Friendship Formation and Network Effects: Experimental Evidence from Ecuador*

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Abstract

We study the impact of the timing and length of exposure during elementary school on friendship formation and persistence, and the impact of friendship networks on cognitive and non-cognitive skills using a unique randomized experiment from Ecuador. In each school, students are randomly assigned to classrooms in every grade from Kindergarten to 6th. We find that both the timing and length of exposure positively affect the probability that a friendship link forms in third grade and persists to sixth grade. Furthermore, we find strong homophily by gender and disruptiveness on how these friendships are formed. Regarding test scores, we find that being randomly assigned to a classroom with more friends reduces scores in math and executive function, particularly among male students. Furthermore, we find that the negative effects are driven by the number of disruptive friends in the classroom. Finally, symptoms of depression are lower among students randomly assigned with more classroom friends, suggesting that the effects on cognitive skills are not driven by lower happiness or self-confidence and likely operate through a distraction or lack of attention channel.

Keywords: Social Networks, Homophily, Cognitive Skills, Non-Cognitive Skills

JEL: D85, I21, J16, Z13

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1 Introduction

Social networks significantly shape behavior, performance, and decision-making across education, workplaces, and social settings (Granovetter, 1973). Previous studies, particularly in developed countries, show that social networks have short-term and long-term consequences on educational outcomes (Sacerdote, 2001; Carrell et al., 2013; Barrios-Fernández, 2022), labor market outcomes (Hellerstein et al., 2011), and social and economic mobility (Chetty et al., 2022). Given the long-term consequences of early childhood development, it is critical to understand how networks form and persist early in life and how these networks affect student outcomes. Identifying how networks affect outcomes and the mechanisms underlying those effects can inform policy interventions aimed at improving children's outcomes.

In this paper, we use data from a unique randomized experiment involving the 2012 entering Kindergarten cohort across 202 elementary schools in Ecuador. In these schools, at the beginning of each grade, from Kindergarten through sixth grade, students and teachers were randomly assigned to classrooms within their schools, each of which had at least two classrooms per grade.[1] Compliance with the random assignment was nearly perfect (98.9% on average). Thus, students who remained in the same school experienced seven exogenous, orthogonal peer groups. This unique random assignment over several years lets us analyze how classroom composition affects friendship formation and persistence, and the impact of these friendship networks on cognitive (math and executive function) skills throughout elementary school, an early and critical period when peer exposure is intense and during which cognitive and non-cognitive skills are strong predictors of long-term outcomes (Moffitt et al., 2011; Heckman et al., 2006, 2013). A major challenge for studying friendship formation, persistence, and their effects is the endogeneity of friendship choice. This design addresses the issue directly, as students and teachers are randomly assigned to classrooms.

For this cohort, we observe rich longitudinal data spanning seven consecutive years, including baseline characteristics, test scores, non-cognitive skills, teacher characteristics,

[1] Each grade is taught by a completely different set of teachers, as is customary in Ecuador

and teacher quality indicators. Furthermore, we elicited students' friendship networks at the end of both third and sixth grades. In third grade, each student could nominate up to three friends from the same school, and in sixth grade, up to five. We use these data to construct directed links (i.e., student i nominates student j, regardless of whether student j reciprocates), reciprocal friendships (i.e., both student i and student j nominate each other), followers (i.e., those who nominated a student but were not reciprocally nominated) and rejecters (i.e., those who are nominated by a classmate but do not reciprocate) in both grades within each school. Based on the third-grade network, we construct, for each student, the number of directed links, reciprocal friends, followers, and rejecters at the school and classroom levels for grades 3–6, using the classroom composition of each grade.

We conduct two analyses to study how classroom composition affects friendship formation and persistence, and how these friendship networks influence later outcomes. First, we estimate how the timing and length of classroom exposure between two students within a school during the first four years of elementary school affect the formation and persistence of directed links and reciprocal friendships. Second, because classrooms are randomly assigned each year, the number of friends a student has in their classroom from fourth to sixth grade varies exogenously. We then estimate how the number of classroom friends affects cognitive (math and executive function) and non-cognitive skills (depression, self-esteem, growth mindset, and grit). Therefore, the variation in the timing and length of exposure, as well as in the number of friends a student has in the classroom, is attributable to the random assignment, enabling us to causally identify the effects on friendship formation and persistence, and the network effects on both cognitive and non-cognitive skills.[2]

For the formation and persistence analyses, our main specification includes school fixed effects. This allows us to compare pairs of students within the same school who were randomly assigned to the same classroom with pairs assigned to different classrooms in the same grade. This leverages the exogenous variation in the timing and length of exposure. We find

[2]Classroom and teacher quality vary but are orthogonal to peer and friend quality, as teachers were also randomly assigned within schools and grades.

that the probability that two students form a directed link increases by 1.2 percentage points (41% increase) and that of a reciprocal friendship by 0.6 percentage points (60% increase) when students are randomly assigned to the same classroom in second grade. Furthermore, for the persistence analysis, we separate pairs by whether they were friends in third grade or not, to distinguish the continuation of existing ties from the creation of new ones. We find that being randomly assigned to the same classroom in sixth grade increases the probability of a directed link by 20.8 percentage points for those who were friends in third grade and by 6.7 percentage points for those who were not previously friends. These results are robust across various specifications, estimation methods, and clustering (detailed in section 4.1.1)

The composition of the peer group and individual characteristics significantly impact network formation as ties tend to be homophilous (Verbrugge, 1977; McPherson et al., 2001; Currarini et al., 2009; Carrell et al., 2013; Chetty et al., 2022; Jackson et al., 2025). For this reason, we conduct a homophily analysis along four characteristics (gender, disruptiveness, maternal education, and PPVT scores). We find that pairs of students who are homophilous on these traits have a higher probability of forming a directed link in third grade and that link persisting into sixth grade. For instance, same-gender pairs have a predicted increase in the probability of forming a directed link of 0.18 percentage points, whereas opposite-gender pairs show only a predicted increase of 0.02 percentage points.

For the network effects analysis, our main specification includes school-by-grade fixed effects and the number of friends in the school. This allows us to compare children who attended the same school and grade, have the same number of school friends, but were randomly assigned to different classrooms. Therefore, the number of friends in the classroom varies exogenously. We find that having one additional directed friend in the classroom reduces math test scores by 0.006 SD, and executive function, a set of basic self-regulatory skills, by 0.023 SD. Alongside these reductions in cognitive skills, we find that having one additional directed friend in the classroom reduces depression in sixth grade. This pattern suggests that the effects are not driven by lower happiness or self-confidence. These results

are robust across various specifications (detailed in section 4.2.1). There are notable gender differences, particularly, the negative effects are concentrated among male students. These results highlight the mixed evidence on whether friendship networks improve performance and how the effects differ by gender. Friends could improve performance if it increases motivation or social pressure (Babcock et al., 2015), but it could also hurt performance if they are used for socializing or if in groups with less able friends (Bandiera et al., 2010).

While we cannot conclusively distinguish between different mechanisms, our findings suggest that the negative effects of the number of friends in the classroom likely operate through a distraction or lack of attention channel. First, when examining friend characteristics, we find that the negative effects for male students are driven by the number of directed disruptive friends in the classroom. Second, the negative effects of disruptive friends are concentrated among high-ability students. Therefore, these results suggest that when high-ability male students are randomly assigned to classrooms with less-able friends or when male students are assigned to the same classroom as disruptive friends, classroom behavior deteriorates, thereby negatively affecting learning.

A potential concern in estimating network effects under random classroom assignment is the weak variation in group composition as classroom size increases (Angrist, 2014). In our setting, identification relies on residual variation in the number of friends in the classroom due to finite-sample imbalances in classroom assignments. To assess this variation, we examine whether the number of classroom friends a student has follows a hypergeometric distribution with school and student-specific parameters. Only 2.01% of classrooms have a number of friends in the classroom that lies outside the 95% confidence interval implied by this distribution. Furthermore, on average, the observed mean and standard deviation match the hypergeometric theoretical expectation. Additional diagnostic analyses, described in Section 3.2, further support the validity of our empirical strategy.

This paper contributes to the literature in four ways. First, it adds to the evidence on network formation. While previous studies have analyzed network formation with structural

models (Currarini et al., 2009; Goldsmith-Pinkham and Imbens, 2013; Graham, 2017; Johnsson and Moon, 2021; Jackson et al., 2025), this study leverages the random assignment of children to classrooms to estimate the causal effects of exposure on friendship formation. Furthermore, a novel aspect of our study is that we leverage a unique longitudinal experiment that elicits friendship networks in two different grades, which enables us to study friendship persistence. Finally, we estimate the extent of homophily and the role it plays in both formation and persistence.

Second, we contribute to the literature on homophily in friendships. Previous studies have examined homophily by race, ethnicity, and gender (Shrum et al., 1988; Jackson et al., 2025), malleable characteristics (e.g., altruism) (Jackson et al., 2025), and substance use (Pearson et al., 2006), primarily among adolescents and college students. We provide new evidence on elementary school children, for whom homophily may be less ingrained. However, we document strong patterns of homophily in both friendship formation and persistence. Furthermore, using our rich data, we extend this literature by analyzing homophily by disruptiveness and prior PPVT scores.

Third, we extend the literature on the impacts of friendship networks beyond labor market outcomes (Bandiera et al., 2010), crime (Billings et al., 2014), health outcomes (Fletcher and Ross, 2018), and achievement (Fletcher et al., 2020; Lavy and Sand, 2019), by studying effects on executive function and non-cognitive skills during elementary school, a period in which children's environments can have long-term effects (Heckman et al., 2013). We leverage a unique experiment with repeated random assignment and nearly perfect compliance to estimate the causal effects of the number of friends in the classroom and to document their non-linear impacts. Moreover, our rich data on teacher quality allow us to analyze how friendship networks interact with other classroom inputs. A novel aspect relative to prior work is that we analyze how friends' characteristics mediate how the network affects learning and likely operate through a distraction or lack of attention channel.

Finally, our findings inform student-grouping policies, especially in developing countries

that experience larger class sizes, tighter resource constraints, and different institutional settings.[3] We provide new evidence from elementary schools in Ecuador, underscoring the importance of accounting for context-specific network dynamics and institutional settings when designing grouping policies to improve student outcomes.

The remainder of the paper is organized as follows. Information about Ecuador, the experimental setting, and data can be found in Section 2. Section 3 outlines the empirical strategy. Section 4 provides the main results, the dynamics of the effects, and heterogeneity analysis. Conclusions and policy discussion can be found in section 5.

2 Setting and Data

2.1 Education system in Ecuador

Ecuador is a middle-income country and one of the smallest in South America, with a population of 15.7 million and a GDP per capita of approximately $11.300 (in PPP U.S. dollars) in 2013. Schooling is compulsory from ages 5 to 14. The education system is divided into elementary school (Kindergarten through 6th grade), middle school (7th through 9th grades), and high school (10th through 12th grades). The school year follows a dual-calendar system. In the coastal region, it runs from May to February (similar to most countries in the Southern Hemisphere and many in Latin America), while in the highlands and Oriente (eastern) regions, it runs from September to June (similar to most countries in the Northern Hemisphere).[4]

Approximately 4.4 million children were enrolled in the education system during the 2012–2013 school year, with 78 percent attending public schools.[5] Ecuador has made significant progress in expanding access to education. In 2013, the primary school net enrollment

[3] See Sacerdote (2011, 2014) for a review of previous studies.

[4] According to the 2010 census, 53% of the population lived on the coast, 42% lived in the highlands, and 5% in the Oriente region.

[5] Data obtained from https://educacion.gob.ec/datos-abiertos/ on November 4th, 2024

rate was 95%, with a completion rate of 97%.[6] However, math achievement among young children remains low (Berlinski and Schady, 2015; Näslund-Hadley and Bando, 2015). For instance, in 2013, only 48.4% of primary school children achieved the minimum proficiency level in mathematics, with a slight gender gap—49.8% for males compared to 46.7% for females.[7] Therefore, like many Latin American nations, Ecuador's critical educational challenge is quality, not access.

The system employs more than 208,000 teachers in the public sector, with salaries primarily determined by seniority. Around 53% of teachers in Ecuador hold tenure, while the remaining 47% work on a contract basis. Between 2012 and 2019, the proportion of qualified teachers in primary increased from 80.1% to 89.3%, contributing to improvements in both the quality of the education system and the instruction provided to students.[8]. However, key challenges persist. For example, the pupil-qualified teacher ratio remained stable at around 27.5 during this period.[9]

2.2 Experimental setting

We use a unique experiment conducted in 202 schools in Ecuador, representative of the country's public education system in the coastal region, to study how peer composition impacts cognitive and non-cognitive skills.[10] Each school had at least two classrooms per grade, with most having exactly two. In the 2012 school year, an incoming cohort of children was randomly assigned to Kindergarten classrooms within each school. These children were

[6]The net enrolment rate is the fraction of children of school age who are enrolled in school, while the completion rate corresponds to the percentage of children that have finished the last grade of primary.

[7]This corresponds to the percentage of children in primary that exceed the minimum proficiency level (MPL) which is the pre-defined proficiency level of basic knowledge in mathematics measured through learning assessments. All data were obtained from the World Development Indicators (https://datatopics.worldbank.org/world-development-indicators/) on November 4th, 2024

[8]This corresponds to the fraction of teachers with the minimum academic qualifications required for teaching in primary school.

[9]All data were obtained from the World Development Indicators (https://datatopics.worldbank.org/world-development-indicators/

[10]These schools are a random sample of all public schools with at least two Kindergarten classrooms in the Ecuador's coastal region 2012. See Araujo et al. (2016) for more details on the school selection. Morevover, they show that the characteristics of students and teachers in the sample closely resemble those in a nationally representative sample of schools in Ecuador.

then randomly reassigned to classrooms in subsequent grades through 6th grade in 2018. Compliance with the assignment rules was very high, averaging 98.9% (Carneiro et al., 2025). As a result, children who remained in the same school throughout elementary school were exposed to seven exogenous, orthogonal shocks to classroom composition.[11]

The random assignment allows us to address concerns about the purposeful matching of students with teachers and peers, a common issue in non-experimental settings (Chetty et al., 2014; Rothstein, 2010).[12] To test the success of the random assignment, we apply the method proposed by Jochmans (2023), which checks for correlation between student i's end-of-grade scores in year $t-1$ and the average scores in $t-1$ of the classroom peers assigned to her in year t. As shown in Appendix Table B.1, we cannot reject the null hypothesis that there is no correlation between child i's achievement and that of her classroom peers, confirming that the random assignment was successful. Further details on the classroom assignment rules, randomization tests, and compliance with randomization are provided in Appendix B.

2.3 Data

2.3.1 Child data

At the beginning of Kindergarten, we collected baseline data on maternal education, household wealth, preschool attendance, and children's vocabulary skills.[13] We administered age-appropriate math tests at the end of each grade from Kindergarten to 6th grade. These

[11] It is worth noting that random reassignment may separate students from their friends. However, out-of-class friendship ties are orthogonal to peer composition given the random assignment.

[12] We use the term "random" for simplicity, but strictly speaking, random assignment only occurred from 3rd to 6th grade. In the other grades, the assignment rules were as-good-as-random. Specifically, in Kindergarten, children were ordered by their last and first names and then assigned to teachers in alternating order. In 1st grade, they were ordered by date of birth, from oldest to youngest, and assigned to teachers in alternating order. In 2nd grade, they were divided by gender, ordered by first and last names, and then assigned in alternating order. From 3rd to 6th grades, students were separated by gender and randomly assigned to classrooms.

[13] To measure baseline receptive vocabulary, we use the Test de Vocabulario en Imágenes Peabody (TVIP), the Spanish-speaking version of the widely-used Peabody Picture Vocabulary Test (PPVT) (Dunn et al., 2015). The TVIP was normed on samples of Mexican and Puerto Rican children and has been widely employed to assess verbal ability and development among Latin American children.

tests included material that teachers were expected to have covered explicitly in class (e.g., addition or subtraction), material that may have been covered during the academic year but in a somewhat different format (e.g., simple word problems), and material that was not covered in class but has been shown to predict current and future math achievement (e.g., the Siegler number line task).[14] We aggregated correct math responses for each component separately using Item Response Theory (IRT) and then computed the total math score, with each component receiving equal weight.

Additionally, we collected data on executive function for each grade from Kindergarten to 4th grade. Executive function encompasses a set of self-regulatory skills involving various regions of the brain, particularly the prefrontal cortex. It is generally divided into three domains: working memory and attention, inhibitory control, and cognitive flexibility.[15] These skills are crucial for young children to adapt and learn effectively in school, as they are needed to pay attention, take turns, ask questions, remember steps, and solve math problems, among other classroom tasks. More importantly, these skills have been shown to predict long-term outcomes in adulthood related to labor market success, health and crime (Moffitt et al., 2011). We compute scores for each of the three domains, as well as an overall score.[16]

In 6th grade, we collected data on child depression, self-esteem, growth mindset, and grit.

[14]The number line task works as follows: children are shown a line with endpoints marked. For example, in 1st grade, the left end of the line is marked with 0, and the right end with a 20. They are then asked to place various numbers on the line (e.g., 2 or 18). The accuracy with which children place the numbers has been shown to predict general math achievement (see Siegler and Booth (2004)).

[15]Working memory measures the ability to retain and manipulate information. For example, 2nd-grade children were asked to remember increasingly long strings of numbers and repeat them in order and then backward. Cognitive flexibility refers to the ability to shift attention between tasks and adapt to different rules. For example, 1st-grade children were shown picture cards featuring trucks or stars, in red or blue, and were first asked to sort the cards by *shape* (trucks versus stars) and then by *color* (red versus blue). Inhibitory control refers to the capacity to suppress impulsive responses. For example, Kindergarten children were quickly shown a series of flashcards displaying either a sun or a moon and were asked to say "day" when they saw the moon and "night" when they saw the sun.

[16]Unlike math test scores, we cannot aggregate questions using factor analysis since some tests are timed. For instance, in one task, children have 2 minutes to find as many sequences of "dog", "house", and "ball" in that exact order on a sheet with rows of dogs, houses, and balls in various possible sequences. The score on this test is the number of correct sequences the child finds. Therefore, we calculate separate scores for working memory, inhibitory control, cognitive flexibility, and a total executive function score, with each domain given equal weight.

To measure depression, we used the Patient-Reported Outcomes Measurement Information System (PROMIS) Depression Scale for children aged 11-17, developed by the American Psychiatric Association. We selected five questions from the National Longitudinal Study of Adolescent to Adult Health (Add Health) to measure self-esteem. For growth mindset, we chose 10 questions from the Dweck "Mindset Quiz"; growth mindset refers to the belief that intelligence is malleable and can be developed with effort (Blackwell et al., 2007). Finally, to measure grit, we adapted four questions from the 8-item Grit Scale for children (Duckworth and Quinn, 2009); grit refers to the ability to persevere at a given task. For each outcome, we aggregated responses using factor analysis. Further details on the child assessments and the IRT are provided in Appendix D.

Most of the tests were administered individually by specially trained enumerators. The only exception is some tests in 4th through 6th grades, which were administered in a group setting by trained enumerators. All tests, except for the non-cognitive tests in 6th grade, were conducted at school. Prior to the official testing, a pilot study was conducted to select appropriate questions based on difficulty and discrimination parameters derived from an Item Response Theory (IRT) procedure. We selected questions that were easily comprehensible to the children based on their context and exhibited sufficient variability in the pilot study to capture the full distribution of students' ability.

Finally, at the end of each grade, we asked teachers to identify five students with the most severe behavioral problems. Therefore, our homophily analysis focuses on the behaviors that teachers believe disrupt learning and captures students with persistent behavioral problems. To mitigate concerns about subjectivity in these rankings, we classify a student as disruptive in third grade if at least 50% of the teachers who observed the student in previous grades identified the student as such.[17] By aggregating multiple, independent evaluations, this procedure reduces measurement error from any single teacher assessment or from indi-

[17]For example, a child identified as having severe behavioral problems by three former teachers would be considered disruptive. Importantly, teachers appear only once in our sample and do not teach in future grades.

vidual teacher behavior toward particular students, and provides a stronger signal of student behavior.

2.3.2 Friends Information

At the end of both third and sixth grades, we collected data on friendship networks. In third grade, each student could nominate up to three friends from the same school, and in sixth grade, up to five. We use these data to construct directed links and reciprocal friendships in both grades within each school, with on average 87 students per network. We define a directed link as one where student i nominates student j, regardless of whether student j reciprocates. For a school with N_s students, the number of potential directed links is $N_s(N_s - 1)$. A reciprocal friendship occurs when both student i and student j nominate each other. The number of potential reciprocal friendships is $N_s(N_s - 1)/2$, since we do not include both ij and ji. Directed links are further classified into two groups: (1) followers, those who nominated a student but were not reciprocally nominated, and (2) rejecters, those who are nominated by a classmate but did not reciprocate.[18]

We rely on both directed and reciprocal links because each provides distinct advantages. Directed links may capture cases in which students nominate peers they aspire to befriend, reflecting an aspirational preference channel that increases the overall level of friendship ties in the network. Furthermore, given that students are only allowed to nominate up to 3 or 5 students, relying only on reciprocal links would miss some genuine friendships. For instance, if a student had a fourth or fifth friend in third grade, these connections would not appear in our data. By contrast, reciprocal friendships are more likely to represent stronger, more established ties (Goodreau et al., 2009). Moreover, these links capture "best friends" rather than acquaintances (Fletcher et al., 2020).

Finally, to estimate the effects of friendship links on test scores, we calculate for each student the number of directed links, followers, rejecters, and reciprocal friends both at the

[18]Followers correspond to out-degrees, and rejecters to in-degrees.

school and classroom levels in third grade. Since classroom composition changes in fourth through sixth grades due to the random assignment process, we also calculate these four types of links for each student at both the school and classroom levels for grades 4–6.

2.3.3 Teacher and Classroom data

We use the Classroom Assessment Scoring System (CLASS) (Pianta et al., 2015) to measure teacher behaviors based on recordings of classroom interactions over the course of an entire school day. The CLASS measures teacher behavior across three domains: Emotional Support, Classroom Organization, and Instructional Support.[19] Within each domain, there are three to four CLASS dimensions, each rated on a scale of 1 to 7. The CLASS protocol provides coders with specific guidance for assigning scores, categorizing them as "low" (1–2), "medium" (3–5), or "high" (6–7). The behaviors coders assess within each dimension are clearly defined and highly specific.

The CLASS has been widely used for research and policy purposes in the U.S., especially in preschool settings. For instance, Head Start grantees in the U.S. are required to achieve a minimum score on the CLASS to be re-certified for funding. The CLASS has also been employed as a measure of teacher quality in Latin America, including earlier work in Ecuador Araujo et al. (2016), Chile (Bassi et al., 2020; Yoshikawa et al., 2015) and Peru (Araujo et al., 2019). All Kindergarten through 4th-grade teachers were filmed for a full day (from approximately 8 a.m. to 1 p.m.) without prior notice. Teachers were informed of the filming only on the day itself, ensuring that the videos captured typical, planned interactions with students. Each classroom has only one teacher that teaches the same class during the calendar year, without a classroom aide, who was responsible for all academic subjects (exluding physical education, art and music when available). We strictly adhered to CLASS protocols when coding the footage. Each video recording was divided into 20-minute segments, with

[19] Emotional Support measures how teachers promote a positive classroom climate and respond to students' emotional needs. Classroom Organization refers to the routines and procedures teachers use to manage students' behavior, time, and attention. Instructional Support evaluates how effectively teachers promote students' thinking through their implementation of the curriculum.

two coders evaluating each segment.[20] Further details on the CLASS dimensions, the scoring protocol, and its application in Ecuador are provided in Appendix E.

One disadvantage of the CLASS is that it is not a cardinal scale, which means it cannot be use directly as an input in the production function, unlike value-added, experience, and other teacher characteristics. However, previous studies have found that teacher behaviors, measured by the CLASS, are associated with higher test scores (Araujo et al., 2016). Following Araujo et al. (2016), we use the CLASS as a measure of Responsive Teaching. We categorize teachers into two groups (low and high quality) based on their CLASS scores, separately for each domain and for the total score.

2.4 Descriptive Statistics and Preliminary Checks

Figure 1 shows the distribution of directed links and reciprocal friends that a student has in third and sixth grades, separately. The Figure shows that around 80% of the students in third grade and 90% in sixth grade report the maximum number of friends possible. This pattern suggests that most students experienced a ceiling effect, as they named all possible friends, and we are unable to determine whether they would have named additional friends. Regarding reciprocal friendships, the Figure shows that approximately half of the students do not have reciprocal friends. Interestingly, despite being able to nominate more students in sixth grade, the distribution of reciprocal friends remains concentrated at zero or one, and no student has more than three reciprocal friends. This pattern indicates that reciprocal links identify a narrower set of stronger ties. Finally, this confirms that using reciprocal friendships diminishes the measurement error stemming from the ceiling effect in directed links.

Figure 2 shows the friendship network for one school in third grade. The Figure presents descriptive patterns related to how friendships form. Each of the three colors represents

[20] In cases where the two coders provided significantly different scores, a third coder was assigned to evaluate the teacher. The inter-coder relability was approximately 0.92, suggesting that measurement error due to from substantial differences across coders was relatively low.

one of the three classrooms within the school, and each dot represents a student. The light-gray lines represent links between students in the same classroom, and the dark-gray lines represent links between students in different classrooms. First, the Figure shows the importance of the third-grade classroom, as most links occur within classrooms, and very few links occur across classrooms. Indeed, less than 4% of the links in this school are among students in different classrooms. Second, the arrows point to the student who was nominated. The figure shows that reciprocal friendships, those with arrows at both ends, are less common (only 35% of the links in this school are reciprocal).

Table 1, Panel A provides summary statistics for the children in the sample. On average, children were eight years old on the first day of third grade, with 62% having attended preschool, and half being girls. The average score on the vocabulary skills (PPVT) test was 83 points, ranging from 55 to 145. Thirteen percent of children were classified as disruptive by their previous teachers. Panel B presents information on household and parental characteristics. The average age of mothers was 30 years and 34 years for fathers. Regarding maternal education, 39% of the children had mothers with some primary education, 31% with some secondary education and 9% with post-secondary education. Finally, regarding household conditions, 85% reported having piped water, and 46% had a toilet at home.

Table 1, Panels C and D present information about the friendship network in third grade and after third grade, respectively. The table reports both the number of directed links and the number of reciprocal friends. On average, students have 2.69 directed links, while reciprocal links are less frequent, averaging 0.85. In third grade, the average number of reciprocal friends in the classroom (0.84) is slightly lower than the number in the school (0.86), which is consistent with the descriptive pattern discussed in the previous figure. Moreover, the Table shows that the number of directed links and reciprocal friends in both the school and the classroom declines after third grade, with a larger decrease in classroom friendships. This pattern is expected, as students may be assigned to a different classroom than their friends due to the random classroom assignment process. We rely on this variation

in the number of friendships in the classroom, which is random conditional on the number of friendships in the school and the school fixed effects, when estimating the impact of the number of friends on students' math test scores after third grade.

We analyze homophily in friendship links by gender and maternal education. First, we examine how the variation in the number of directed links across groups can affect the observed number of homophilous links.[21] Table 2 reports the Coleman homophily index, which compares the observed number of directed links within groups to the expected number of links under random assignment (Coleman, 1958). In this index, a value of 1 represents perfect homophily, while 0 indicates no sorting due to random assignment. The table shows that homophily by gender is high, with an index value close to 1 in third grade, but it decreases by sixth grade as students start interacting more with opposite-gender classmates, which is expected given that, during elementary school, female students tend to befriend other females, and male students tend to befriend other males (McPherson et al., 2001; Garrote et al., 2023). Regarding maternal education, the index is close to 0 but still positive, suggesting a weaker sorting process. Moreover, we observe differences by gender. In particular, female students appear to exhibit more homophily when their mothers have post-secondary education, while male students exhibit less homophily when their mothers have post-secondary education.

Furthermore, in Appendix C we provide additional descriptive analysis of homophily. First, Appendix Table C.1 shows that there is substantial within-gender linking; by contrast, the analogous pattern for maternal education is present but weaker. It also shows that these patterns reflect homophilous preferences rather than mechanical composition effects. Second, Appendix Table C.2 compares the expected and observed percentages of homophilous friendships. It shows that the observed share exceeds the expected share. For instance, for gender, we would expect approximately 50% of links to be between students of the same gender, but we observe around 97%. These results are consistent with ear-

[21] For example, even if friendships are formed randomly, the expected fraction of homophilous friendships is not $\sum_{i=1}^{n} p_i^2$ when different groups have different numbers of friends. Instead, it becomes $\frac{\sum_{i=1}^{n} p_i^2 k_i}{\sum_{i=1}^{n} p_i k_i}$ where p_i is the fraction of students with characteristic i in the sample and k_i is the number of nominations made by students with characteristic i

lier descriptive findings and suggest that homophily is more pronounced by gender than by maternal education.

3 Empirical Strategy

3.1 Friendship Formation and Persistence Model

The goal is to estimate the impact of random assignment on friendship formation in third grade and friendship persistence in sixth grade. For this reason, we construct binary indicators of whether there is a directed link and whether there is a reciprocal friendship between students i and j in both grades, as well as binary indicators for whether (i, j) were in the same classroom in each grade from Kindergarten to third grade for the formation analysis and from fourth grade to sixth grade for the persistence analysis. With these data, we can investigate the effects of being randomly assigned to the same classroom and the length of exposure on friendship formation and persistence. Therefore, we estimate the following dyadic link formation model:

$$y_{ijs} = \alpha + \sum_{t=0}^{n} \beta_t SC_{ijst} + \delta_s + \mu_{ijs} \tag{1}$$

where y_{ijs} is a binary indicator that denotes whether there is a directed link or reciprocal friendship between student i and student j at school s in third or sixth grade. SC_{ijst} is a binary indicator that equals one if students i and j were randomly assigned to the same classroom at school s in grade t. δ_s is a school fixed effect. We cluster standard errors at the school level, which allows the probability of students becoming friends or the friendship persisting in different classrooms to be correlated within schools. The parameters of interest, β_t, capture the impact of being randomly assigned to the same classroom in grade t on the probability that students i and j form a directed or reciprocal link in third grade and on the probability that the link persists to sixth grade.

Previous literature has shown that homophily, the tendency of individuals to associate with others who share similar demographics and background characteristics, plays a central role in friendship formation and persistence (McPherson et al., 2001; Moody, 2001; Currarini et al., 2009). We explore the role of homophily in friendship formation and persistence by interacting the number of years that students i and j were randomly assigned to the same classroom (from Kindergarten to third grade for the formation analysis and from fourth grade to sixth grade for the persistence analysis) with an indicator for differences in observable characteristics. Therefore, we estimate the following dyadic link formation model:

$$y_{ijs} = \alpha + \sum_{k=1}^{4} \beta_k \mathbb{1}\{Years_{ijs} = k\} + \gamma x_{ijs} + \sum_{k=1}^{4} \phi_k \mathbb{1}\{Years_{ijs} = k\} \cdot x_{ijs} + \delta_s + \mu_{ijs} \quad (2)$$

where $\mathbb{1}\{Years_{ijs} = k\}$ denotes a binary indicator equal to 1 if students i and j were randomly assigned to the same classroom for exactly k years between Kindergarten and third grade for the formation analysis, or between fourth and sixth grades for the persistence analysis. x_{ijs} is a binary indicator that indicates whether the link between students i and j is homophilous. To construct this variable, we calculate the absolute difference between the characteristics of students i and j, $|x_i - x_j|$, and define $x_{ijs} = 1$ if this difference is zero. Using the estimated parameters of interest β_k, γ and ϕ_k we compute the effects of length of exposure and homophily in observable characteristics on the probability that students i and j have a directed link in third grade and on the probability that the link persists to sixth grade.

Identification

The empirical strategy exploits variation in shared classroom exposure across student pairs i and j within the same school. The key identification assumption is that, conditional on school fixed effects, potential friendship links between student pairs with different classroom assignments do not differ systematically on other dimensions. The school fixed effects ac-

count for school-level characteristics that are constant across students and may affect the probability of forming a directed link or a reciprocal friendship. As a result, any systematic difference in the probability of forming a directed link or a reciprocal friendship between students assigned to the same classroom and those assigned to different classrooms must be attributable to the classroom assignment itself, rather than other pre-existing differences. Importantly, this key assumption is supported by the random assignment of students to classrooms at the beginning of each grade.

A potential concern is whether the Stable Unit Treatment Value Assumption (SUTVA) holds. In our context, the variation in exposure depends entirely on random assignment. However, students may differ in their ability to make and maintain friendships, and they may interact with their classmates outside the classroom (e.g., during breaks or after school). In this case, our estimates would be a lower bound because out-of-class interaction would produce attenuation bias. This is because directed links and reciprocal friendships among students assigned to different classrooms would increase, and the difference between that group and students assigned to the same classroom would be smaller. Reassuringly, fewer than 4% of third-grade directed and reciprocal friendships occur across classrooms as shown earlier, so any spillovers are limited.

The main specification in Equation 1 does not explicitly model the choice process by which students nominate their friends. Recognizing these concerns, we estimate three alternative specifications. First, we estimate a logit model to account for the binary outcome. Second, we include a student i fixed effect, which absorbs time-invariant differences in sociability, ability to make friends, and other traits that affect the propensity to nominate peers. This fixed effect also partially accounts for the heterogeneity in the decision-making process whereby students select their friends from the set of students in the school. We do not treat this specification as our preferred one because a student's sociability (captured by the i fixed effect) may itself be shaped by prior random classroom assignments, making it a post-treatment control that can attenuate treatment effects. Finally, we include a student i

and student j fixed effects, which jointly absorb unobserved heterogeneity in sending and receiving propensities (sociability and popularity), rather than dyad-specific characteristics. As we show later, the results from these specifications are similar to those obtained using the main specification.

Finally, we estimate dyadic-robust standard errors because errors are likely correlated across dyads that share a student, which would bias standard errors downward when clustering only at the school level (Cameron and Miller, 2014; Aronow et al., 2017; Graham, 2020). One potential solution is two-way clustering by student i and student j, but this does not fully account for the correlation across dyads. For this reason, we estimate the non-parametric dyadic-robust variance estimator proposed by Aronow et al. (2017). The results show no significant changes.

3.2 Network Effects

The goal is to estimate the impact of the number of links (directed, reciprocal, followers and rejecters) a student has on her subsequent learning and non-cognitive outcomes in elementary school. The dataset allows us to construct measures of the number of friends of each type that a given student has at the school and classroom levels in each grade from fourth to sixth, based on the third-grade friendship network. Therefore, to estimate the effect of a student's network on cognitive and non-cognitive skills, we estimate the following model pooling observations from all grades for the full sample, and separately for male and female students:

$$y_{icst} = \alpha + \beta FC_{it} + \mu FS_{it} + \delta_{st} + \varepsilon_{icst} \tag{3}$$

where y_{icst} is one of students' i performance (measured by the corresponding test score) in classroom c in school s at the end of grade t. FC_{ict} and FS_{ict} are the numbers of friends of each type at the classroom and school levels for student i in grade t, respectively. δ_{st} is a school-by-grade fixed effects. We cluster standard errors at the school-by-grade level, which

allows students' outcomes in different classrooms to be correlated within schools in a given grade. The parameter of interest, β, measures the impact of the number of classroom friends of each type on students' cognitive and non-cognitive skills.

Identification

The empirical strategy exploits variation in exposure to friends across classrooms within the same school and grade. The key identification assumption is that, conditional on school-by-grade fixed effects and student's total number of friends in the school, classrooms with and without a student's friend do not differ systematically along other dimensions. The school-by-grade fixed effects account for differences across cohorts within a given school and for school-grade characteristics that are constant across students. Importantly, this key assumption is supported by the random assignment of students to classrooms at the beginning of each grade.

A potential concern is weak variation in group composition, similar to challenges encountered when estimating peer effects under random assignment to classrooms (Angrist, 2014). While our paper does not rely on a linear-in-means model, the probability that a student is assigned to a classroom with none of her friends should decrease as class size increases. This issue is particularly relevant in settings with large peer groups, as they are more prone to experiencing weak variation. In our context, the variation in the number of friends in the classroom tends to decrease with class size, and identification relies on residual variation due to finite-sample imbalances in classroom assignments. However, this concern is mitigated in our setting, as most classrooms have fewer than 45 students, with an average class size of 37.

However, recognizing these potential concerns, we conduct two diagnostic analyses to assess the extent of variation in the number of friends in the classroom and to test for random assignment. First, we assess whether the number of friends in the classroom that a student has follows a hypergeometric distribution with school- and student-specific parameters. Panel

A in Figure 3 shows the observed mean and the predicted mean based on the hypergeometric distribution. It shows that, on average, students get exactly as many friends in the classroom as the hypergeometric predicts and suggests no systematic sorting of friends into classrooms. Panel B of the same figure analyzes the dispersion of the number of friends. It shows that the finite-sample variation in the number of friends in the classroom matches what the theory predicts. Furthermore, only 2.01% of classrooms have a number of friends in the classroom that lies outside the 95% confidence interval implied by the hypergeometric distribution. These results suggest that the observed variation in friend composition is consistent with theoretical expectations under random assignment.

Second, we test whether the observed probability of having k friends in the classroom, conditional on the number of friends in the school, matches the expected probability implied by the hypergeometric distribution. We simulate the probability of having k friends in the classroom based on the school- and student-specific parameters. Conditioning on the number of friends in the school holds constant degree heterogeneity, so differences in the probabilities of having k friends in the classroom are not driven by some students having more (or fewer) friends overall. Appendix Figure A.1 reports the observed and expected probabilities separately for students who have 1, 2 or 3 friends in the school. The figure shows that the observed and expected probabilities match for each number of friends in the classroom, conditional on the number of friends in the school.

Finally, the ability to exploit friends composition relies on sufficient residual variation in the key variables after accounting for fixed effects and the total number of friends in the school. Given the random assignment, the distribution of the number of friends in classroom, conditional on school-by-grade fixed effects and the number of friends in school, should be approximately normal. Appendix Figure A.2 shows that the distribution of the residualized number of directed links and reciprocal friends in the classroom is indeed approximately normal, consistent with random assignment. More importantly, the figure also shows some within school-grade variation in the number of friends in the classroom, further supporting

the validity of our empirical strategy.

Nevertheless, to further support the causal interpretation of the estimates, we provide several sensitivity tests. First, we conduct sensitivity tests on the functional form, controls, and sample definition. Specifically, we estimate three alternative specifications: i) non-linear effects in the number of friends in the school to allow for a non-parametric estimation; ii) we include teacher controls to account for the possibility that teachers may influence the classroom environment and affect student outcomes; and (iii) we restrict the sample to fourth grade only, the year immediately following the friendship data collection. As we show later, the results from these specifications are similar to those obtained using the main specification.

Second, we test the sensitivity of the estimates to the exclusion of one school-grade at a time to ensure that the results are not driven by a single school in a given grade. Appendix Figure A.3 shows the distribution of the leave-one-out coefficient estimates. In particular, one unique regressions was estimated following our preferred specification, omitting one school-grade in each iteration. The figure suggests that the results are not driven by one particular school-grade. Indeed, the distribution is very tight and centers around the value of the coefficient found in the main analysis.

4 Results

4.1 Friendship Formation and Persistence

We estimate the regression model specified in Equation 1 for directed links and reciprocal friendships using all possible dyads of students (i, j). Columns (1) and (3) in Table 3 show that being randomly assigned to the same classroom increases the probability that a pair of students has a directed link or a reciprocal friendship. For instance, being randomly assigned to the same classroom in second grade increases the probability of having a directed

link by 1.2 percentage points, which corresponds to a 41% increase relative to the mean.[22] For reciprocal friendships the effect corresponds to a 60% increase relative to the mean. Interestingly, the magnitude of the effects increases with grade level. This result is not surprising as children at this age spend most of the day in the same classroom with the same group of peers and teachers. As a result, the set of people they can interact with is restricted to their peers in the classroom, and this increased interaction makes them more likely to form friendships which is consistent with our descriptive evidence discussed above.

Furthermore, the length of exposure also plays a significant role in friendship formation. In particular, being randomly assigned to the same classroom for multiple years fosters repeated interactions and increases the likelihood that students i and j meet through mutual friends. Columns (2) and (4) in Table 3 show that each additional year of being randomly assigned to the same classroom increases the probability of having a directed link by 2.2 percentage points, which corresponds to a 76% increase relative to the mean. Regarding reciprocal friendships, the effect corresponds to an 80% increase relative to the mean. Interestingly, the standard errors for reciprocal friendships are smaller (i.e., estimates are more precise), but, as discussed earlier, this reflects a stronger tie and a more selected outcome.

A novel aspect of our study is that we can analyze friendship persistence patterns given longitudinal data on friendship links. For this reason, we estimate Equation 1 separately for pairs of students who had a directed link in third grade and pairs who did not have a directed link. Table 4 shows that being randomly assigned to the same classroom increases the probability that a pair of students have a directed link in sixth grade for both groups. However, when comparing the estimates across groups, we observe that, for those who were already friends, the effects are larger and statistically different from those for pairs that were not previously friends. For instance, being randomly assigned to the same classroom in sixth grade increases the probability of a directed link in sixth grade by 20.8 percentage points for those who were friends in third grade and by 6.7 percentage points for those who were

[22] The mean in this table is small because it includes all possible student dyads (i, j).

not previously friends. As in the formation analysis, each additional year of exposure also increases the probability that the friendship persists.[23]

One concern about the results is whether the directed links provide a meaningful tie comparable to the stronger ties reflected in reciprocal friendships. While we cannot conclusively estimate the strength of these directed ties, we provide two pieces of evidence. First, based on the persistence results, if directed links in third grade were not meaningful, we would expect them not to persist. However, as discussed earlier, the effects on friendship persistence are larger and statistically different for pairs who were already friends in third grade than for those who were not. Second, if the links were not meaningful, we would expect zero exposure between fourth and sixth grades to have no impact on persistence. However, in Appendix Figure A.4, we show that for those who were friends in third grade the effect of being zero years together in the same classroom between fourth and sixth grades on persistence is of 16%. Overall, these results suggest that these links were meaningful enough to persist and exhibit some degree of strength.

Nevertheless, the previous results on the length of exposure assume that the effect of each additional year is linear. Figure 4 reports estimates of the nonlinear effects on friendship formation separately for directed links and reciprocal friendships and on persistence of directed links separately for those who were friends in third grade and those who were not. Panel A presents the results for formation and indicates that the marginal impact of an extra year of exposure is nonlinear. Specifically, the magnitude of the effect increases with the number of years spent together in the same classroom for both directed links and reciprocal friendships. For example, being in the same classroom for two years increases the probability of having a directed link by 3.3 percentage points, while being together for four years increases it by 9.9 percentage points. Similarly, Panel B presents the persistence results. As before, the impact increases with the number of years spent together, and the effects are larger for those who were friends in third grade. Overall, these results suggest that repeated exposure

[23] Appendix Table A.1 shows the results for reciprocal friendships. Overall, the results are similar to those found for directed links but the magnitudes in percentage points are smaller.

and interaction over multiple years significantly enhance the formation and persistence of friendship links.

The results on the length and timing of exposure suggest that the interaction between them could also play a role on the formation and persistence of friendships. Figure 5 reports estimates of the interaction between exposure length and grade timing. In Panel A, we present the effects on friendship formation for directed and reciprocal friendships. Interestingly, for a given number of years of exposure, the effect is larger when exposure occurs in the most recent grades, suggesting that third grade has a particularly strong effect, as discussed before. For instance, for the pairs of students randomly together for three years, we observe that the effect of being randomly assigned in first, second and third grades is larger than the other sequences, with the effect of being randomly assigned in Kindergarten, first, and second having the smallest effect. In Panel B, we present the effects on friendship persistence, and we observe a similar pattern to that for formation.

4.1.1 Robustness checks and Alternative Specifications

This section provides a brief summary of several alternative specifications and robustness checks to address concerns about the main specification. The first specification check estimates a logit model to account for the binary outcome. Appendix Tables A.2 and A.3 present the results of this alternative estimation for the classroom assignments and the years of exposure. Following the main results (i.e., the main specification) reported in Columns (1) and (5), Columns (2) and (6) in each table show that estimates are insensitive to the estimation method and that the logit marginal effects are very similar to the main result.

The next robustness checks test the sensitivity of the estimates to different ways of accounting for time-invariant differences in sociability, ability to make friends, and other traits that affect the propensity to nominate peers. These checks also partially account for the heterogeneity in the decision-making process whereby students select their friends from the set of students in the school. For this reason we estimate two additional models: (i) we

include a student i fixed effect; and (ii) we include a student i and student j fixed effects. Columns (3), (4), (7) and (8) in Appendix Tables A.2 and A.3 present these results. These four columns show that the estimates are not sensitive to the inclusion of these sets of fixed effects.

4.1.2 Role of Homophily

Given that the descriptive evidence presented above suggests some degree of homophily in the formation of friendships, we estimate the regression model specified in Equation 2 and use the estimates to calculate the predicted increase in the probability of having a directed link for eight different groups. These groups are defined by the interaction between the number of years a given pair of students was randomly assigned to the same classroom and whether they share the same characteristic. We conduct this analysis separately for four characteristics: (i) same-gender pairs compared with opposite-gender pairs; (ii) pairs of students that are both disruptive compared with pairs were one is disruptive and one is not; (iii) pairs of students that both have post-secondary educated mothers compared with pairs were one does and one does not; and (iv) pairs of students were both are in the highest quintile of the PPVT distribution compared with pairs were one is and one is not. It is important to note that for disruptiveness, post-secondary maternal education, and PPVT, we exclude pairs of students in which neither student has the focal characteristic. For instance, in the disruptive analysis, pairs in which both students are not disruptive are excluded.

Figure 6 shows that the probability of having a directed link increases with the number of years spent together across all groups and characteristics. For instance, Panel A shows a remarkable difference between same-gender and opposite-gender pairs. In particular, same-gender pairs experience significantly larger increases in friendship formation and are more likely to become friends compared to opposite-gender pairs. These results are consistent with previous findings that, during elementary school, female students tend to befriend other females and male students tend to befriend other males (McPherson et al., 2001; Garrote

et al., 2023). Panels C and D in this Figure show the results for maternal education and PPVT and suggest that homophilous links are more likely to form.

Interestingly, Panel B shows that pairs in which both students are disruptive are more likely to become friends than those in which one student is and one is not. However, this result could be confounded by the gender composition of disruptive students, as 18% of male students are identified as disruptive, while less than 3% of female students are. For this reason, in Appendix Figure A.5, we analyze the effects of disruptiveness separately for pairs of students who are both male (Panel A) and pairs of students who are both female (Panel B). As expected, the Figure shows that the results are driven by the male pairs.

Finally, Appendix Figure A.6 presents the results of the predicted increase in the probability of a directed link persists for eight different groups using the same four characteristics. Overall, the Figure shows a similar pattern to that observed in the formation figure. However, the differences between homophilous pairs and the non-homophilous pairs appear to be smaller than those observed in formation. This pattern is consistent with the fact that, as students grow, they start interacting with more peers and making new friends, which helps explain the smaller differences.

4.2 Network Effects

We estimate the regression model specified in Equation 3 separately for each cognitive and non-cognitive test score. Table 5 shows that having more friends in the classroom reduces test scores on math and executive function tests. For instance, having one additional directed friend in the classroom reduces math test scores by 0.006 standard deviations. Similarly, one additional directed friend in the classroom is associated with a 0.023 standard deviation decrease in executive function. Interestingly, the effect is driven by the number of rejecters in the classroom, which could reflect a behavioral response, as students are negatively affected when they are randomly assigned to a classroom with peers they believe are friends, but who do not reciprocate.

There are three plausible explanations for our findings. First, the presence of directed friends, particularly rejecters, may lower students' happinness, reducing effort and self-confidence, which can negatively affect academic performance. Second, the characteristics of friends could negatively affect academic results. For instance, in the previous section, we show that disruptive students tend to befriend one another, which could depress test scores, in line with previous evidence on the effects of neglected and abused students (Santavirta and Sarzosa, 2025). Finally, teachers may adjust their teaching strategies and classroom management, potentially mediating the effects on learning outcomes.

Given the potential differential effects by gender, Table 6 shows that male students are negatively affected by the presence of directed links or rejecters in the classroom, while female students are not. These results highlight the mixed evidence on whether friendship networks improve performance and how the effects differ by gender. On the one hand, working with friends could improve performance if it increases motivation or social pressure (Babcock et al., 2015). On the other hand, friendship networks may reduce performance if they are used for socializing or if in groups with less able friends (Bandiera et al., 2010). Therefore, in Section 4.3, we analyze potential mechanisms that could drive these results and explain the observed gender differences.

Additionally, we estimate the non-linear effects of the number of friends in the classroom. Accordingly, we create binary indicators of whether a student has zero, one, two, or three friends in the classroom. Figure 7 shows that negative effects on test scores emerge only when a student has three friends in the classroom. This result suggests that as the size of the friendship network increases, potentially increasing opportunities to socialize, negative effects may appear.

4.2.1 Robustness checks and Alternative Specifications

This section provides a brief summary of three alternative specifications and robustness checks to address concerns about the main specification. The first check estimates the non-

linear effects for the number of friends in the school to allow for a non-parametric estimation and is motivated by evidence that the impact of classroom friend counts is non-liner. The second includes teacher controls to account for how teachers may influence the classroom environment and affect student outcomes through their interactions and management. Finally, we restrict the sample to fourth grade only, the year immediately following the friendship data collection and the grade least affected by attrition.

Figure 8 presents the results of these alternative specification checks. Following the main result (i.e., the main specification), the next three estimates show that the results are insensitive to these robustness checks. The wider confidence intervals represent the 95% confidence intervals and the darker ones represent the 90% confidence intervals. Overall, the first two robustness checks are similar in magnitude and significance to the main result, while the last one is similar in magnitude but not statistically significant. However, the estimates using the restricted sample should be interpreted cautiously, as the smaller sample size leads to noisier estimates, and our power to detect effects is reduced.

4.3 Potential Mechanisms of the Network Effects

Having shown that the number of friends in the classroom, particularly directed and rejecters, negatively affects test scores in both cognitive (math and executive function) skills, we now explore potential mechanisms that might explain these results. We focus on three main channels: (i) the role of friends' characteristics, (ii) the effects on mental health and non-cognitive skills, and (iii) the role of teacher quality.

4.3.1 Friend Characteristics

In this section, we explore the role of the friends' characteristics in mediating the negative effects of friendship networks on cognitive skills. First, we construct the number of directed friends at the classroom and school levels that a student has who are female, whose mothers have post-secondary education, who are disruptive, or who are in the highest quintile of the

PPVT distribution. Using this information, we estimate the regression model specified in Equation 3 separately for each friend characteristic. Figure 9 presents the results of these regressions. In this figure, each line plots regression estimates for math test scores using the numbers of friends at the classroom and school levels with the given characteristic. This figure shows that the numbers of female friends, friends with post-secondary educated mothers, and friends in the highest quintile of the PPVT distribution are not associated with lower math test scores. However, the number of disruptive directed friends in the classroom has a negative effect on math scores. These findings align with prior literature showing that exposure to disruptive peers negatively affects test scores (Santavirta and Sarzosa, 2025).

Given the previous results on how homophily plays a role in the formation and persistence of friendships and how the negative effects on cognitive scores were experienced only by male students, we separate this analysis by gender. Table 7 shows the results of these regressions. In this table, each column reports regression estimates for math test scores using the numbers of friends at the classroom and school levels with the given characteristic. This table shows no negative effects for female students, whereas for male students, we find negative effects of the number of disruptive directed friends in the classroom. These findings, combined with the evidence that male students are more likely to be disruptive, suggest that when disruptive students are together in the classroom, they may not behave properly and thereby affect learning.

Finally, we analyze how ability plays a role in the results, given that previous evidence finds that when students are placed together with less able friends, the effects of friendship networks are negative (Bandiera et al., 2010). Figure 10 divides the sample into two groups based on prior math scores (i.e., above and below the median) and presents regression results for each group by gender. Overall, there do not appear to be differential effects by ability. However, for high-ability male students, we find negative effects. These findings align with previous evidence, as disruptive students in our sample tend to have lower math test scores than non-disruptive students. Therefore, when high-ability male students are randomly

assigned to classrooms with less able friends, they experience reductions in test scores.

4.3.2 Effects on other outcomes

In the previous section, we show that the friendship network effects appear to be mediated by homophily. In this section, we explore how friendship networks affect other outcomes, particularly mental health and non-cognitive skills. First, Table 8 shows reductions in depression associated with both directed and reciprocal friendships, suggesting that, if anything, the presence of friends in the classroom creates a positive spillover on students' mental health. This rules out the possibility that the effects are driven by lower happiness or self-confidence. Moreover, this result, combined with the results on disruptive friends, suggests that negative effects on test scores likely operate through a distraction or lack of attention channel. Finally, Appendix Table A.6 shows no significant effects on the other non-cognitive skills (growth mindset and grit).

4.3.3 Teacher Quality

Given the existing literature on teacher quality and its positive effect on test scores, we test whether teacher behaviors, as measured by the CLASS, can mitigate the negative friendship network effects. Panel A in Figure 11 shows that high-quality (those above the median) teachers reduce the negative effects. However, when separating the results by CLASS domain, Panel B does not show any differences between high-quality and low-quality teachers. While we cannot conclusively identify what high-quality teachers do to mitigate the effects, these findings suggest that high-quality teachers are better at managing the negative externality, particularly those stemming from disruptive friends. More importantly, this highlights the role of classroom management and the importance of appropriate incentives to improve teachers' performance that could positively affect student outcomes.

5 Conclusion

This paper analyzes the impact of timing and length of exposure on friendship formation and persistence, and the impact of friendship networks on students' cognitive and non-cognitive skills in elementary school setting. These data come from a unique longitudinal experiment in Ecuador in which children are randomly assigned to classrooms at the beginning of each school year for seven consecutive years. Compliance with the random assignment was nearly perfect, averaging 98.9% over the seven years.

The random assignment creates variation along two dimensions that we leverage. First, the variation in the timing and length of exposure between two students within a school is random. Notably, in our data, two students with the same underlying ability who attend the same school can experience different exposure to their peers because they are randomly assigned to different classrooms, each with slightly different peers. Therefore, we compare pairs of children who were randomly assigned to the same classroom with pairs who were not. Second, conditional on school-by-grade fixed effects and the student's number of friends in the school, the variation in the number of friends a student has in the classroom is random. Therefore, in our data, two students with the same underlying ability who attend the same school and have the same number of friends in that school can be placed together in classrooms with different numbers of friends due to the random assignment.

First, we find that both the timing and length of exposure positively affect the formation and persistence of friendship links. Additionally, we document the extent of homophily in these friendship links across four characteristics (gender, disruptiveness, maternal education, and PPVT scores) and show that homophilous links are more likely to form and persist. Second, we find that the number of friends in the classroom negatively affects math and executive function scores, but we find reductions in depression, suggesting that the results are not driven by lower happiness or self-confidence. Moreover, we show that these negative effects are concentrated among male students and are driven by the number of disruptive directed friends in the classroom, suggesting that the effects likely operate through a distraction or

lack of attention channel. These findings contribute to the understanding of how friends' characteristics and gender composition influence student outcomes during formative years. Finally, having higher-quality teachers can help mitigate the adverse effects on learning, but future research should explore and identify what, specifically, those teachers do.

This research has several advantages compared to previous studies. First, we leverage the random assignment in elementary schools to analyze how exposure affects friendship formation and persistence in a developing country in Latin America. This setting allows us to explore the variation in the timing and length of exposure to a peer in the classroom, overcoming any selection and reflection biases present in other network effects studies. Second, we leverage the random assignment to analyze how friendship networks affect cognitive and non-cognitive skills. This allows us to show that networks have potential long-term effects as they affect the human capital accumulation process. However, we also provide evidence addressing the concerns about weak variation, similar to those encountered when estimating peer effects under random assignment to classrooms. Third, we explore the role of homophily in friendship formation and persistence, and as a potential mechanism mediating the observed network effects. Our results highlight the importance of understanding how friendships form and whether they persist, and their potential impacts on cognitive and non-cognitive skills. More importantly, we provide insights into the complex dynamics of friendship networks in early education settings.

Finally, given that network effects are context-specific and depend on the outcome being studied, these results raise essential policy questions about how to optimally allocate children to classrooms, how to address adverse effects in Latin America, and which policies are most effective, especially because these effects stem from a particular group of peers (i.e., friends). Future research should explore the underlying mechanisms through which friendship networks affect test scores, how other factors influence the network formation process and its persistence, and whether the effects persist into high school or adulthood.

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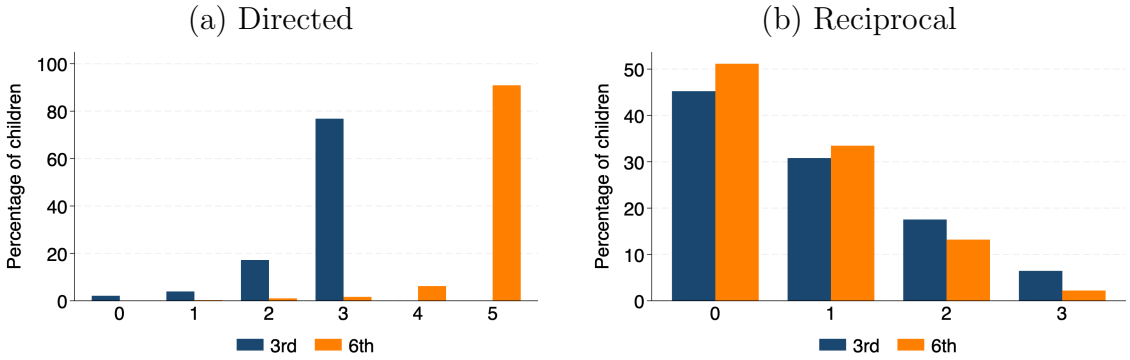
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6 Figures and Tables

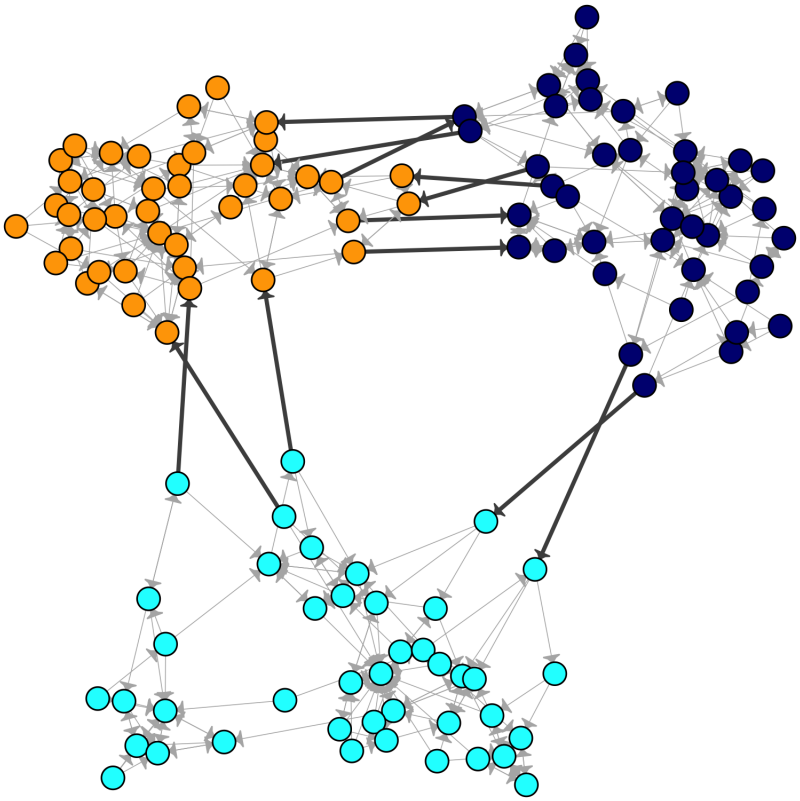
6.1 Figures

Figure 1: Distribution of Friends per Grade



Notes: The figure above represents the distribution of the number of directed friendship links and reciprocal friends in the 3rd and 6th grades, respectively. A directed link is defined as one in which student i nominates student j, regardless of whether student j reciprocates, and a reciprocal friendship is defined as one in which both student i and student j nominate each other.

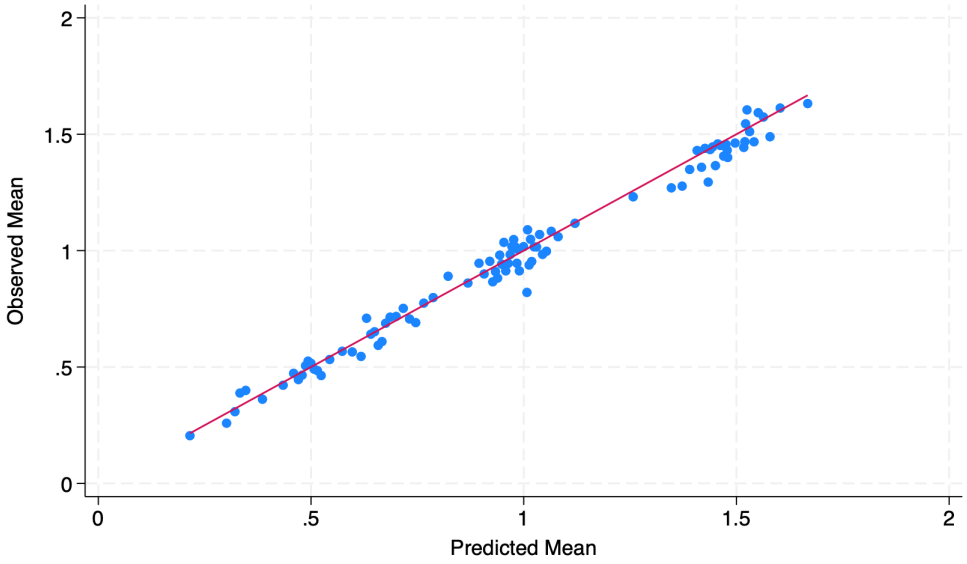
Figure 2: Friendship Network in 3rd grade



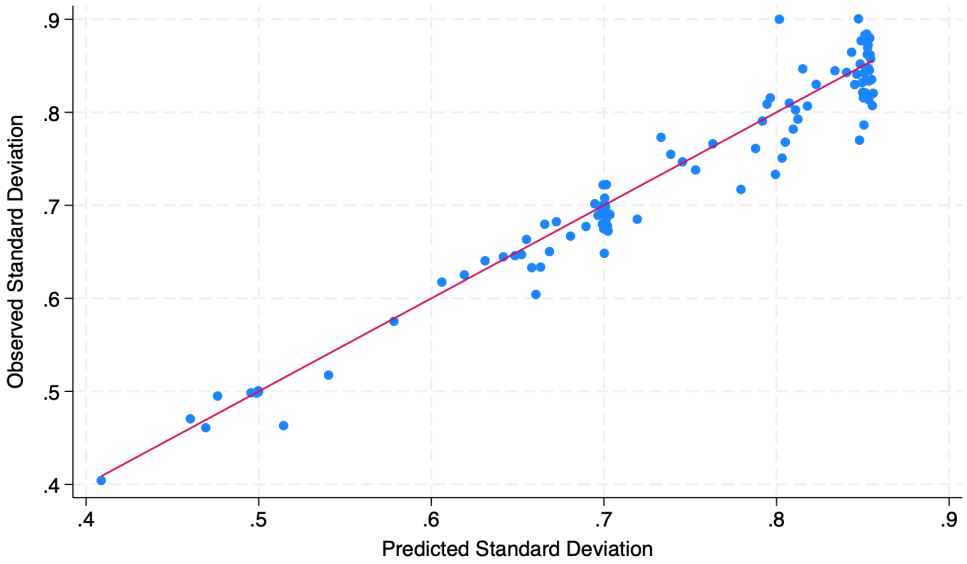
Notes: The figure above represents the directed and reciprocal links for a given school in 3rd grade. The three colors represent the three classrooms within the school. Directed links have a single arrow, while reciprocal links have arrows at both ends. Darker arrows indicate links between children in different classrooms. A directed link is defined as one in which student i nominates student j, regardless of whether student j reciprocates, and a reciprocal friendship is defined as one in which both student i and student j nominate each other.

Figure 3: Observed Vs Predicted Mean and Standard Deviations of Friends in Classroom

(a) Mean



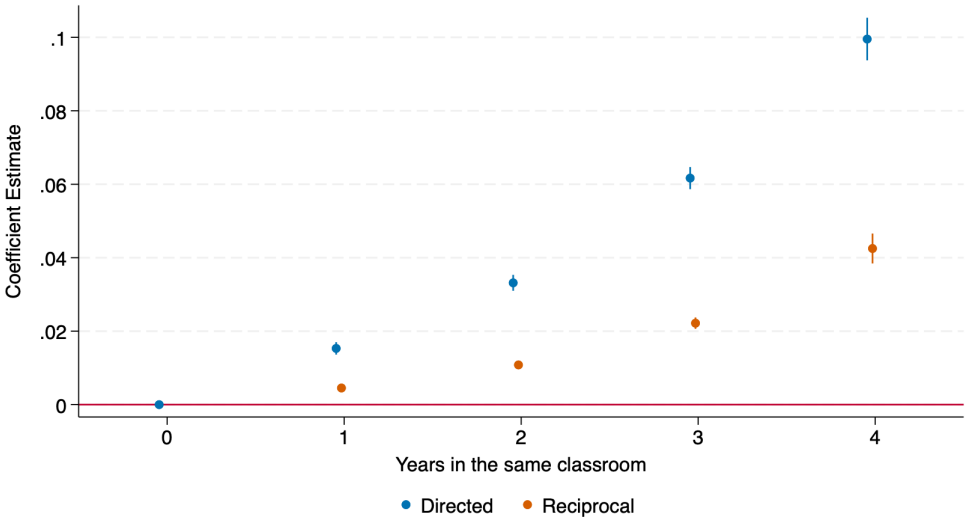
(b) Standard Deviation



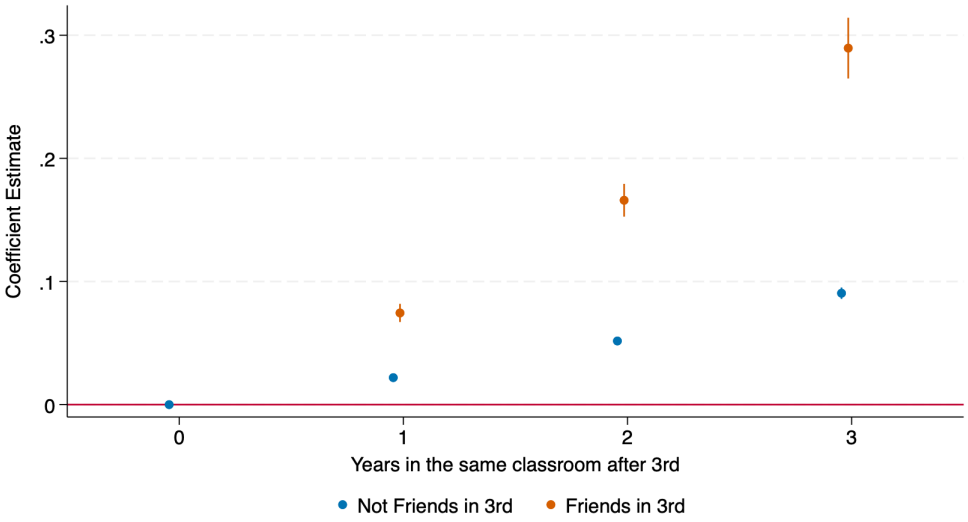
Notes: Panel A in the figure above shows the observed mean of the number of directed friends in the classroom and the expected mean coming from the hypergeometric distribution based on the school- and student-specific parameters. Panel B in the figure shows a similar analysis but using the observed and expected standard deviations. A directed link is defined as one in which student i nominates student j, regardless of whether student j reciprocates

Figure 4: Impacts on Friendship Formation and Persistence by Years of Exposure

(a) Formation



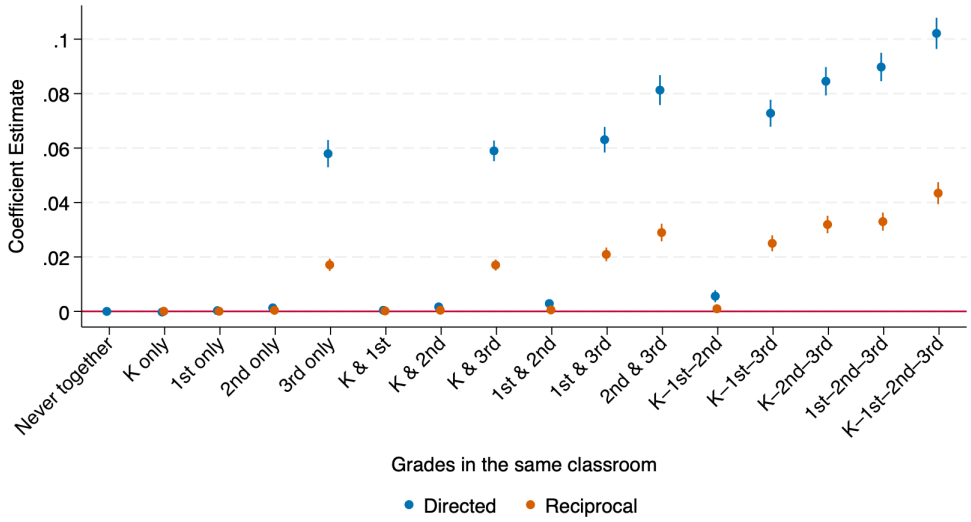
(b) Persistence



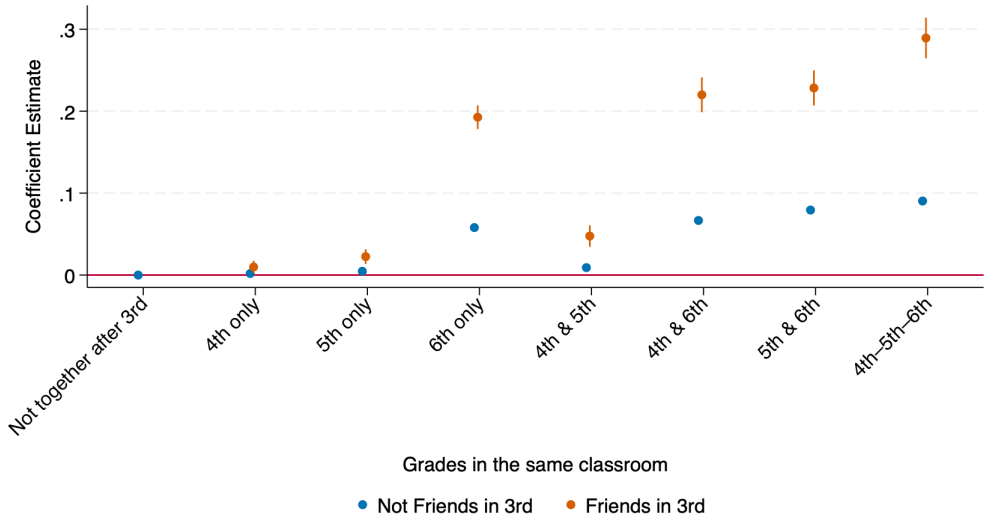
Notes: The figures above report non-linear estimates from regressions of binary indicators for the number of years of exposure. Panel A presents the results for friendship formation for both directed and reciprocal links. Panel B presents the results for friendship persistence only for directed links, separately for those who were friends in third grade and those who were not. A directed link is defined as one in which student i nominates student j, regardless of whether student j reciprocates, and a reciprocal friendship is defined as one in which both student i and student j nominate each other. All regressions are limited to schools with at least two classrooms per grade. Vertical bars represent 95% confidence intervals. Standard errors are corrected for heteroskedasticity and are clustered at the school level.

Figure 5: Impacts on Friendship Formation and Persistence by Timing and Years of Exposure

(a) Formation

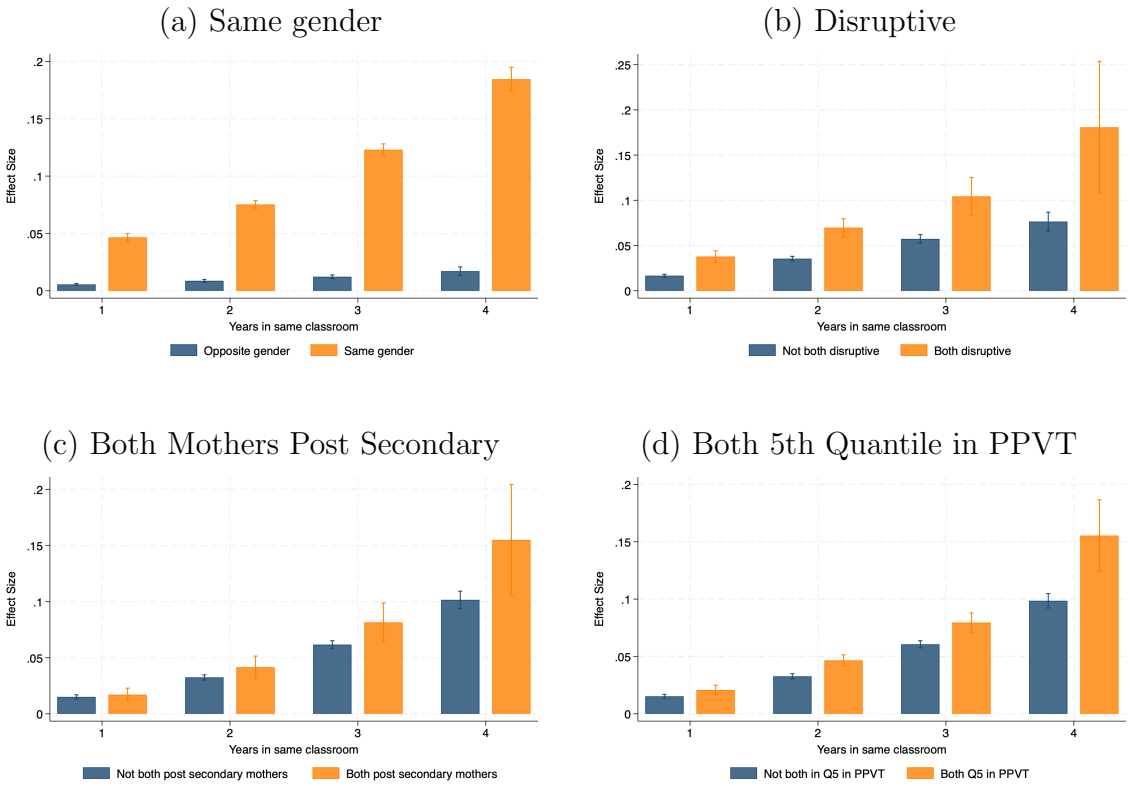


(b) Persistence



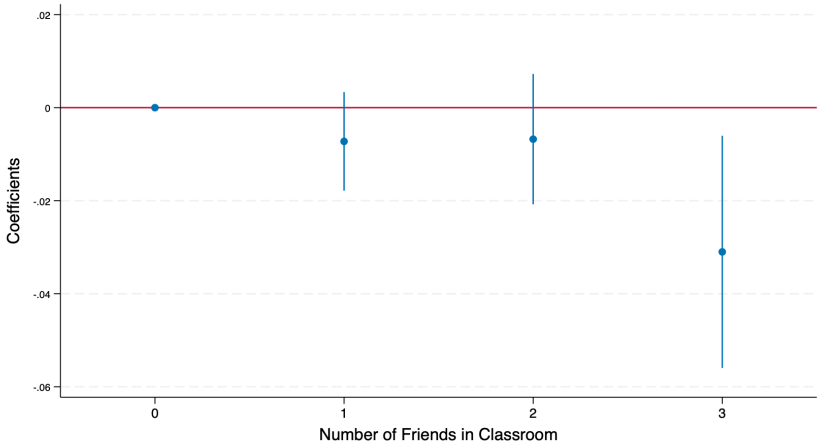
Notes: The figures above reports estimates from regressions of binary indicators for the sequences of the interaction between the timing and the length of exposure. Panel A presents the results for friendship formation for both directed and reciprocal links. Panel B presents the results for friendship persistence only for directed links, separately for those who were friends in third grade and those who were not. A directed link is defined as one in which student i nominates student j, regardless of whether student j reciprocates, and a reciprocal friendship is defined as one in which both student i and student j nominate each other. All regressions are limited to schools with at least two classrooms per grade. Vertical bars represent 95% confidence intervals. Standard errors are corrected for heteroskedasticity and are clustered at the school level.

Figure 6: Impacts on Friendship Formation by Years of Exposure and Homophily



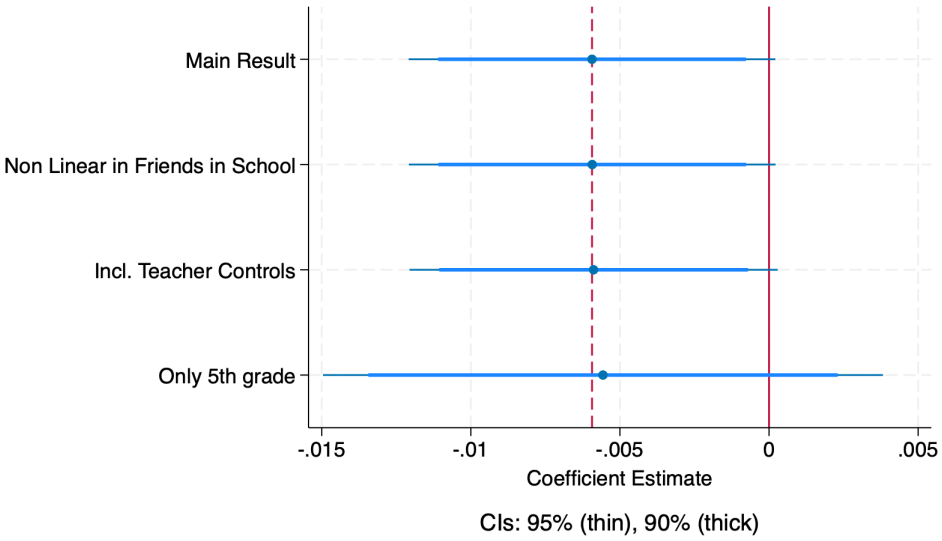
Notes: The figures above reports estimates of the predicted increase of the probability that students i and j have a directed link. The estimates were obtained from regressions of binary indicators of the number of years students i and j are randomly assigned to the same classroom interacted with a binary indicator of homophily among four characteristics: (i) same-gender pairs compared with opposite-gender pairs; (ii) pairs of students that are both disruptive compared with pairs were one is disruptive and one is not; (iii) pairs of students that both have post-secondary educated mothers compared with pairs were one does and one does not; and (iv) pairs of students were both are in the highest quintile of the PPVT distribution compared with pairs were one is and one is notA directed link is defined as one in which student i nominates student j, regardless of whether student j reciprocates. All regressions are limited to schools with at least two classrooms per grade. Vertical lines represent 95% confidence intervals. Standard errors are corrected for heteroskedasticity and are clustered at the school level.

Figure 7: Non-Linear Effects of Friendship Links on Math Scores



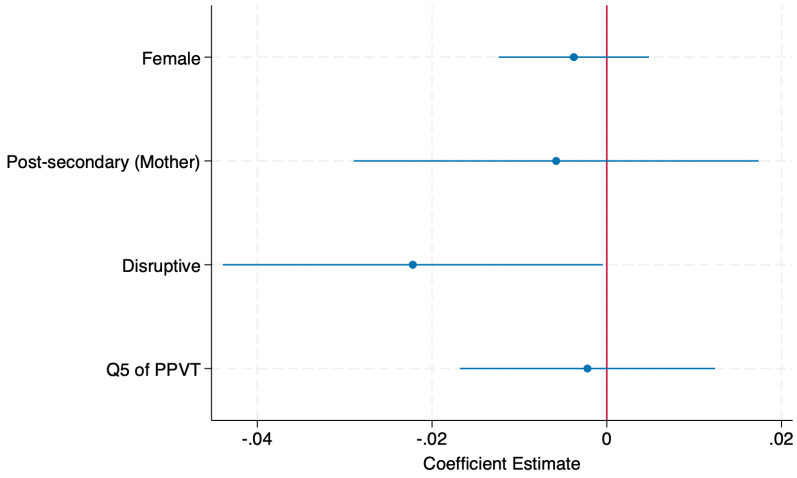
Notes: The figure above report non-linear estimates from regressions of binary indicators for the number of directed friends in the classroom on math scores, conditional on the school-by-grade fixed effects and the number of directed friends in school. A directed link is defined as one in which student i nominates student j, regardless of whether student j reciprocates, and a reciprocal friendship is defined as one in which both student i and student j nominate each other. All regressions are limited to schools with at least two classrooms per grade. All models include controls for children's biological sex, age, age squared, and the lagged test score in the previous year or baseline. Vertical bars represent 95% confidence intervals. Standard errors are corrected for heteroskedasticity and are clustered at the school level.

Figure 8: Robustness Checks on Math Scores



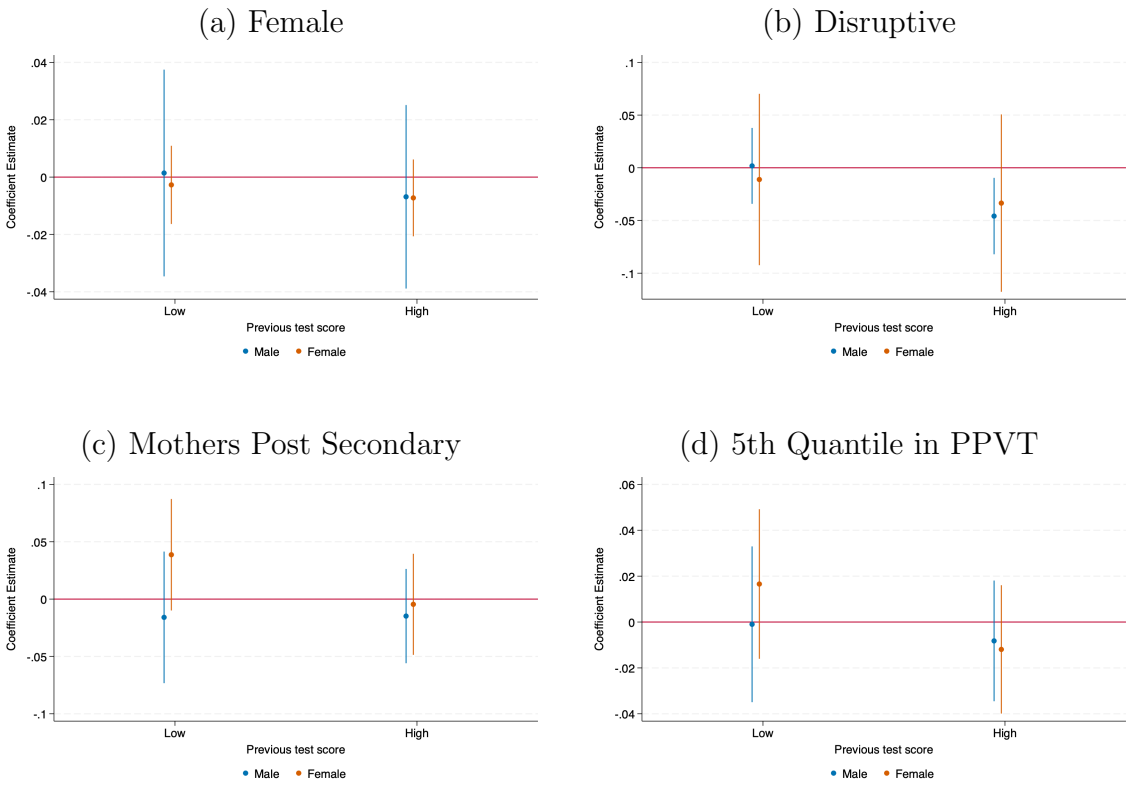
Notes: The figure above reports estimates from regressions of the number of directed friends in the classroom on math scores, conditional on the school-by-grade fixed effects and the number of directed friends in school. A directed link is defined as one in which student i nominates student j, regardless of whether student j reciprocates. All regressions are limited to schools with at least two classrooms per grade. All models include controls for children's biological sex, age, age squared, and the lagged test score in the previous year or baseline. Wider horizontal bars represent 95% confidence intervals and darker horizontal bars represent 90% confidence intervals. Standard errors are corrected for heteroskedasticity and are clustered at the school-by-grade level. The "Main Result" estimate (at the top) uses the specification in Table 5. All other estimates are variations on the baseline model. Estimate 2 includes the number of friends in a non-linear way. Estimate 3 includes teacher controls, and estimate 4 restricts the sample to fourth grade only.

Figure 9: Effect of Directed Friendships on Math Scores by Friend Characteristics



Notes: The figure above reports estimates from regressions of the number of directed friends that have a certain characteristic in the classroom on math scores, conditional on the school-by-grade fixed effects and the number of directed friends that have a certain characteristic in school. A directed link is defined as one in which student i nominates student j, regardless of whether student j reciprocates. All regressions are limited to schools with at least two classrooms per grade. All models include controls for children's biological sex, age, age squared, and the lagged test score in the previous year or baseline. Horizontal bars represent 95% confidence intervals. Standard errors are corrected for heteroskedasticity and are clustered at the school-by-grade level. Each line plots regression estimates for math test scores using the number of friends at the classroom and school levels with the given characteristic.

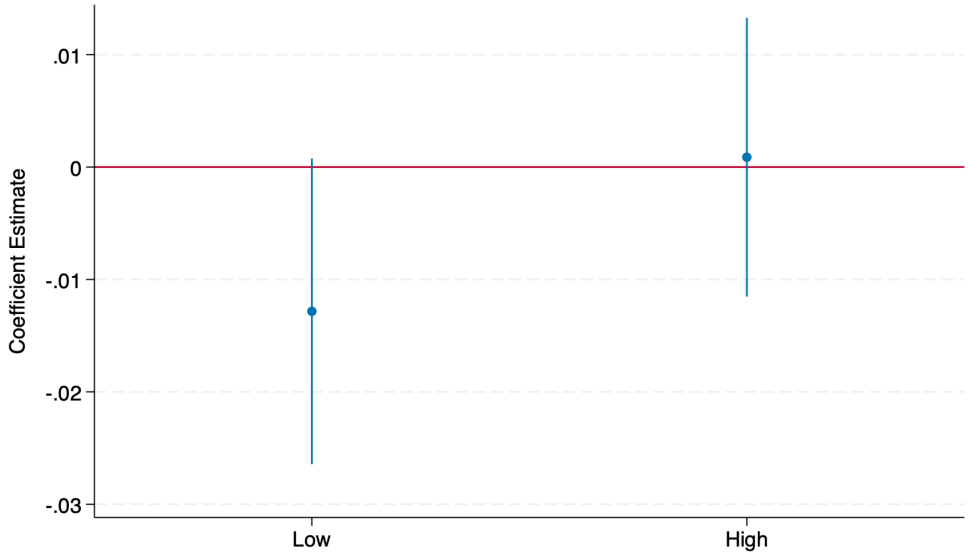
Figure 10: Effect of Directed Friendships on Math Scores by Gender, Friend Characteristics, and Previous Test Results



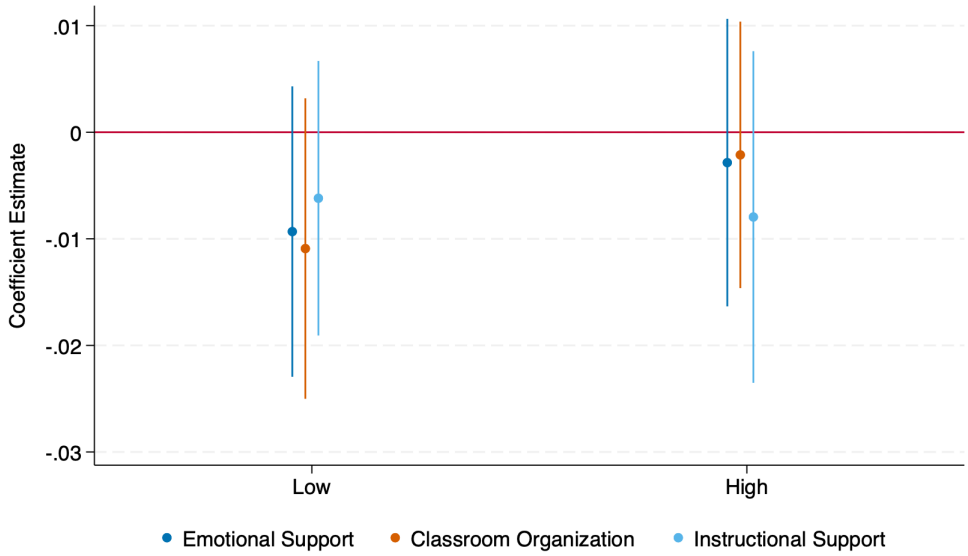
Notes: The figure above reports estimates from regressions of the number of directed friends that have a certain characteristic in the classroom on math scores, conditional on the school-by-grade fixed effects and the number of directed friends that have a certain characteristic in school. Each panel shows the results for a certain characteristic by gender and the test result in the previous year. A directed link is defined as one in which student i nominates student j, regardless of whether student j reciprocates. All regressions are limited to schools with at least two classrooms per grade. All models include controls for children's biological sex, age, age squared, and the lagged test score in the previous year or baseline. Vertical bars represent 95% confidence intervals. Standard errors are corrected for heteroskedasticity and are clustered at the school-by-grade level.

Figure 11: Heterogeneous Effects of Directed Friendships on Math Scores by Teacher Quality

(a) CLASS Score



(b) Components



Notes: The figures above report estimates from regressions of the number of directed friends in the classroom on math scores by teacher quality measured using the CLASS *(Classroom Assessment Scoring System)* score, conditional on the school-by-grade fixed effects and the number of directed friends in school. Teachers are separated into two groups: low and high quality, using the median score as the cutoff. A directed link is defined as one in which student i nominates student j, regardless of whether student j reciprocates. All regressions are limited to schools with at least two classrooms per grade. All models include controls for children's biological sex, age, age squared, and the lagged test score in the previous year or baseline. Vertical bars represent 95% confidence intervals. Standard errors are corrected for heteroskedasticity and are clustered at the school level.

6.2 Tables

Table 1: Child, Parents, and Friends Network Characteristics

	Mean	SD	Median	Min	Max
A. Child characteristics					
Age of child in 2015	8.63	0.36	8.61	7.21	13.21
Sex (1 = Female)	0.50	0.50	1.00	0.00	1.00
Receptive vocabulary score (PPVT)	83.30	15.76	82.00	55.00	145.00
Lagged Math Test Score	0.00	1.00	0.02	-3.83	3.58
Depression	-0.00	1.00	0.08	-4.17	1.55
Self-esteeem	-0.00	1.00	-0.02	-4.76	1.91
Growth Mindset	-0.00	1.00	0.09	-4.79	2.19
Grit	0.00	1.00	0.02	-4.43	1.79
Disruptive	0.11	0.32	0.00	0.00	1.00
Proportion who attended preschool	0.62	0.49	1.00	0.00	1.00
B. Household characteristics					
Maternal Education					
Some Primary	0.39	0.01	0.40	0.38	1.00
Some Secondary	0.51	0.01	0.51	0.00	0.52
Post Secondary	0.09	0.00	0.09	0.00	0.10
Mother's age	30.40	6.58	30.00	5.00	87.00
Father's age	34.73	7.94	33.00	5.00	99.00
Household has piped water in home	0.85	0.36	1.00	0.00	1.00
Household has flush toilet in home	0.46	0.50	0.00	0.00	1.00
C. Friendship Network in 3rd grade					
No. of Directed Friends in School	2.69	0.65	3.00	0.00	3.00
No. of Directed Friends in Classroom	2.58	0.74	3.00	0.00	3.00
No. of Reciprocal Friends in School	0.85	0.93	1.00	0.00	3.00
No. of Reciprocal Friends in Classroom	0.84	0.93	1.00	0.00	3.00
D. Friendship Network in 4th-6th grade					
No. of Directed Friends in School	2.35	0.86	3.00	0.00	3.00
No. of Directed Friends in Classroom	0.98	0.87	1.00	0.00	3.00
No. of Reciprocal Friends in School	0.75	0.88	1.00	0.00	3.00
No. of Reciprocal Friends in Classroom	0.32	0.57	0.00	0.00	3.00

Notes: The Table reports summary statistics of the children in the sample. It includes children's characteristics, household's characteristics, and those of their friendship networks in the school.

Table 2: Coleman Homophily Index for Directed Links

	3rd grade			6th grade		
	Share same group	Group share	Index	Share same group	Group share	Index
A. Child's Gender						
Female	90.40	48.30	0.814	81.58	48.53	0.642
Male	87.75	51.70	0.746	81.05	51.47	0.610
B. Maternal Education						
Female						
Some Primary	45.55	40.16	0.090	46.95	40.48	0.109
Some Secondary	55.32	50.95	0.089	55.70	51.06	0.095
Post Secondary	19.97	8.89	0.122	14.56	8.45	0.067
Male						
Some Primary	47.19	38.44	0.142	44.44	38.80	0.092
Some Secondary	57.60	52.03	0.116	58.69	52.45	0.131
Post Secondary	14.87	9.53	0.059	15.58	8.75	0.075

Notes: The Table reports statistics about homophily in directed links. A directed link is defined as one in which student i nominates student j, regardless of whether student j reciprocates. The "Share same group" column presents the mean of the percentage of directed friends from the same gender or same maternal education as their own. The "Group share" column provides the distribution of students by gender and maternal education in the full sample. The "Index" shows the Coleman Homophily Index, which compares the observed number of directed links within groups to the expected number of links under random assignment (Coleman, 1958). In this index, a value of 1 represents perfect homophily, while 0 indicates no sorting due to random assignment.

Table 3: Impacts on Friendship Formation

	Directed		Reciprocal	
	(1)	(2)	(3)	(4)
Same classroom in K	0.003***		0.001***	
	(0.001)		(0.000)	
Same classroom in 1st	0.005***		0.003***	
	(0.001)		(0.000)	
Same classroom in 2nd	0.012***		0.006***	
	(0.001)		(0.000)	
Same classroom in 3rd	0.071***		0.024***	
	(0.002)		(0.001)	
Years in same classroom		0.022***		0.008***
		(0.001)		(0.000)
Mean of Dependent Variable	0.029	0.029	0.010	0.010
Observations	707568	707568	353784	353784
School FE	Yes	Yes	Yes	Yes

Notes: The table reports estimates from regressions on a binary indicator of whether students i and j have a directed link or are reciprocal friends in third grade. A directed link is defined as one in which student i nominates student j, regardless of whether student j reciprocates, and a reciprocal friendship is defined as one in which both student i and student j nominate each other. Columns (1) and (3) present the results using binary indicators for whether the students were randomly assigned to the same classroom on each grade between Kindergarten and 3rd grade. Columns (2) and (4) present the results using the total number of years the students were randomly assigned to the same classroom between Kindergarten and 3rd grade. All regressions are limited to schools with at least two classrooms per grade. *** indicates significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level. Standard errors are corrected for heteroskedasticity and are clustered at the school level.

Table 4: Impacts on Persistence of Directed Friendships

	Not Friends in 3rd		Friends in 3rd	
	(1)	(2)	(3)	(4)
Same classroom in 4th	0.005***		0.026***	
	(0.000)		(0.004)	
Same classroom in 5th	0.012***		0.037***	
	(0.001)		(0.004)	
Same classroom in 6th	0.067***		0.208***	
	(0.002)		(0.006)	
Years in same classroom after 3rd		0.028***		0.091***
		(0.001)		(0.003)
Mean of Dependent Variable	0.029	0.029	0.119	0.119
Observations	990641	990641	27593	27593
School FE	Yes	Yes	Yes	Yes

Notes: The table reports estimates from regressions on a binary indicator of whether students i and j have a directed link in sixth grade, separately for pairs of students who were friends in third grade and pairs that were not. A directed link is defined as one in which student i nominates student j, regardless of whether student j reciprocates. Columns (1) and (3) present the results using binary indicators for whether the students were randomly assigned to the same classroom on each grade between 4th and 6th grade. Columns (2) and (4) present the results using the total number of years the students were randomly assigned to the same classroom between 4th and 6th grade. All regressions are limited to schools with at least two classrooms per grade. *** indicates significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level. Standard errors are corrected for heteroskedasticity and are clustered at the school level.

Table 5: Impact of Friendships on Math Scores

	Directed	Reciprocal	Followers	Rejecters
	(1)	(2)	(3)	(4)
A. Math				
No. of Friends in Classroom	-0.006*	-0.003	0.002	-0.007*
	(0.003)	(0.006)	(0.004)	(0.004)
Mean of Dependent Variable	0.031	0.031	0.031	0.031
Treatment Effect of 1SD increase	-0.005	-0.002	0.002	-0.005
Observations	41431	41431	41431	41431
B. Executive Function				
No. of Friends in Classroom	-0.023**	0.001	0.001	-0.031***
	(0.009)	(0.014)	(0.010)	(0.011)
Mean of Dependent Variable	0.034	0.034	0.034	0.034
Treatment Effect of 1SD increase	-0.019	0.000	0.001	-0.024
Observations	14707	14707	14707	14707
Controls	Yes	Yes	Yes	Yes
School-by-grade FE	Yes	Yes	Yes	Yes

Notes: The table reports estimates from regressions of the number of friends in the classroom on math scores, conditional on the school-by-grade fixed effects and the number of friends in the school. Each column represents one of the friendship types analyzed: directed links (i.e., student i nominates student j, regardless of whether student j reciprocates), reciprocal friendships (i.e., both student i and student j nominate each other), followers (i.e., those who nominated a student but were not reciprocally nominated) and rejecters (i.e., those who are nominated by a classmate but do not reciprocate). All regressions are limited to schools with at least two classrooms per grade. All models include controls for children's biological sex, age, age squared, and the lagged test score in the previous year or baseline. *** indicates significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level. Standard errors are corrected for heteroskedasticity and are clustered at the school-by-grade level.

Table 6: Impact of Friends on Math Test Scores by Gender

	Directed	Reciprocal	Followers	Rejecters
	(1)	(2)	(3)	(4)
A. Male				
No. of Friends in Classroom	-0.009**	-0.003	0.008	-0.011**
	(0.004)	(0.008)	(0.006)	(0.005)
Mean of Dependent Variable	0.091	0.091	0.091	0.091
Treatment Effect of 1SD increase	-0.008	-0.002	0.008	-0.008
Observations	21308	21308	21308	21308
B. Female				
No. of Friends in Classroom	-0.003	-0.005	-0.003	-0.002
	(0.005)	(0.008)	(0.005)	(0.006)
Mean of Dependent Variable	-0.032	-0.032	-0.032	-0.032
Treatment Effect of 1SD increase	-0.002	-0.003	-0.003	-0.001
Observations	20123	20123	20123	20123
Controls	Yes	Yes	Yes	Yes
School-by-grade FE	Yes	Yes	Yes	Yes

Notes: The table reports estimates from regressions of the number of friends in the classroom on math scores by gender, conditional on the school-by-grade fixed effects and the number of friends in the school. Each column represents one of the friendship types analyzed: directed links (i.e., student i nominates student j, regardless of whether student j reciprocates), reciprocal friendships (i.e., both student i and student j nominate each other), followers (i.e., those who nominated a student but were not reciprocally nominated) and rejecters (i.e., those who are nominated by a classmate but do not reciprocate). All regressions are limited to schools with at least two classrooms per grade. All models include controls for children's biological sex, age, age squared, and the lagged test score in the previous year or baseline. *** indicates significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level. Standard errors are corrected for heteroskedasticity and are clustered at the school-by-grade level.

Table 7: Impact of Friend Characteristics of Directed Friendships on Math Test Scores by Gender

	Female	Post-secondary (Mother)	Disruptive	Q5 of PPVT
	(1)	(2)	(3)	(4)
A. Male				
No. of Friends in Classroom	-0.002	-0.018	-0.022*	-0.003
	(0.012)	(0.017)	(0.013)	(0.011)
Mean of Dependent Variable	0.091	0.091	0.091	0.091
Treatment Effect of 1SD increase	-0.001	-0.004	-0.007	-0.001
Observations	21308	21308	21308	21308
B. Female				
No. of Friends in Classroom	-0.005	0.007	-0.030	-0.001
	(0.005)	(0.016)	(0.028)	(0.011)
Mean of Dependent Variable	-0.032	-0.032	-0.032	-0.032
Treatment Effect of 1SD increase	-0.004	0.002	-0.004	-0.000
Observations	20123	20123	20123	20123
Controls	Yes	Yes	Yes	Yes
School-by-grade FE	Yes	Yes	Yes	Yes

Notes: The table reports estimates from regressions of the number of friends that have a certain characteristic in the classroom by gender, conditional on the school-by-grade fixed effects and the number of friends that have a certain characteristic in the school. Each column represents one of the friends' characteristics analyzed: female, maternal education, disruptiveness and prior PPVT scores. A directed link is defined as one in which student i nominates student j, regardless of whether student j reciprocates. All regressions are limited to schools with at least two classrooms per grade. All models include controls for children's biological sex, age, age squared, and the lagged test score in the previous year or baseline. *** indicates significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level. Standard errors are corrected for heteroskedasticity and are clustered at the school-by-grade level.

Table 8: Impact of Friendships on Non-Cognitive Skills

	Directed	Reciprocal	Followers	Rejecters
	(1)	(2)	(3)	(4)
A. Depression				
No. of Friends in Classroom	-0.034**	-0.053**	-0.012	-0.021
	(0.015)	(0.026)	(0.019)	(0.019)
Mean of Dependent Variable	-0.007	-0.007	-0.007	-0.007
Treatment Effect of 1SD increase	-0.028	-0.029	-0.011	-0.015
Observations	7535	7535	7535	7535
B. Self-esteem				
No. of Friends in Classroom	-0.017	-0.008	0.022	-0.020
	(0.018)	(0.025)	(0.019)	(0.022)
Mean of Dependent Variable	-0.002	-0.002	-0.002	-0.002
Treatment Effect of 1SD increase	-0.014	-0.005	0.021	-0.014
Observations	7535	7535	7535	7535
Controls	Yes	Yes	Yes	Yes
School-by-grade FE	Yes	Yes	Yes	Yes

Notes: The table reports estimates from regressions of the number of friends in the classroom on non-cognitive skills, conditional on the school-by-grade fixed effects and the number of friends in the school. Each column represents one of the friendship types analyzed: directed links (i.e., student i nominates student j, regardless of whether student j reciprocates), reciprocal friendships (i.e., both student i and student j nominate each other), followers (i.e., those who nominated a student but were not reciprocally nominated) and rejecters (i.e., those who are nominated by a classmate but do not reciprocate). All regressions are limited to schools with at least two classrooms per grade. All models include controls for children's biological sex, age, and age squared. *** indicates significance at the 1 percent level, ** at the 5 percent level, and * at the 10 percent level. Standard errors are corrected for heteroskedasticity and are clustered at the school-by-grade level.

Friendship Formation: Experimental Evidence from Ecuador

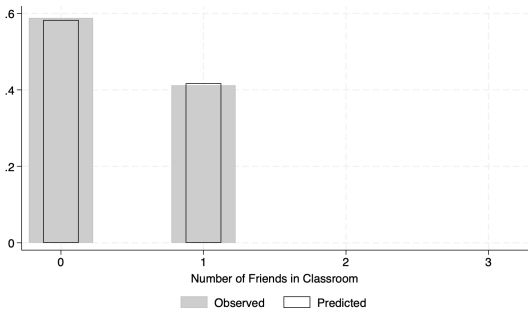
Nicolás Fuertes-Segura Yyannú Cruz-Aguayo

Online Appendix

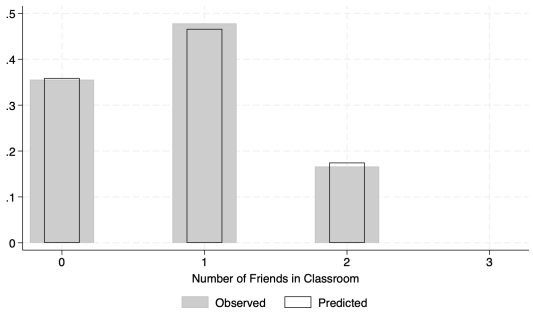
A Supplemental Figures and Tables

Figure A.1: Observed Vs Expected Probability of Friends in Classroom

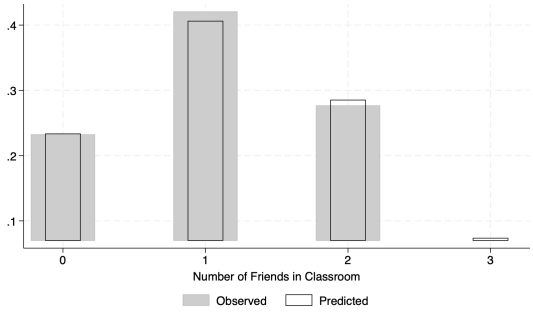
(a) 1 Friend in School



(b) 2 Friends in School



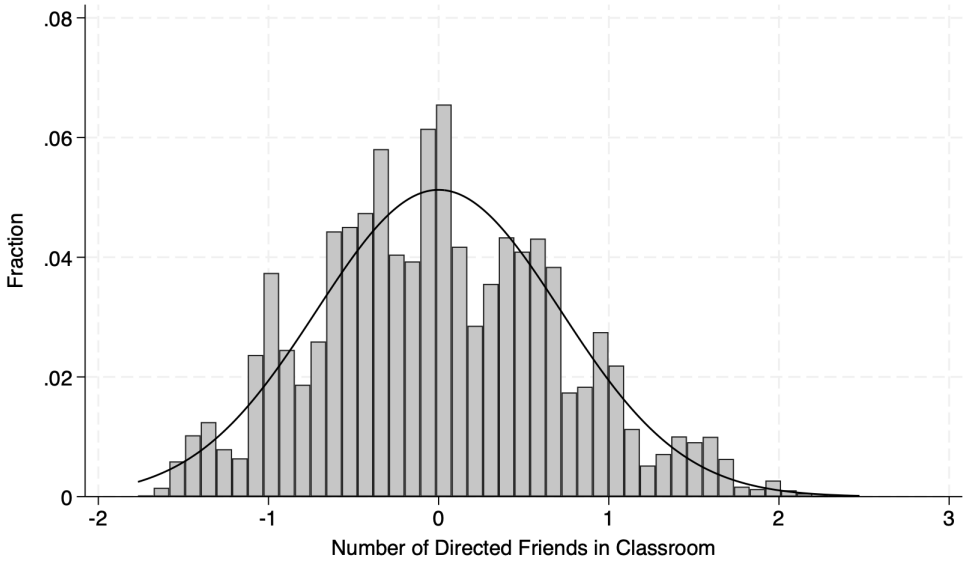
(c) 3 Friends in School



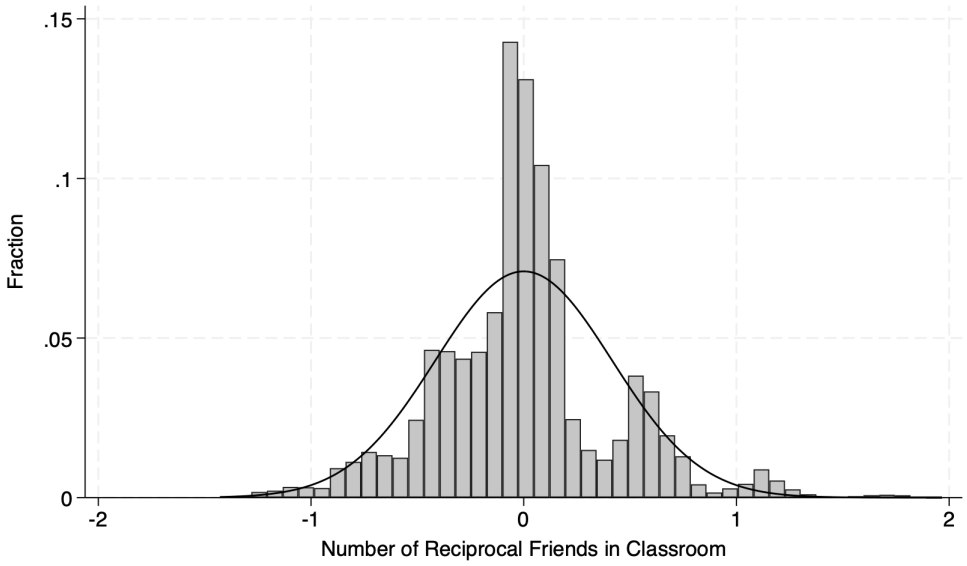
Notes:

Figure A.2: Residual Share of Number of Friends Across School-Grades

(a) Directed

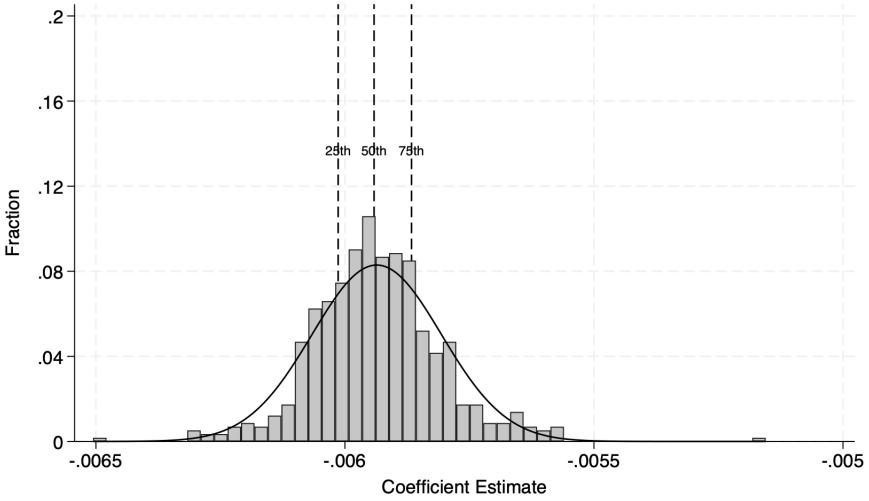


(c) Reciprocal



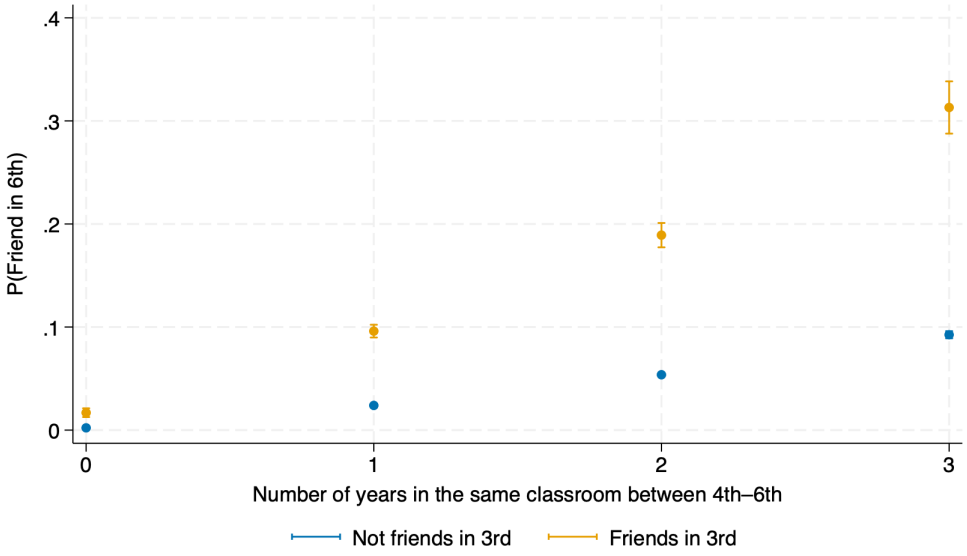
Notes:

Figure A.3: Distribution of Coefficients of the Effect of Friends in Classroom on Math Scores



Notes:

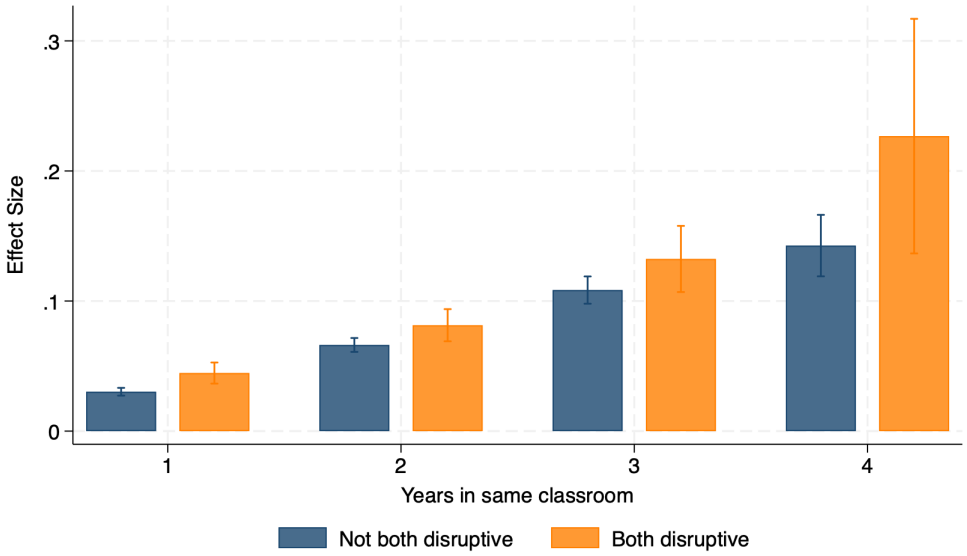
Figure A.4: Impacts on the Probability of Friendship Persistence by Years of Exposure



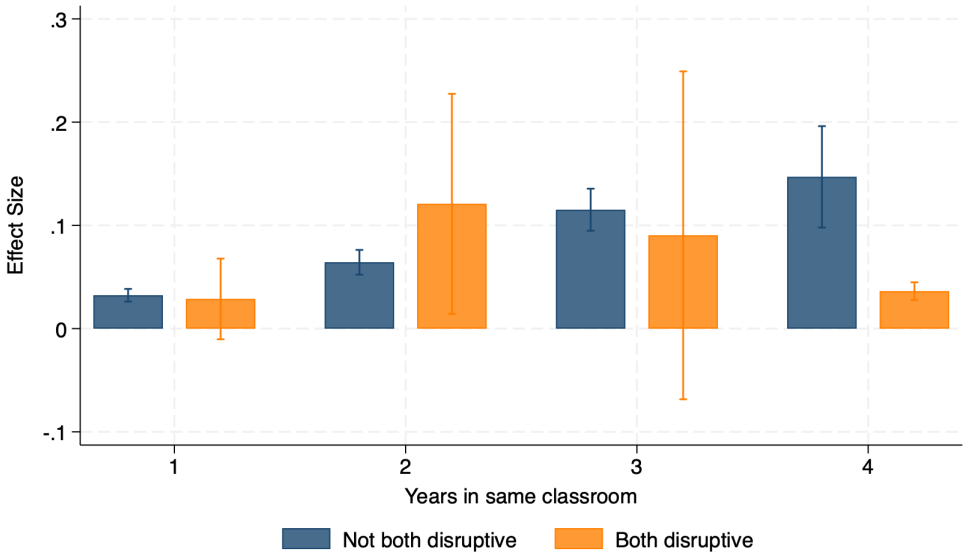
Notes:

Figure A.5: Impacts on Friendship Formation by Years of Exposure and Homophily (Disruptive)

(a) Male



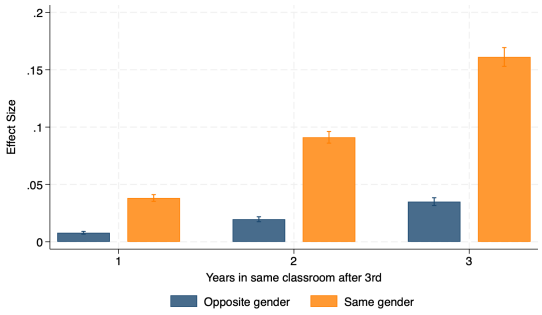
(b) Female



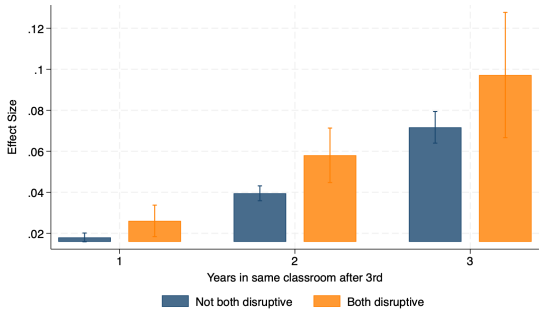
Notes:

Figure A.6: Impacts on Friendship Persistence by Years of Exposure and Homophily

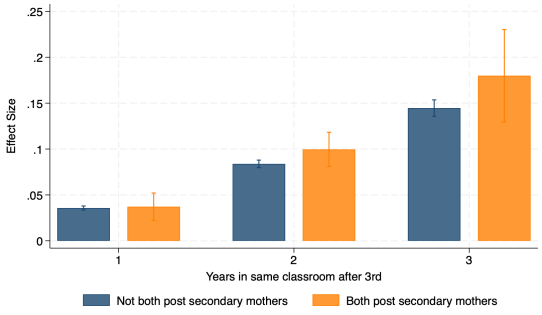
(a) Same gender



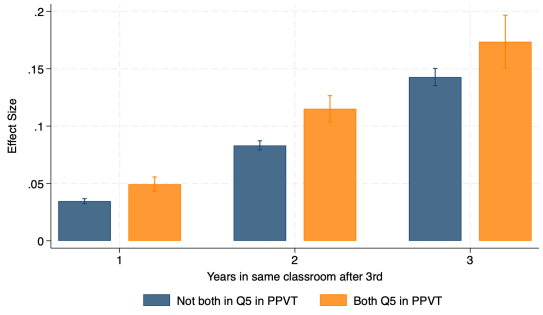
(b) Disruptive



(c) Both Mothers Post Secondary



(d) Both 5th Quantile in PPVT



Notes:

Table A.1: Impacts on Persistence of Reciprocal Friendships

	Not Friends in 3rd		Friends in 3rd	
	(1)	(2)	(3)	(4)
Same classroom in 4th	0.001***		0.013	
	(0.000)		(0.008)	
Same classroom in 5th	0.003***		0.022***	
	(0.000)		(0.007)	
Same classroom in 6th	0.012***		0.110***	
	(0.001)		(0.009)	
Years in same classroom after 3rd		0.005***		0.049***
		(0.000)		(0.005)
Mean of Dependent Variable	0.005	0.005	0.053	0.053
Observations	504661	504661	4456	4456
School FE	Yes	Yes	Yes	Yes

Notes:

Table A.2: Robustness Checks of Classroom Assignments on Friendship Formation

	Directed				Reciprocal			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Same classroom in K	0.003***	0.002***	0.003***	0.003***	0.001***	0.001***	0.002***	0.002***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Same classroom in 1st	0.005***	0.005***	0.005***	0.005***	0.003***	0.002***	0.003***	0.003***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Same classroom in 2nd	0.012***	0.011***	0.012***	0.011***	0.006***	0.005***	0.006***	0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Same classroom in 3rd	0.071***	0.100***	0.071***	0.071***	0.024***	0.044***	0.024***	0.024***
	(0.002)	(0.003)	(0.002)	(0.002)	(0.001)	(0.002)	(0.001)	(0.001)
Mean of Dependent Variable	0.029	0.029	0.029	0.029	0.010	0.010	0.010	0.010
Observations	707568	707568	707568	707568	353784	353756	353586	353388
School FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Student i FE	No	No	Yes	Yes	No	No	Yes	Yes
Student j FE	No	No	No	Yes	No	No	No	Yes
Clusters	School	School	School	School	School	School	School	School

Notes:

Table A.3: Robustness Checks of Years of Exposure on Friendship Formation

	Directed				Reciprocal			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Years in same classroom	0.022***	0.020***	0.022***	0.022***	0.008***	0.008***	0.008***	0.008***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
Mean of Dependent Variable	0.029	0.029	0.029	0.029	0.010	0.010	0.010	0.010
Observations	707568	707568	707568	707568	353784	353756	353586	353388
School FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Student i FE	No	No	Yes	Yes	No	No	Yes	Yes
Student j FE	No	No	No	Yes	No	No	No	Yes
Clusters	School	School	School	School	School	School	School	School

Notes:

Table A.4: Robustness Checks of Classroom Assignments on Friendship Persistence

	Not Friends in 3rd				Friends in 3rd			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Same classroom in 4th	0.005***	0.005***	0.005***	0.005***	0.027***	0.026***	0.026***	0.032***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.004)	(0.004)	(0.005)	(0.008)
Same classroom in 5th	0.012***	0.011***	0.012***	0.012***	0.036***	0.036***	0.036***	0.050***
	(0.001)	(0.000)	(0.001)	(0.001)	(0.005)	(0.004)	(0.005)	(0.008)
Same classroom in 6th	0.067***	0.075***	0.067***	0.067***	0.207***	0.197***	0.214***	0.224***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.006)	(0.005)	(0.007)	(0.009)
Mean of Dependent Variable	0.029	0.029	0.029	0.029	0.119	0.120	0.120	0.124
Observations	990641	990641	990608	990608	27593	27499	25872	20900
School FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Student i FE	No	No	Yes	Yes	No	No	Yes	Yes
Student j FE	No	No	No	Yes	No	No	No	Yes
Clusters	School	School	School	School	School	School	School	School

Notes:

Table A.5: Robustness Checks of Years of Exposure on Friendship Persistence

	Not Friends in 3rd				Friends in 3rd			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Years in same classroom	0.028***	0.026***	0.028***	0.028***	0.090***	0.086***	0.092***	0.101***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.003)	(0.003)	(0.004)	(0.005)
Mean of Dependent Variable	0.029	0.029	0.029	0.029	0.119	0.120	0.120	0.124
Observations	990641	990641	990608	990608	27593	27499	25872	20900
School FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Student i FE	No	No	Yes	Yes	No	No	Yes	Yes
Student j FE	No	No	No	Yes	No	No	No	Yes
Clusters	School	School	School	School	School	School	School	School

Notes:

Table A.6: Impacts on Friendships on Other Non-Cognitive Skills

	Directed	Reciprocal	Followers	Rejecters
	(1)	(2)	(3)	(4)
A. Growth Mindset				
No. of Friends in Classroom	-0.015	0.003	0.017	-0.022
	(0.017)	(0.026)	(0.019)	(0.022)
Mean of Dependent Variable	-0.001	-0.001	-0.001	-0.001
Treatment Effect of 1SD increase	-0.012	0.002	0.016	-0.016
Observations	7535	7535	7535	7535
B. Grit				
No. of Friends in Classroom	-0.012	-0.029	0.017	-0.002
	(0.015)	(0.027)	(0.019)	(0.018)
Mean of Dependent Variable	-0.002	-0.002	-0.002	-0.002
Treatment Effect of 1SD increase	-0.009	-0.016	0.016	-0.001
Observations	7535	7535	7535	7535
Controls	Yes	Yes	Yes	Yes
School-by-grade FE	Yes	Yes	Yes	Yes

Notes:

B Randomization details

Table B.1: Testing for random assignment of children to classrooms, math

	Kindergarten	Grade 1	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6
Test statistic	1.359	-0.383	0.905	0.300	-0.445	-0.222	0.980
P-value	0.174	0.702	0.366	0.764	0.657	0.825	0.327

Notes: The table reports results for tests of random assignment of children to classrooms within schools using a methodology proposed by Jochmans (2023). The null hypothesis is the absence of correlation between a child's ability measured at the end of the previous grade and the average ability of classroom peers assigned to her at the beginning of a given grade, conditional on school. The sample includes all children.

C Homophily Descriptives

In this appendix, we estimate additional descriptive analysis of homophily. First, Appendix Table C.1 examines homophily in directed links using both observed and expected link counts. Column (1) reports the average number of directed links. Column (2) reports the average share of each student's friends who share the same characteristic as the student. For example, among female students, 90.40% of their friends are also female, indicating substantial within-gender linking; by contrast, the analogous pattern for maternal education is present but weaker. However, these patterns should not be interpreted as evidence of homophilous preferences because they can arise mechanically from the underlying composition of the population. For instance, if all students had mothers with post-secondary education, then 100% of the links would be within that group. To separate composition from preference, Column (3) reports population shares for each characteristic in the sample. Comparing Columns (2) and (3), the share of same-type friends exceeds the corresponding population share, with the largest gaps observed for gender. Under random sorting, the shares in Column (2)) would match the population share in Column (3). Their systematic excess indicates homophily in friendship formation.

Second, we compare the percentage of directed links in which both students share the same characteristic in the data to the percentage expected under random assignment. Assuming that all students form the same number of links, we compute the expected share of homophilous links based on the distribution of characteristics in the population.[24] Appendix Table C.2 compares the expected and observed percentages of homophilous friendships. For gender, we would expect approximately 50% of links to be between students of the same gender, but we observe around 97%. For maternal education, the expected share of homophilous links is around 43%, while the observed share is approximately 48%. These results are consistent with earlier descriptive findings and suggest that homophily is more pronounced by

[24] If there are n characteristics, the expected fraction of homophilous friendships is $\sum_{i=1}^{n} p_i^2$ where p_i is the fraction of students with characteristic i in the sample.

gender than by maternal education.

Table C.1: Directed links by gender and by maternal education

	3rd grade			6th grade		
	No. of Friends	Share same group	Group share	No. of Friends	Share same group	Group share
A. Child's Gender						
Female	2.70	90.40	48.30	4.86	81.58	48.53
Male	2.68	87.75	51.70	4.87	81.05	51.47
B. Maternal Education						
Female						
Some Primary	2.74	45.55	40.16	4.85	46.95	40.48
Some Secondary	2.73	55.32	50.95	4.87	55.70	51.06
Post Secondary	2.78	19.97	8.89	4.86	14.56	8.45
Male						
Some Primary	2.72	47.19	38.44	4.88	44.44	38.80
Some Secondary	2.71	57.60	52.03	4.86	58.69	52.45
Post Secondary	2.73	14.87	9.53	4.88	15.58	8.75

Notes:

Table C.2: Expected and Actual Homophilous Friendships

	Homophilous Friendships	
	Expected	Observed
A. Child's Gender		
Female	23.45	52.55
Male	26.60	44.71
B. Maternal Education		
Female		
Some Primary	16.00	18.53
Some Secondary	26.02	28.03
Post Secondary	0.81	1.94
Male		
Some Primary	15.00	16.96
Some Secondary	26.88	30.18
Post Secondary	0.89	1.53

Notes:

D Details on the Tests and IRT

In this appendix, we cover more details on tests applied and the IRT procedure implemented to calculate the math test scores. First, Table D.1 and Table D.2 show summary statistics of each of the tests applied by grade for math and executive function, respectively.

We normalize the end-of-year tests by subtracting the mean and dividing by the national sample's standard deviation. We then create three test aggregates for math and executive function, respectively. Each of the four tests within an aggregate receives the same weight. Like the underlying tests, the aggregates are normalized to have zero mean and unit standard deviation.

Table D.1: Summary Statistics for Math Test Score Components

	N	Mean	SD
A. 4th Grade			
Sequences	17432	0.091	0.074
Word problems	17424	0.078	0.101
Position Value	17424	0.058	0.067
Arithmetic	17426	0.205	0.150
B. 5th Grade			
Sequences	17529	0.538	0.219
Word problems	17529	0.481	0.208
Position Value	17529	0.453	0.201
Arithmetic	17529	0.455	0.220
C. 6th Grade			
Sequences	17266	0.483	0.240
Word problems	17266	0.411	0.178
Position Value	17266	0.564	0.251
Arithmetic	17266	0.466	0.209

Notes: The table presents the results from pairwise correlations between CLASS score and its components collected in 4th grade. All the correlations are significant at the 1 percent level.

Table D.2: Summary Statistics for Executive Function Score Components

	N	Mean	SD
A. 4th Grade			
Triangles and squares	17424	0.768	0.146
Memory	17425	0.466	0.161
Pair Cancellation	17434	0.454	0.112
Words and colors - Stroop	16920	0.271	0.066

Notes: The table presents the results from pairwise correlations between CLASS score and its components collected in 4th grade. All the correlations are significant at the 1 percent level.

E Application of the CLASS in Ecuador

CLASS Protocol

In this appendix, we cover minute details of the Classroom Assessment Scoring System (CLASS) (Pianta et al., 2015) application protocol and how it was applied in Ecuador. We use the CLASS to measure teacher behaviors. The CLASS measures teacher behaviors in three domains: Emotional Support, Classroom Organization, and Instructional Support. Emotional support includes children's emotional and social expressions in the classroom, Classroom Organization relates to the classroom routines and teachers' proactiveness, and Instructional Support is related to promoting order thinking and providing quality feedback.

Each of the domains is composed of three of four dimensions that are scored separately by the coders. Figure E.1 provides an overview of the dimensions included in each domain. For each dimension, the CLASS protocol gives coders concrete guidance on whether the score given should be "low" (scores of 1–2), "medium" (scores of 3–5), or "high" (scores of 6–7). Each domain is scored individually, and the coders look for specific behaviors. For example, within the behavior management dimension, a coder would assess whether there are clear behavior rules and expectations and whether these are applied consistently. The CLASS protocol would assign a high score to a teacher whose rules and expectations for behavior are clear and consistently enforced. In contrast, a teacher whose rules and expectations are absent, unclear, or inconsistently enforced would be assigned a low score. (See Appendix Table B1 in Araujo et al. (2016) for more details). Under the CLASS protocol, the scoring process does not consist of running down a checklist of the presence or absence of certain behaviors or indicators but a holistic and composite description of the classroom experience.

Application in Ecuador

We filmed all teachers for an entire school day (from approximately eight to one in the afternoon for morning schools and from two to six in the afternoon for the afternoon schools).

Teachers only knew on what day they would be filmed until the day itself. Following CLASS protocols, we discarded the first hour of filming, times that were not instructional (e.g., lunch and breaks), and where the main teacher was not in the classroom (e.g., PE Class). The remaining video was cut into usable 20-minute segments in which at least five children and their main teacher were in the segment for at least 15 of the 20 minutes that the segment ran. For each teacher, we selected the first four segments that comply with the protocol (over 9,000 segments in total).

Once the videos were separated into segments, a group of 6-8 coders explicitly trained for this purpose by a Teachstone-certified CLASS K-3 trainer scored them. The trainer also provided feedback and supervised the coders while coding the segments. All the segments were double-coded by two independent coders who scored each segment on the ten dimensions explained previously. The videos with large differences in their scores between the two coders were flagged and sent to a third coding process by an independent coder.[25] Additionally, during the entire process, we interacted extensively with the developers of the CLASS at the University of Virginia.

Figure E.2 graphs univariate densities of the distribution of CLASS score and each domain in 4th grade. The figure shows that teachers score the highest in Classroom Organization, with teachers distributed in the "medium" and "high" parts of the distribution; somewhat lower in Emotional Support, with most teachers in the "medium" range; and lowest in Instructional Support, where all teachers have "low" CLASS scores. As a result, most teachers have a medium total Score in the CLASS, and some are in the Low score range.

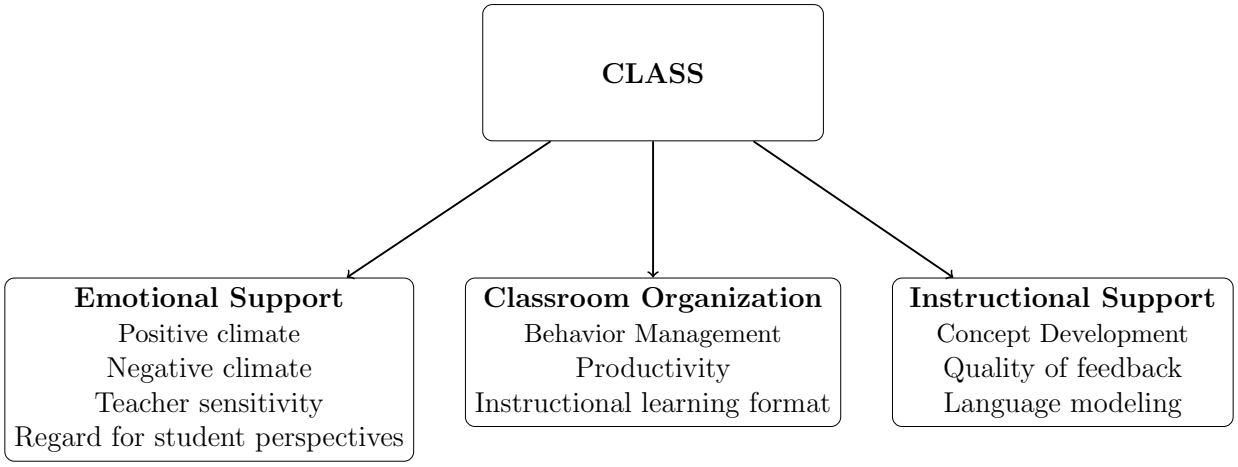
Table E.1 shows the correlation between the total CLASS score and each of its components. It shows that the scores of the components are highly correlated with the total, which is consistent with how the total score is calculated. Moreover, it shows that the correlation among components is lower, consistent with the fact that each measures different behaviors

[25]Based on a preliminary analysis of CLASS data from Ecuador that revealed a breakdown of high-and low-variability dimensions, videos are coded a third time if they have a difference of more than 1 point in the dimensions of Negative Climate, Concept Development, Quality of Feedback, or Language Modeling; if there is a difference of more than 2 points in any of the other dimensions they are also flagged for re-coding

and dimensions of the teacher's quality.

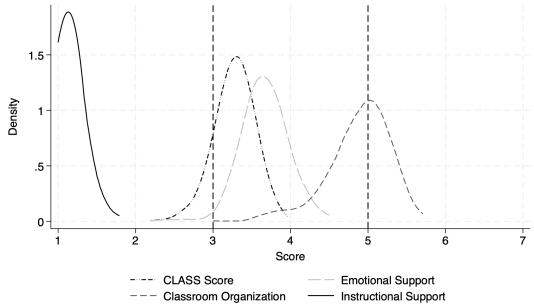
The filming and coding Protocols for the CLASS in Ecuador provide further details on how the process was implemented and how the segments were scored. The authors provide these upon request.

Figure E.1: ClASS Domains and Dimensions



Notes: The figure shows the three domains of the Classroom Assessment Scoring System (CLASS) and the dimensions included in each domain.

Figure E.2: Distribution of CLASS Score and domains



Notes: The figure above presents univariate densities of the distribution of Classroom Assessment Scoring System (CLASS) score and its domains in 4th grade.

Table E.1: Correlation across CLASS scores

	Total Score	Emotional Support	Classroom Organization	Instructional Support
	(1)	(2)	(3)	(4)
Total Score	1.000			
Emotional Support	0.869	1.000		
Classroom Organization	0.871	0.589	1.000	
Instructional Support	0.622	0.400	0.382	1.000

Notes: The table presents the results from pairwise correlations between CLASS score and its components collected in 4th grade. All the correlations are significant at the 1 percent level.