer high performance		−0.0375	
		(0.185)	
High performance * Average peer low performance			0.0802
			(0.208)
High performance * Average peer medium performance			−0.109
			(0.292)
High performance * Average peer high performance			0.0300
			(0.180)
Constant	3.703 ***	3.876 ***	3.899 ***
	(0.977)	(0.977)	(0.975)
Individual characteristics	yes	yes	yes
Year dummies	yes	yes	yes
Faculty dummies	yes	yes	yes
Observations	17,447	17,447	17,447
R^2	0.156	0.156	0.156

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A8. Effects of heterogeneous peers according to student's socioeconomic level in Communication Skills I—OLS.

	OLS
	Model (7)
%stratum 1	−0.291 ***
	(0.0842)
%stratum 6	−0.154 ***
	(0.0592)
Stratum bajo * %stratum 1	0.298 ***
	(0.0958)
Stratum bajo * %stratum 6	−0.222 **
	(0.0949)
Average peer low performance	−0.130
	(0.185)
Average peer medium performance	0.0201
	(0.297)
Average peer high performance	0.102
	(0.160)
Low performance * Average peer low performance	0.00231
	(0.227)
Low performance * Average peer medium performance	0.180
	(0.341)
Low performance * Average peer high performance	0.0885
	(0.194)
Constant	4.496 ***
	(1.089)
Individual characteristics	Yes
Year dummies	Yes
Faculty dummies	Yes
Observations	17,447
R^2	0.156

Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table A9. Effects of heterogeneous peers according to students' socioeconomic level in Communication Skills I—Multilevel.

	Multilevel
	Model (10)
%stratum 1	−0.272 **
	(0.119)
%stratum 6	−0.211 *
	(0.118)
Stratum bajo * %stratum 1	0.210 **
	(0.0975)
Stratum bajo * %stratum 6	−0.174 *
	(0.103)
Average peer low performance	−0.195
	(0.347)
Average peer medium performance	1.164 *
	(0.625)
Average peer high performance	0.254
	(0.335)
Low performance * Average peer low performance	0.323
	(0.240)
Low performance * Average peer medium performance	−0.0517
	(0.362)
Low performance * Average peer high performance	0.237
	(0.220)
Constant	−0.620
	(2.499)
u	0.0640
e	0.2451
Individual characteristics	Yes
Year dummies	Yes
Faculty dummies	yes
Observations	17,467
Group number	753

Robust standard errors in parentheses. ** $p < 0.05$, * $p < 0.1$.

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