Can School Integration Eliminate Racial Segregation? Implications from Friendship Segregation

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Abstract

This paper estimates the impact of friendship segregation on student achievement. Estimation results show that friendship segregation lowers educational achievement of minorities and increases the minority-white achievement gap. Integration policy cannot completely eliminate friendship segregation because policymakers fail to manipulate racial preferences of students. Simulation results show that students' racial sorting substantially offsets the potential achievement gains of integration policy.

JEL Classification: I21, J15, Z13

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1 Introduction

Ever since the U.S. Supreme Court ruled segregation in the public schools is unconstitutional in *Brown v. Board of Education* (1954), school integration has played a key role in providing equal educational opportunities to all students regardless of race. The fundamental reason for school integration is to improve black students' achievement, which is supported by the empirical evidence that test scores of black students and black enrollment shares are inversely related (Coleman, 1966). Since then, subsequent studies have further investigated the impact of racial composition in schools on educational outcomes. Although the findings differ across studies, the consensus from the literature is that a higher exposure to minority schoolmates, such as blacks and Hispanics, is detrimental to educational achievement of minorities and thus increases the minority-white achievement gap.[1]

Based on such findings, policymakers are motivated to implement school integration policy, such as desegregation busing, to achieve racial balance across schools. The key idea of my paper is that across-school integration policy cannot completely eliminate racial segregation - even though schools are integrated, friendships are still racially segregated within school. For instance, students disproportionately have higher social interactions with peers of the same race. It is important to understand whether friendship segregation is harmful or beneficial to student achievement. The first objective of this paper is to estimate the effects of racial composition in friendships on student achievement and the racial achievement gap.[2][3]

Estimating the effects of racial composition in friendships on individual achievement is

[1] See Hoxby (2000), Rivkin (2000), Angrist and Lang (2004), Guryan (2004), Card and Rothstein (2007), Hanushek et al. (2009), Cooley (2010), and Reber (2010). Rivkin and Welch (2006) and Vigdor and Ludwig (2008) provide an overview of the findings in the literature.

[2] Echenique et al. (2005) apply the spectral segregation index developed by Echenique and Fryer (2007) to estimate the relationship between within-school segregation and outcomes. They find that within-school segregation has a substantively unimportant relationship with academic achievement. However, they note that the finding is not causal.

[3] For descriptive works on friendship segregation in the sociology literature, see Moody (2001) and Mouw and Entwisle (2006).

challenging, because individuals do not randomly choose their friends. A credible research design has to deal with the possibility that individuals select their friends based on some unobservable factors that also influence their achievement (Manski, 1993).[4] My identification strategy is to use panel structure to isolate the effects of friendship segregation from selection bias. I first control for individual, parental, neighborhood, classroom, and school observable factors that affect both friendship decisions and achievement. Based on friendship nominations, I empirically define peer groups within a school and each individual is assigned to one peer group. Peer group assignment is based on the idea that there are direct or indirect friendships among individuals within a group and no friendships between individuals in different groups. An inclusion of peer group fixed effects can eliminate correlated effects (Manski, 1993). Individuals, however, probably choose their friends based individual unobservables, such as ability and personality traits, within a peer group. To deal with this, I use lagged test score, which is a function of such individual unobservables, to control for selection bias. This identification strategy is credible as long as unobserved individual ability and personality traits hardly change between two years. Robustness analysis indicates that adding lagged test score is sufficient to control for selection bias.

Estimating models with panel data from the National Longitudinal Study of Adolescent Health (Add Health), I find that a higher exposure to minority friends lowers the standardized test scores of minorities, but do not have significant effects on whites. Specifically, a one-standard-deviation (0.4) increase in the proportion of minority friends lowers 48% of a standard deviation in the standardized vocabulary test scores of minorities. The effect is large enough to conclude that friendship segregation increases the minority-white achievement gap. Integrating friendships can close 30% of the racial achievement gap. In the primary specification, I do not distinguish the direct effects of exposing to minority friends

[4]The literature on racial segregation applies different econometric methods to deal with the selection problem, for example, using instrumental variables (Rivkin, 2000; Cooley, 2010), using panel data methods (Hoxby, 2000; Hanushek et al., 2009), aggregating individual observations to the metropolitan level (Card and Rothstein, 2007), and exploiting policy experiments (Angrist and Lang, 2004; Guryan, 2004). See Epple and Romano (2011) and Sacerdote (2011) for an overview of estimation strategies of peer effects in education.

from the indirect effects of race is a proxy of other characteristics of friends. Conditioning on friend-related variables, such as social behavior like smoking and drinking and cognitive skills like GPA and homework efforts, hardly change the estimate of exposure effects. This implies that race is not just a proxy of other attributes of friends, but it generates effects on individual achievement *per se*.

From a policy point of view, policymakers cannot completely integrate friendships. This is because policymakers can only affect students' friendship opportunities by school enrollments, but they cannot manipulate students' preferences to achieve a desired friendship outcome. If students have racial bias of making friends, the potential effectiveness of the policy could be partially undone by students' racial sorting behavior. The second objective of this paper is to endogenize friendship decisions to estimate how much of the potential gains of integration policy could be offset by students' optimizing decisions.

I estimate a discrete choice model to understand the determinants of friendship decisions. Estimation results show that friendship choices are characterized by homophily - individuals prefer to make friends with others similar to themselves. In particular, individuals prefer to make same-race friends. To evaluate to what extent the effectiveness of integration policy could be offset by students' racial sorting behavior, I simulate integration policies by relocating students across schools to balance their friendship opportunities. Simulation results show that the percentage changes in the proportion of minority friends are much smaller than the percentage changes in the proportion of minority schoolmates of students. The intuition is that even though the friendship opportunities of students change, they self-segregate by making friends with own race. Because of students' racial sorting, school integration policy cannot completely integrate friendships and thus about 70% of the potential achievement gains are forgone.

The results in this paper are related to the literature in three aspects. First, this paper

provides empirical evidence that endogenous group formation fails to achieve the desired outcomes of policies (Carrell et al., 2012). Second, the literature finds that school quality (Boozer et al., 1992; Card and Krueger, 1992; Jackson, 2009) and neighborhood income (Card and Rothstein, 2007) can explain the negative relationship between school minority ratio and test scores. This paper argues that friendship peer effect is an alternative explanation. The mechanism is as follows: a shift from integrated to minority schools exposes students to higher proportions of minority schoolmates. Given that students make friends within school, a higher exposure to minority schoolmates is associated with having a higher proportion of minority friends, which in turn lowers students' test scores through friendship peer effects. This mechanism is independent of school quality and neighborhood income, because school and neighborhood characteristics are controlled for in the estimation. Third, this paper helps to understand the findings of Card and Rothstein (2007). They find that there are no independent effects of school segregation conditional on neighborhood segregation. Given that friends are a subset of students' schoolmates, this paper shows that the effects of school segregation actually exist, but they operate at the friendship level. To the extent that only closely-connected peers (friends) can affect individual achievement, broadly defining schoolmates as peers may fail to identify effects of school segregation.

The remainder of this paper is organized as follows. Section 2 describes the data. Section 3 lays out the empirical model and presents the estimation results. Section 4 simulates integration policies. Section 5 performs robustness checks, and Section 6 concludes.

2 Data Description

Friendship information is indispensable for analyzing friendship segregation. The data used in this paper comes from the National Longitudinal Study of Adolescent Health (Add Health).[5] The distinctive feature of the data is that students were asked to provide the

[5]This research uses data from Add Health, a program project directed by Kathleen Mullan Harris and designed by J. Richard Udry, Peter S. Bearman, and Kathleen Mullan Harris at the University of North

names of their friends, so that demographic characteristics of friends were obtained. As shown in Figure 1, Add Health is a longitudinal study of a nationally representative sample of adolescents in grades 7-12. In the 1994-95 in-school survey, 90,118 individuals attending 145 sampled schools on the interview days filled out a short-form questionnaire in which they were asked to nominate their friends. On the interview days, school administrators were also asked to provide school information such as student enrollments and teacher qualification, etc. Based on the information collected in the in-school survey, 20,745 students were asked to fill out a long-form questionnaire during in-home interviews in which their individual, parental, and neighborhood particulars were collected. In particular, they were asked to take the standardized vocabulary test (AHPVT). Seven years later when all individuals had left high schools, a subset of individuals were interviewed again in which their high-school transcripts were collected and they were asked to take the AHPVT again.

With respect to data trimming, I start with 20,745 individuals who participated in in-home interviews in 1994-95. 1,032 individuals having no standardized test scores and 1,727 individuals attending private schools were dropped. 4,520 individuals were excluded because they were not selected to have in-school interviews so that their friendship information is not available. An additional 492 individuals who had missing demographic and identification information were excluded. Further, another 1,551 individuals were excluded because complete observations on key variables are unavailable for each of them. 11,423 individuals are left in the sample: 1,164 individuals (10.2%) had zero friends because they did not nominate any friends; another 849 individuals (7.43%) had zero friends because their nominated friends did not attend the same school.[6] In short, 9,410 individuals had positive in-school

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[6]For the sake of comparison, Conti et al. (2012) find that roughly 11% of students nominated zero friends in the Wisconsin Longitudinal Study (WLS), and Ennett and Bauman (2000) document that about 5% of students nominated friends at different schools in the North Carolina sample in 1980.

In-School Survey 1994-95	90,118 Individuals in grades 7-12	Friendship Information School Covariates
In-Home Survey 1994-95	20,745 Individuals in grades 7-12	Individual Covariates Parental Covariates Neighborhood Covariates Standardized Test Scores
In-Home Survey 2001-02	15,701 Individuals aged 18-26	Academic Transcript Standardized Test Scores

Figure 1: Road Map of Add Health Survey

friends; and 5,966 out of 9,410 individuals provided academic transcripts. The estimation samples differ across educational outcomes.

2.1 Friendship Information

The classification of races in this paper is based on self-reports of individuals in the 1994-95 in-school survey. If an individual is of Hispanic origin, he or she is classified as Hispanic. Non-Hispanics are whites, blacks, Asians, and American Indians. Minorities are non-whites. Because of a relatively small sample size, there are two racial groups in this study - whites and minorities.

Table 1: Number of Friends

No. of Friends	Full Sample	White	Minority
1	8.89%	6.42%	11.9%
2	11.0%	8.62%	13.1%
3	11.9%	10.8%	13.3%
4	13.2%	12.2%	14.4%
5	12.9%	13.9%	11.7%
6	11.4%	11.8%	10.8%
7	10.9%	11.7%	9.87%
8	9.77%	11.5%	7.62%
9	7.10%	8.60%	5.25%
10	3.36%	4.38%	2.11%
Mean No. of Friends	5.04	5.41	4.57
Number of Observations	9,410	5,184	4,226

In the 1994-95 in-school survey, individuals were asked to nominate their friends (up to five males and five females). The nominated friends not included in school rosters cannot be identified and therefore were excluded from the analysis, which implies that an individual's nominated friends are also his or her schoolmates. Friendship nominations are unilateral - individual i nominates individual j as a friend, but the reverse is not necessarily true. The nominated number of friends of the full sample and of each racial group is presented in Table

1. One concern is that the number of friends is censored when some individuals actually had more than, but were constrained to nominate at most, ten friends. Nevertheless, Table 1 shows that only 3.4% of individuals nominated ten friends, which implies that the upper bound of ten-friend nominations may not often be binding. Table 2 shows that 10.2% of individuals nominated five male friends and Table 3 shows that 15.8% of individuals nominated five female friends. Censoring is not a large concern because the key variable of interest is the proportion of minority friends rather than the number of friends.

Regarding popularity, Table 1 shows that the mean number of friends is around five and that whites have more friends than do minorities. In particular, 25% of whites and 38% of minorities have three friends or less, and 24% of whites and 15% of minorities have eight friends or more. This indicates that generally whites are more active in social interactions than are minorities in high school. Tables 2 and 3 indicate that females are more highly valued as friends than males, as the mean number of male friends is 2.30 and the mean number of female friends is 2.70.

Table 2: Number of Male Friends

No. of Male Friends	Full Sample	White	Minority
0	17.1%	14.1%	20.9%
1	17.5%	16.1%	19.3%
2	18.6%	18.4%	18.8%
3	19.3%	20.0%	18.4%
4	17.3%	19.2%	15.0%
5	10.2%	11.9%	7.52%
Mean No. of Male Friends	2.33	2.51	2.10
Number of Observations	9,410	5,184	4,226

Table 3: Number of Female Friends

No. of Female Friends	Full Sample	White	Minority
0	12.7%	11.4%	14.4%
1	14.3%	11.6%	17.6%
2	16.3%	14.7%	18.4%
3	19.3%	19.9%	18.8%
4	19.4%	23.9%	18.3%
5	15.8%	18.1%	12.2%
Mean No. of Female Friends	2.70	2.89	2.46
Number of Observations	9,410	5,184	4,226

2.2 Measurements of Educational Achievement

The measurements of educational achievement are presented in Table 4. Standardized vocabulary tests, English GPA, and mathematics GPA are used to measure students' educational achievement. The former are the scores of the Add Health Picture Vocabulary Test (AHPVT) taken during in-home interviews in 1994-95 and 2001-02.[7] The latter are scores of within-school tests in English and mathematics in 1994-95. As shown in Table 4, the mean AHPVT of whites is higher than that of minorities. Regarding within-school subject tests, on average the GPAs of whites are higher than those of minorities in all subjects. It is, therefore, evident that whites perform better than minorities in both standardized test scores and within-school GPAs. Table 5 provides summary statistics of observable covariates used in the estimation, which include individual, parental, classroom, school, and neighborhood covariates of sampled students.

Table 4: Summary Statistics of Educational Achievement

	Full Sample	White	Minority
AHPVT in 1995	100.5 (14.3)	104.6 (12.2)	95.6 (15.2)
AHPVT in 2002	102.0 (15.5)	105.7 (11.3)	97.2 (18.6)
English GPA in 1995	2.52 (1.08)	2.63 (1.07)	2.31 (1.05)
Mathematics GPA in 1995	2.22 (1.15)	2.38 (1.14)	1.91 (1.10)

[1] Means in entries and standard deviations in parentheses.

[7] The AHPVT is a computerized, abridged version of the Peabody Picture Vocabulary Test, which assesses individual verbal ability or scholastic aptitude.

2.3 Measurements of Racial Segregation

I measure friendship segregation by calculating the minority share in friendships for each individual. For minorities, if the proportion of minority friends is high then friendship segregation is high; for whites, if the proportion of minority friends is high then friendship segregation is low. By using this idea, I respectively calculate racial segregation in friendship, classroom, school, and neighborhood as follows:

Friendship Segregation: the ratio of the number of minority friends to the total number of friends of an individual.

Classroom Segregation: the ratio of the number of minority classmates to the total number of classmates of an individual.

School Segregation: the ratio of the number of minority students to the total number of students in a school. Private schools are excluded and 110 public schools are included in the study.

Neighborhood Segregation: the ratio of the number of minority inhabitants to the total number of inhabitants in a neighborhood. A neighborhood is defined as a census block group, where on average there are 1,700 inhabitants in a block group.

Table 6 reports summary statistics of racial segregation. Whites (minorities) have a lower (higher) minority share than the national average in each type of racial segregation. This provides clear evidence of racial segregation. In particular, the gap in the proportion of minority friends between whites and minorities is 0.66, whereas the gaps of the other two segregation measures are about 0.46-0.53. This indicates that segregation in friendships is

Table 5: Summary Statistics of Variables

	Full Sample	White	Minority
Individual Covariate			
Minority	0.45 (0.50)	-	-
Male	0.44 (0.50)	0.45 (0.50)	0.44 (0.50)
Age	15.0 (1.68)	14.9 (1.67)	15.2 (1.68)
Grade	9.70 (1.61)	9.57 (1.62)	9.85 (1.60)
Club Participation	0.79 (0.41)	0.81 (0.39)	0.77 (0.42)
Smoking	1.15 (2.00)	1.44 (2.20)	0.79 (1.67)
Drinking	1.19 (1.49)	1.28 (1.50)	1.08 (1.46)
Lying to Parents	2.15 (1.79)	2.14 (1.75)	2.15 (1.83)
School Skipping	0.59 (1.20)	0.53 (1.12)	0.66 (1.30)
TV Watching Time	2.36 (1.06)	2.18 (1.01)	2.58 (1.08)
Homework Effort	3.26 (0.68)	3.21 (0.67)	3.32 (0.68)
Parental Covariate			
Parental Education	0.39 (0.49)	0.40 (0.49)	0.38 (0.49)
Proportion Living with Mother	0.93 (0.25)	0.94 (0.24)	0.93 (0.26)
Proportion Living with Father	0.77 (0.42)	0.83 (0.37)	0.69 (0.46)
Number of Siblings	0.81 (0.96)	0.75 (0.89)	0.87 (1.03)
Proportion Mother Professional	0.28 (0.45)	0.29 (0.46)	0.27 (0.44)
Proportion Father Professional	0.19 (0.39)	0.22 (0.42)	0.14 (0.35)
Living Condition	3.41 (0.81)	3.49 (0.76)	3.32 (0.85)
Classroom Covariate			
AP Classes	0.04 (0.19)	0.04 (0.20)	0.03 (0.18)
Honor Classes	0.15 (0.36)	0.14 (0.35)	0.16 (0.37)
Proportion Minority Classmates	0.44 (0.36)	0.21 (0.22)	0.74 (0.28)
School Covariate			
Proportion Minority Schoolmates	0.41 (0.36)	0.20 (0.23)	0.67 (0.31)
Student Attendance Rate	4.06 (0.85)	4.27 (0.75)	3.80 (0.89)
Average Class Size	26.7 (5.33)	24.9 (4.34)	28.8 (5.63)
Percent Senior Teachers	65.4 (21.1)	67.4 (22.5)	63.0 (19.0)
Percent New Teachers	9.68 (14.5)	9.75 (16.4)	9.61 (11.9)
Percent Teachers Hold MA or Higher	46.2 (26.5)	50.1 (24.8)	41.6 (27.6)
School Size	2.39 (0.68)	2.28 (0.68)	2.52 (0.66)
Neighborhood Covariate			
Proportion Minority Neighbors in block	0.31 (0.34)	0.10 (0.16)	0.56 (0.32)
Population in Block/100	17.7 (14.6)	17.0 (13.5)	18.5 (15.8)
Proportion Urban in Block	0.55 (0.49)	0.42 (0.48)	0.71 (0.45)
Proportion Aged 25+ W/O HS Diploma in Block	0.29 (0.15)	0.24 (0.13)	0.34 (0.17)
Proportion Aged 25+ W College Degree in Block	0.22 (0.14)	0.23 (0.14)	0.21 (0.13)
Unemployment Rate in Block	0.08 (0.05)	0.06 (0.04)	0.09 (0.06)
Median Household Income in Block/1000	30.8 (13.6)	32.0 (12.5)	29.4 (14.7)
Number of Observations	9,410	5,184	4,226

[1] Means in entries and standard deviations in parentheses.

[2] Smoking, drinking, lying to parents, and school skipping are coded as follows: each category is distinguished between "never," "once or twice," "once a month or less," "2 or 3 days a month," "once or twice a week," "3-5 days a week," "nearly everyday," coded as 1 to 7. TV watching time is distinguished between "none," "less than 1 hour," "1-2 hours," "3-4 hours," "more than 4 hours," coded as 1 to 5. Homework effort is distinguished between "I never try at all," "I don't try very hard," "I try hard enough," "I try very hard to do my best," coded as 1 to 4. Parental education is coded as 1 if either one of parents graduated from

relatively high. Table 7 shows that the correlation coefficients for four types of racial segregation.

Table 6: Means and Standard Deviations of Racial Segregation

	Full Sample	White	Minority	Racial Gap
Proportion Minority Friends	0.43	0.14	0.80	0.66
	(0.43)	(0.23)	(0.33)	-
Proportion Minority Classmates	0.44	0.21	0.74	0.53
	(0.36)	(0.22)	(0.28)	-
Proportion Minority Schoolmates	0.41	0.20	0.67	0.47
	(0.36)	(0.23)	(0.31)	-
Proportion Minority Neighbors	0.31	0.10	0.56	0.46
	(0.34)	(0.16)	(0.32)	-
Number of Observations	9,410	5,184	4,226	

[1] Means in entries and standard deviations in parentheses.
[2] Racial gap is defined as the difference in minority shares between white and minority.

Table 7: Correlation Coefficients of Segregation Types

	Friendship	Classroom	School	Neighborhood
Friendship	1.00	0.81	0.77	0.78
Classroom	-	1.00	0.97	0.86
School	-		1.00	0.84
Neighborhood	-	-	-	1.00

Note: Number of observations = 9,410.

2.4 Definition of Peer Groups

Each student belongs to one peer group in a school. The boundary of a peer group is defined such that there are direct or indirect friendships among individuals within a peer group and no friendships between individuals in different peer groups. The idea is illustrated in Figure 2. Nodes are students and links are friendships. There are two peer groups formed by seven

students in the school, where 0, 1, and 2 belong to group A and 3, 4, 5, and 6 to group B. Table 8 provides peer group statistics in this study. The 9,410 students are divided into 138 different groups with a mean of 68.2 students in a group. The smallest group has 2 students and the largest one has 779 students.

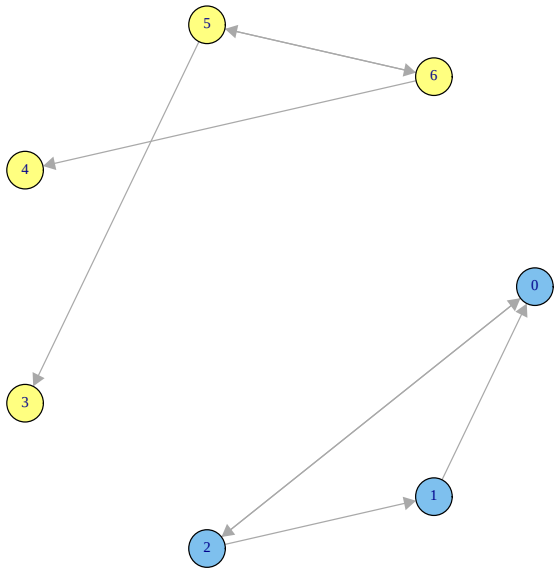

Figure 2: Peer Group Detection

Table 8: Peer Group Statistics

	Value
Individual	9,410
Number of Peer Group	138
Mean Group Size	68.2
Smallest Group Size	2
Largest Group Size	779

3 Identification and Estimation

3.1 Identification Strategy

I model the educational production function as follows:

$$A_{ig}^{95} = \underbrace{X_{ig}^{95}\beta^{95} + P_{ig}^{95}\gamma^{95} + \epsilon_{ig}^{95}}_{CurrentInputs} + \underbrace{\theta_i}_{Ability} + \underbrace{(X_{ig}^{94}\beta^{94} + P_{ig}^{94}\gamma^{94} + \epsilon_{ig}^{94}) + (X_{ig}^{93}\beta^{93} + P_{ig}^{93}\gamma^{93} + \epsilon_{is}^{93}) + ...}_{CumulativePastInputs} \quad (1)$$

where the variable of interest is P_{ig}^{95}, which measures the proportion of minority friends of individual i who is in peer group g in 1995. The key parameter is γ^{95}, which measures the contemporary effect of exposing to minority friends on current test score. A_{ig}^{95} is the test score, X_{ig}^{95} is a vector of observable current inputs, and ϵ_{ig}^{95} is a vector of unobservable current inputs. θ_i is permanent ability. Cumulative observable and unobservable past inputs are also determinants of test score in 1995.

Since I cannot observe ability and all of past inputs, so I follow the education production literature to use the lagged test score, A_{ig}^{94}, as a sufficient statistic to measure permanent ability and past inputs (Todd and Wolpin, 2003; Hanushek et al. 2003, 2009). Hence, the education production function can be rewritten as follows:

$$\begin{aligned} A_{ig}^{95} =& X_{ig}^{95}\beta^{95} + P_{ig}^{95}\gamma^{95} + \epsilon_{ig}^{95} + \alpha A_{ig}^{94} \\ =& \alpha A_{ig}^{94} + X_{ig}^{95}\beta^{95} + P_{ig}^{95}\gamma^{95} + \theta_g^{95} + \eta_{ig}^{95} \end{aligned} \quad (2)$$

where the error term ϵ_{ig}^{95} is decomposed into θ_g^{95} and η_{ig}^{95}. θ_g^{95} is the group-specific unobservable, which captures the correlated effects (Manski, 1993). By assuming $\mathbb{E}(\eta_{ig}^{95}|A_{ig}^{94}, X_{ig}^{95}, P_{ig}^{95}, \theta_g^{95}) = \mathbb{E}(\eta_{ig}^{95}|A_{ig}^{94}, X_{ig}^{95}, \theta_g^{95})$, γ^{95} is consistently estimated.

3.2 Estimation Results

Table 9 reports the results on the AHPVT in 1995. In the specification in column 1 where I control for all observable variables such as individual covariates, parental covariates, neighborhood covariates. I also include peer group fixed effects to control for correlated effects. Because peer groups are defined within a school, school covariates are excluded because they are absorbed by peer group fixed effects. Importantly, neighborhood segregation and school segregation are conditioned in this specification. Estimation results shows that a standard-deviation increase in the proportion of minority friends lowers the test scores of minorities by a standard deviation of 0.54. However, there is no statistically significant effect on whites. Individuals may choose their friends based on individual unobservables within a peer group. Hence, lagged overall GPA is included in the specification in column 2 to control for cumulative past inputs as well as permanent individual unobservables.[8] I find that the negative effects of exposing to minority friends decrease for both minorities and whites, while the effect on minorities is still statistically significant at the 1% level. It is likely that an individual taking AP and honor classes has a higher exposure to white peers and thus make fewer minority friends. To deal with this, I control for an individual taking AP and honors classes and an individual's proportion of minority classmates in the specification in column 3. This specification only slightly decreases the negative effects of exposing to minority friends, which implies the effects of friendship segregation are not confounded by classroom segregation. To summarize, a higher exposure to minority friends lowers the test scores of minorities but do not affect the test scores of whites. Specifically, a one-standard-deviation increase in the proportion of minority friends lowers 48% of a standard deviation in the standardized test scores of minorities.

[8]Because there were no AHPVT taken in 1994, so I use overall GPA in 1994 as a substitute for measuring individual unobservables and past inputs. For English and math GPA, I use English GPA in 1994 and math GPA in 1994 as a regressor in the estimation, respectively.

Table 9: Estimation Results on Standardized Vocabulary Test

	Dependent Variable: $AHPVT_{1995}$		
	(1)	(2)	(3)
Minority*PropMinorityFriends$_{1995}$	-0.537***	-0.493***	-0.478***
	(0.107)	(0.101)	(0.092)
White*PropMinorityFriends$_{1995}$	-0.116	-0.056	-0.047
	(0.082)	(0.079)	(0.077)
Overall GPA_{1994}		0.224***	0.173***
		(0.020)	(0.025)
AP Classes$_{1995}$			0.357***
			(0.076)
Honor Classes$_{1995}$			0.425***
			(0.050)
PropMinorityClassmates$_{1995}$			-0.140
			(0.093)
Grade Fixed Effects	√	√	√
Peer Group Fixed Effects	√	√	√
Individual Covariates	√	√	√
Parental Covariates	√	√	√
Neighborhood Covariates	√	√	√

[1] Number of observations = 3,277.
[2] *** Sig. at 1%; ** Sig. at 5%; * Sig. at 10%.
[3] Robust standard errors clustered by peer groups in parentheses.

Table 10: Summary Results on Educational Achievement (Std. Dev.)

	(1)	(2)	(3)	(4)
	$AHPVT_{1995}$	$AHPVT_{2002}$	English GPA_{1995}	Math GPA_{1995}
A) Minority*PropMinorityFriend	-0.478***	-0.362***	-0.100	-0.191**
	(0.092)	(0.083)	(0.075)	(0.096)
B) White*PropMinorityFriend	-0.047	-0.064	-0.035	-0.253**
	(0.077)	(0.096)	(0.075)	(0.109)
C) Racial Achievement Gap	-0.189***	-0.152***	-0.047	-0.145***
	(0.041)	(0.041)	(0.035)	(0.048)

[1] All model specifications include grade fixed effects, peer group fixed effects, individual covariates, parental covariates, classroom covariates, and neighborhood covariates.
[2] *** Sig. at 1%; ** Sig. at 5%; * Sig. at 10%.
[3] Robust standard errors clustered by peer groups in parentheses.

The estimation results for the AHPVT in 2002, English GPA in 1995, and math GPA in 1995 are reported in Table 10. The model specification is the same as the one in column 3 of Table 9. For each column, row A and row B show the estimates of minorities and whites, respectively. On the one hand, except for English GPA, educational achievement of minorities decrease if they face a higher exposure to minority friends. The negative effects are stronger on the standardized test scores (AHPVT) than within-school GPA. On the other hand, except for math GPA, educational achievement of whites do not significantly change if they have a higher proportion of minority friends.

Simple calculations show that friendship segregation, i.e. minorities have a higher proportion of minority friends and whites have a lower proportion of minority friends, increases the minority-white achievement gap in the AHPVT and math GPA. Given that the mean proportion minority friends is 0.43, row C shows how much of the minority-white achievement gap narrows if friendships are integrated, namely, the average proportion of minority friends of minorities decreases from 0.80 to 0.43 and the average proportion of minority friends of whites increases from 0.1 to 0.43. It turns out that the minority-white achievement gap declines by $15\% - 19\%$ of a standard deviation, which is about 30% of the raw achievement gap.

3.3 Channels of Exposure Effects

The effect from exposure to minority friends captures the total peer effect at the friendship level in the primary specification in equation (2). In this section, I open the black box of the effect of friendship segregation by investigating whether the race of friends is just a proxy for other attributes of friends. I consider three types of channels through which the race of friends could affect individual achievement: demographic aspects of friends, social behavior of friends, and cognitive aspects of friends. The summary statistics of friend variables are reported in Table 11.

Table 11: Summary Statistics of Friend Variables

	Full Sample	White	Minority
Demographic Aspects of friends			
Fraction Male Friends	0.46 (0.30)	0.46 (0.29)	0.44 (0.31)
Average Grade of Friends	9.73 (1.54)	9.66 (1.55)	9.87 (1.51)
Social Behavior of Friends			
Average Smoking of Friends	1.13 (1.37)	1.32 (1.46)	0.77 (1.08)
Average Drinking of Friends	1.20 (0.99)	1.23 (0.99)	1.15 (0.99)
Average Lying to Parents of Friends	2.05 (1.05)	2.06 (1.00)	2.04 (1.13)
Average School Skipping of Friends	0.58 (0.80)	0.54 (0.74)	0.66 (0.88)
Average Club Participation of Friends	0.80 (0.26)	0.83 (0.25)	0.76 (0.28)
Cognitive Aspects of Friends			
Average Parental Education of Friends	0.33 (0.30)	0.37 (0.30)	0.27 (0.29)
Average GPA of Friends	2.50 (0.80)	2.64 (0.75)	2.24 (0.81)
Average TV Watching Time of Friends	2.24 (0.69)	2.12 (0.62)	2.48 (0.74)
Average Homework Effort of Friends	3.15 (0.52)	3.15 (0.47)	3.14 (0.60)
Number of Observations	9,410	5,184	4,226

[1] Means in entries and standard deviations in parentheses.

[2] Smoking, drinking, lying to parents, and school skipping are coded as follows: each category is distinguished between "never," "once or twice," "once a month or less," "2 or 3 days a month," "once or twice a week," "3-5 days a week," "nearly everyday," coded as 1 to 7. TV watching time is distinguished between "none," "less than 1 hour," "1-2 hours," "3-4 hours," "more than 4 hours," coded as 1 to 5. Homework effort is distinguished between "I never try at all," "I don't try very hard," "I try hard enough," "I try very hard to do my best," coded as 1 to 4. Parental education is coded as 1 if either one of parents graduated from college, 0 otherwise.

The results of five different specifications are reported in Table 12. All specifications are the same as the specification in column 3 of Table 9. Column 1 shows the benchmark specification without controlling for any friend-related variables. Column 2 shows the specification that controls for gender and school grade of friends. It turns out that this addition hardly changes the coefficient of the proportion of minority friends. In the specification in column 3, I control for social behavior of friends, for example, smoking, drinking, club participation, etc. It turns out that social behavior of friends cannot explain the exposure effects as the coefficients on the proportion of minority friends do not significantly change. In the specification in column 4, I control for the cognitive aspects of friends, which are measured by parental education, GPA, time spent watching TV on school days, and efforts put into doing homework. Again, an addition of these variables hardly explain the exposure effect. Comparing the results between column 1 and column 5, an inclusion of friend-related variables barely change the coefficients of the proportion of minority friends. This implies that race is not just a proxy of other attributes of friends, but it generates effects on individual achievement *per se*.

4 Policy Simulations

The previous section shows that friendship segregation lowers educational achievement of minorities and increases the minority-white achievement gap, so it is important to evaluate to what extent integration policy is capable of eliminating friendship segregation and thus lowers the racial achievement gap. First, I estimate a discrete choice model to understand the determinants of friendship choices. Second, by using the estimates of the friendship model, I simulate the effects of integration policies on friendship decisions and thus test scores.

Table 12: Estimation Results on Standardized Vocabulary Test

	Dependent Variable: $AHPVT_{1995}$				
	(1)	(2)	(3)	(4)	(5)
Minority*PropMinorityFriends	-0.478***	-0.471***	-0.481***	-0.476***	-0.473***
	(0.092)	(0.091)	(0.091)	(0.095)	(0.092)
White*PropMinorityFriends	-0.047	-0.051	-0.058	-0.043	-0.055
	(0.077)	(0.077)	(0.077)	(0.077)	(0.078)
Demographic Aspects of Friends					
Proportion Male Friends		0.160***			0.162***
		(0.040)			(0.040)
Average Grade of Friends		-0.047*			-0.050*
		(0.028)			(0.030)
Social Behavior of Friends					
Avg. Smoking of Friends			-0.001		0.000
			(0.016)		(0.015)
Avg. Drinking of Friends			-0.013		-0.016
			(0.022)		(0.021)
Avg. Lying to Parents of Friends			0.034**		0.032*
			(0.016)		(0.016)
Avg. School Skipping of Friends			0.026		0.028
			(0.021)		(0.022)
Avg. Club Participation of Friends			0.158**		0.156*
			(0.075)		(0.085)
Cognitive Aspects of Friends					
Avg. Parental Education of Friends				0.114*	0.090
				(0.063)	(0.068)
Avg. GPA of Friends				0.007	0.006
				(0.024)	(0.023)
Avg. TV Watching Time of Friends				0.036*	0.027
				(0.020)	(0.021)
Avg. Homework Effort of Friends				-0.033	-0.014
				(0.035)	(0.041)

[1] Number of observations = 3,277. Robust standard errors clustered by peer groups in parentheses.
[2] All model specifications include the fraction of minority neighbors, number of friends, grade fixed effects, network fixed effects, individual covariates, parental covariates, and neighborhood covariates.
[3] *** Sig. at 1%; ** Sig. at 5%; * Sig. at 10%.

4.1 A Model of Friendship Decisions

My model of friendship decisions is based on the matching model of Hitsch et al. (2010).[9] Suppose friendship decisions are denoted by D_{ij} where $D_{ij} = 1$ if i identifies j as a friend and zero otherwise. A friendship is unilateral whenever D_{ij} is not necessarily equal to D_{ji}. In general, there are N students in a school and each student has to make $N-1$ binary friendship decisions such that D is an $N \times N$ matrix with diagonal elements of zero. Modeling friendship decisions is equivalent to endogenizing D_{ij}, $\forall\, ij$. Three assumptions are made to simplify the model estimation. First, it is assumed that $Pr(D_{ij}|D_{ik}) = Pr(D_{ij})$ for $j \neq k$. It means that individual i does not take the friendship decision toward k into account when he or she considers making friends with j. In other words, the individual characteristics of k do not provide any information for i to make a decision about making friends with j. Second, it is assumed that there are no strategic interactions between individuals, i.e., $Pr(D_{ij}|D_{ji}) = Pr(D_{ij})$ for $i \neq j$.[10] Third, it is assumed that all schoolmates of an individual constitute his or her choice set of potential friends. Based on the three assumptions, by using the discrete choice approach, the utility of i to choose j as a friend in school s is represented as follows:

$$U_{ij}^s = \overbrace{|Z_i - Z_j|'\Omega^s + Z_j'\Theta^s + \epsilon_{ij}}^{V_{ij}^s} + \gamma_i, \quad j = 1, ..., J_s$$

$$D_{ij} = \begin{cases} 1 & \text{if } V_{ij}^s > -\gamma_i \\ 0 & \text{if } V_{ij}^s \leq -\gamma_i \end{cases}$$

where i regards j as a friend if and only if the utility of friendship V_{ij}^s is larger than the individual threshold $-\gamma_i$, which can be interpreted as the reservation utility of making friends or the minimum value of a friendship. The threshold-crossing rule above is in line

[9] For the recent empirical literature on friendship formation, see Mayer and Puller (2008); Christakis, et al. (2010); Currarini, et al. (2010); Goldsmith-Pinkham and Imbens (2011); Conti, et al. (2012).

[10] It is reasonable to argue that adolescents are not sophisticated in forming friendships strategically on the ground that they have limited social experience.

with the theoretical result of a typical search model with nontransferable utility (e.g. Adachi, 2003).

With respect to the covariates of the empirical model, $|Z_i - Z_j|$ are observable differences in demographic characteristics between i and j. Z_j are observable characteristics of potential friend j. Ω^s and Θ^s are school-specific parameters, which capture heterogenous effects of making friends across schools. γ_i is individual i fixed effect which affects own decisions. On the one hand, γ_i captures the situation in which individual i is outgoing and sociable so that he or she has a high intrinsic value of friendships; on the other hand, $-\gamma_i$ is the individual reservation utility of making friends (outside option), in the sense that an outgoing person has a lower reservation utility of doing so. ϵ_{ij} is an $i.i.d$ random shock of match quality.[11] By assuming ϵ_{ij} follows the type one extreme value distribution, the probability of i to choose j as a friend is expressed as:

$$\pi_{ij} = Pr(D_{ij} = 1) = \frac{\exp\left(|Z_i - Z_j|'\Omega^s + Z_j'\Theta^s + \gamma_i\right)}{1 + \exp\left(|Z_i - Z_j|'\Omega^s + Z_j'\Theta^s + \gamma_i\right)}$$

And the likelihood function is derived as follows:

$$\mathcal{L} = \prod_{i=1}^{N} \prod_{j=1}^{J_i} \pi_{ij}^{D_{ij}} (1 - \pi_{ij})^{1 - D_{ij}} \tag{3}$$

Owing to multiple binary friend choices of each individual, γ_i can be identified. On average one school has 700 students, there are $700 \times 699 = 489,300$ friendship observations in a school. Therefore, estimating the model by pooling observations of more than 100 schools is computationally infeasible. To reduce computational burden, I estimate equation (3) separately by school. This approach does not affect the estimates of preference parameters because these parameters are heterogenous across schools; it also does not affect the estimates of individual fixed effects because individuals make friends within school.

[11] The value function of j to choose i as a friend is written as: $U_{ji}^s = |Z_j - Z_i|'\Omega^s + Z_i'\Theta^s + \gamma_j + \epsilon_{ji}$, where $D_{ji} = 1$ if $U_{ji}^s > 0$ and $D_{ji} = 0$ if $U_{ji}^s \leq 0$.

4.2 Determinants of Friendship Decisions

The model of friendship formation in equation (3) is estimated by maximum likelihood. The results are reported in Tables 13. I find that the parameters differ across schools. Because the estimates are school-specific, I only report the ones that will be used in the simulation.

Table 13: Determinants of Friendship Decisions

|Minority(i) - Minority(j)|	-2.688***	(0.169)
|Male(i) - Male(j)|	-0.185***	(0.033)
|Grade(i) - Grade(j)|	-0.720***	(0.040)
|ParentEduc(i) - ParentEduc(j)|	-0.116*	(0.061)
|BrokenFamily(i) - BrokenFamily(j)|	-0.102**	(0.041)
|Sibling(i) - Sibling(j)|	-0.051**	(0.026)
|Age(i) - Age(j)|	-0.224***	(0.032)
|Smoke(i)-Smoke(j)|	-0.101***	(0.019)
|Drink(i)-Drink(j)|	-0.074***	(0.022)
|GPA(i)-GPA(j)|	-0.163***	(0.037)
|TimeWatchTV(i)-TimeWatchTV(j)|	0.015	(0.021)
|HomeworkEffort(i)-HomeworkEffort(j)|	-0.067*	(0.038)
|ClubParticipation(i)-ClubParticipation(j)|	-0.288***	(0.073)
Potential Friend Covariates $Z(j)$	$\surd$	
Individual Fixed Effects $\gamma(i)$	$\surd$	

[1] Robust standard errors clustered by individuals in parentheses.
[2] The number of total observations is 332,029.

The results are consistent with the theory of homophily - individuals tend to make friends with others who share similar characteristics - all the estimated coefficients of differences in covariates are negative. In particular, the estimated coefficient of $|Minority_i - Minority_j|$ is negative and statistically significant at 1%, which means that there is racial sorting in friendships.

4.3 Integration Policy One

In this section, I simulate the effects of integration policy on friendship decisions. Specifically, I simulate the changes in the proportion of minority friends and the standardized test score of a minority male student if he is bused from a segregated school to an integrated one. The characteristics of schools in experiments are shown in Table 14. The home school of the student is a segregated school with a school minority ratio of 0.87, which is above the national average, 0.45. In experiments, he is bused to two different integrated schools. The two schools have the same school minority ratio, 0.52-0.53, but have a different number of students (school size).

Table 14: Characteristics of Schools in Experiments

	School Minority Ratio	Number of Students
Segregated School A	0.87	608
Integrated School B	0.53	619
Integrated School C	0.52	1,100

In the first experiment the student is bused from school A to school B. This experiment is to understand how the school minority ratio (school segregation) affects friendship decisions while holding the sizes of the home and receiving schools the same. Given that the minority ratios of the two receiving schools are the same, the second experiment further investigates the effects of school size on friendship decisions by moving the student from school A to School C. Model predictions of each experiment are simulated 10,000 times and the average of the simulated statistics are reported in Table 15.

The first row of Table 15 shows the friendship data for the minority male student. He has 6 friends and all of them are minorities, so his fraction of minority friends is 1. As shown in the second row, the friendship model can accurately predict the number of total friends

Table 15: Effects of Policy One on Friendship Decisions

	Total Friend	Minority Friend	Proportion Minority Friend
Data	6.00	6.00	1.00
Model Fit	6.04	5.93	0.98
Move to School B	5.88	5.17	0.88
Move to School C	7.90	6.86	0.87

[1] The results show the effects of an integration policy on the friendship decisions of a minority student by transferring him from a segregated school to two different integrated schools.
[2] 10,000 simulations are performed and the average of the simulated statistics are reported.

(6.04) and the proportion of minority friends (0.98). The third row reports the results of the first experiment. In this experiment, the student is moved to a school with a lower school minority ratio. In this situation, the student makes a slightly smaller total number of friends (5.88) and has a lower fraction of minority friends (0.88). In the second experiment, the student is moved to an integrated school that is larger. The finding is that the total number of friends substantially increases to 7.90 and the proportion of minority friends decreases to 0.87.

The above experimental results show that the policy is successful in integrating friendships by raising the proportion of opposite-race friends of the bused student. However, racial sorting offsets the effort of school integration, in the sense that the percentage decline in the proportion of minority friends (10%) is much smaller than the percentage decline in the proportion of minority schoolmates (40%) of the bused student under the policy. This can be explained by the estimates of the friendship model that students prefer to make friends with peers of the same race. If there is no racial sorting, i.e., the coefficient of $|Minority(i) - Minority(j)| = 0$ and the coefficient of $|Minority(j)| = 0$, the friendship minority ratio becomes 0.50 and is close to the school minority ratio 0.53.

I proceed to discuss the effects of the integration policy on the change in the student's standardized test score (AHPVT). The results are reported in Table 16. The change in the student's test score is positive under the policy, because he has a lower proportion of

minority friends in the receiving school. The gain in test score is 4.8%(5.3%) of a standard deviation if he is moved from school A to school B (School C). However, if there is no racial sorting, the test score gain is predicted to be 18%(20%) of a standard deviation. Therefore, friendship sorting on race offsets the potential achievement gains of the integration policy by about 75%. This finding is important because it shows that policymakers cannot completely manipulate friendship decisions to achieve a desired social objective, which provides additional evidence that policy's outcomes could be confounded by endogenous peer group formation (Carrell et al., 2012). My findings are related to the literature of within-school segregation, in which several papers find that minority and white students are segregated to different classes within schools, which offsets the integrative effort of across-school desegregation (Mickelson, 2001; Clotfelter, 2004; Card and Rothstein, 2007; Clotfelter et al., 2009). This paper contributes to this literature by showing that friendship segregation in schools is another mechanism through which the effects of school integration are partially offset. From a policy's point of view, the mian difference between classroom segregation and friendship segregation is that policymakers can completely eradicate the former but not the later.

Table 16: Effects of Policy One on Test Scores

	Gain in Test Score (Std. Dev.)
With Racial Sorting	
Move to School B	0.048
Move to School C	0.053
Without Racial Sorting	
Move to School B	0.181
Move to School C	0.197

[1] The results show the effects of an integration policy on the friendship decisions of a minority student by transferring him from a segregated school to two different integrated schools.

[2] 10,000 simulations are performed and the average of the simulated statistics are reported.

4.4 Integration Policy Two

The previous policy is to transfer one minority student from a segregated school to an integrated one, which does not affect the distributions of test scores and other variables. In this section, I simulate a policy with mass movements of many students. In particular, I integrate two segregated schools by swapping students between two schools so that two schools have the same school minority ratio. As shown in Table 17, before implementing the policy, the minority school is dominated by minority students with a school minority ratio of 0.97; the white school is dominated by white students with a school minority ratio of 0.07. By moving 258 minority students from the minority school to the white school and moving 258 white students from the white school to the minority school, two schools are racially integrated with a school minority ratio of 0.52.

Table 18 reports the simulation results. Before implementing the policy, the mean proportion of minority friends of minorities is 0.93 and that of whites is 0.09. The minority-white gap in the proportion of minority friends is 0.84, which indicates that friendship segregation is high. In addition, the standardized test scores of minorities is lower than that of whites by a standard deviation of 0.63. In exercising the policy of mass movements of students, the average proportion of minority friends of minorities decreases from 0.93 to 0.80 and that of whites increases from 0.09 to 0.41. Under this policy the minority-white test score gap declines from 0.63 to 0.55 of a standard deviation. This policy cannot completely integrating friendship as the minority-white gap in the proportion of minority friends is still positive, i.e. 0.39. The reason is that even though two schools are integrated, students have racial bias of making friends with others of the same race. Suppose there are no racial preferences, i.e., the coefficient of $|Minority(i) - Minority(j)| = 0$ and the coefficient of $|Minority(j)| = 0$, the minority-white gap in the proportion of minority friends becomes 0.03. It means that students' racial sorting partially offsets the effectiveness of the integration policy. In this counterfactual scenario, the minority-white test score gap further drops to 0.41 of a standard deviation, which implies that 67% of potential achievement gains are offset by students'

racial sorting.

Table 17: Characteristics of Schools in Experiments

	School Minority Ratio	Number of Students
Before Policy		
Minority School	0.97	574
White School	0.07	579
After Policy		
Minority School	0.52	574
White School	0.52	579

Table 18: Effects of Policy Two

	Prop. Minority Friend	Standardized Test Score
Before Policy		
Minority	0.93	-0.34
White	0.09	0.29
Minority-White Gap	0.84	-0.63
After Policy		
Minority	0.80	-0.28
White	0.41	0.27
Minority-White Gap	0.39	-0.55
After Policy + No Racial Sorting		
Minority	0.51	-0.14
White	0.48	0.27
Minority-White Gap	0.03	-0.41

4.5 Discussion

I proceed to relate my findings to the literature. A few papers (Boozer et al., 1992; Card and Krueger, 1992; Jackson, 2009) argue that minority schools are associated with poor school quality. Card and Rothstein (2007) find that students from low-income neighborhood are enrolled in minority schools. Apart from school quality and neighborhood income, this paper finds that friendship peer effects provide an alternative mechanism to understanding the

negative relationship between school segregation and student achievement. The mechanism is as follows: a shift from integrated to segregated schools exposes students to higher proportions of minority schoolmates. Given that students make friends in school, a higher exposure to minority schoolmates is associated with having a higher proportion of minority friends, which in turn lowers students' test scores through friendship peer effects. This mechanism is independent of school quality and neighborhood income, because school and neighborhood characteristics are controlled for in the estimation. Therefore, the inverse relationship between school segregation and student achievement also operates through friendship peer effects.

This paper helps to explain the finding of Card and Rothstein (2007), which find that there are no independent effects of school segregation conditional on neighborhood segregation. Given that friends are a subset of students' schoolmates, I find that effects of school segregation actually exist, but they operate at the friendship level. Suppose there are two levels of school peer effects, one is measured at the school level, i.e., exposure to schoolmates; the other one is measured as the individual level, i.e., exposure to friends. To the extent that only closely connected peers (friends) can affect individual achievement, measuring peers at the school level, i.e., schoolmates, may fail to identify school peer effects. This paper precisely measures peers at the individual level using network data and this key feature distinguishes it from previous studies that broadly measure peers at the classroom or school level.

5 Robustness Checks

My primary analysis defines friendships are unilateral in the sense that individual i chooses j as a friend, but it may not be the case that j also chooses i as a friend. To check the results are not sensitive to this definition, I also measure the proportion of minority friends based on an alternative definition under which friendships are mutual. The results are reported in Table 19. The qualitative results are robust to different friendship definitions. The magni-

tude of the negative effect is slightly smaller when the mutual friendship definition is used. One possible explanation is that if friendships are mutual, it fails to capture a part of peer effects when i is unilaterally influenced by j.

Table 19: Summary Results on Educational Achievement (Std. Dev.)

	AHPVT_{1995}	AHPVT_{2002}	English GPA_{1995}	Math GPA_{1995}
Unilateral Friendships				
Minority*PropMinorityFriend	-0.478***	-0.362***	-0.100	-0.191**
	(0.092)	(0.083)	(0.075)	(0.096)
White*PropMinorityFriend	-0.047	-0.064	-0.035	-0.253**
	(0.077)	(0.096)	(0.075)	(0.109)
Mutual Friendships				
Minority*PropMinorityFriend	-0.415***	-0.347***	-0.056	-0.153*
	(0.094)	(0.079)	(0.067)	(0.087)
White*PropMinorityFriend	-0.077	-0.045	0.108	-0.121
	(0.097)	(0.086)	(0.066)	(0.108)

[1] All model specifications include grade fixed effects, peer group fixed effects, individual covariates, parental covariates, classroom covariates, and neighborhood covariates.
[2] *** Sig. at 1%; ** Sig. at 5%; * Sig. at 10%.
[3] Robust standard errors clustered by peer groups in parentheses.

My main model specification uses the lagged test score as a regressor to control for unobserved individual heterogeneity. This specification fails if individual unobservables are different between 1994 and 1995. An alternative specification, which is illustrated in Figure 3, is to use test score in 2002, A^{2002}, as a dependent variable and test score in 1995, A^{1995}, as a control variable. This specification can control for all individual unobservables that affect the proportion of minority friends in 1995, $PropMinorityFriend^{1995}$. However, because A^{1995} and $PropMinorityFriend^{1995}$ are contemporaneous, it is possible that there exists an indirect effect of $PropMinorityFriend^{1995}$ on A^{2002} through A^{1995}. Therefore, controlling for A^{1995} eliminate both selection bias as well as indirect exposure effects.

Column 1 of Table 20 shows the results in the specification without controlling for past or contemporary test score. In the specification in column 2, I use overall GPA_{1994} as a

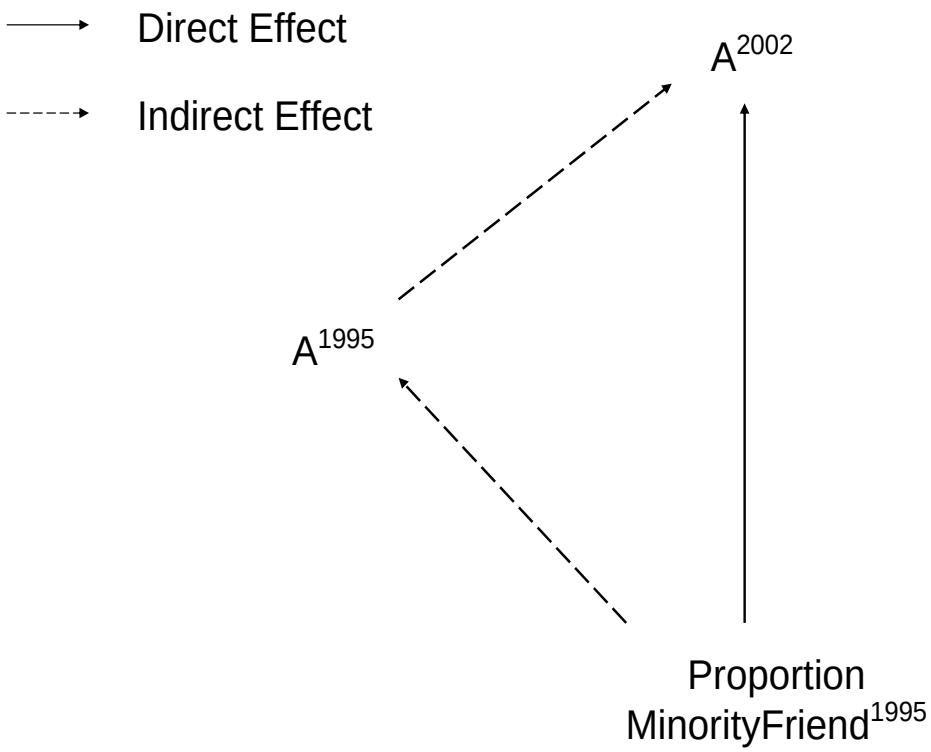

Figure 3: Direct and Indirect Exposure Effects

Table 20: Estimation Results on Vocabulary Test

	Dependent Variable: $AHPVT_{2002}$		
	(1)	(2)	(3)
A. Minority*PropMinorityFriends$_{1995}$	-0.394***	-0.362***	-0.176**
	(0.085)	(0.083)	(0.072)
B. White*PropMinorityFriends$_{1995}$	-0.098	-0.064	-0.063
	(0.100)	(0.096)	(0.094)
Overall GPA$_{1994}$		0.172***	
		(0.020)	
$AHPVT_{1995}$			0.436***
			(0.034)
Grade Fixed Effects	√	√	√
Peer Group Fixed Effects	√	√	√
Classroom Covariates	√	√	√
Individual Covariates	√	√	√
Parental Covariates	√	√	√
Neighborhood Covariates	√	√	√

[1] Number of observations = 3,186.
[2] *** Sig. at 1%; ** Sig. at 5%; * Sig. at 10%.
[3] Robust standard errors clustered by peer groups in parentheses.

regressor. It shows that the estimates of proportion of minority friends decrease for both minorities and whites. In the specification in column 3, I control for $AHPVT_{1995}$ and find that the coefficient of the proportion of minority friends of whites does not change. It means that individual unobservables of whites do not change between 1994 and 1995 and whites do not face contemporary effects from exposure to minority friends. The latter is confirmed by the estimate in row B and column 1 of Table 10. If the individual unobservables do not change between 1994 and 1995 for whites, then it is reasonable to assume that the individual unobservables do not change for minorities either. Comparing the results between column 2 and column 3, the estimate of the proportion of minority friends of minorities further decreases, it is because controlling for $AHPVT_{1995}$ eliminate the indirect contemporary exposure effect as discussed above. This is confirmed by the estimate in row A and column 1 of Table 10. In summary, this sensitivity analysis provides convincing evidence that the estimates of exposure effects given in the primary specification in equation (2) are free from selection bias.

6 Concluding Remarks

This paper makes three contributions to the literature on racial segregation. First, it shows that friendship segregation lowers educational achievement of minorities and widens the minority-white achievement gap. Second, it finds that students' racial sorting substantially offsets the potential gains of school integration policy. Last, this paper finds that the inverse relationship between school minority ratio and student achievement also operates through friendship peer effects.

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