Why are schools segregated? Evidence from the secondary-school match in Amsterdam

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Abstract

We use rich data from the secondary-school match in Amsterdam to nonparametrically decompose school segregation by ethnicity and by household income into five additive sources: i) ability tracking, ii) noise, iii) residential segregation, iv) preference heterogeneity, and v) capacity constraints. Important features of the Amsterdam school district are its diverse population, that students can freely choose any school at their ability level, that school density is high and that private schools are absent. We find that school segregation is mainly driven by ability tracking and students from different groups having different preferences. Residential segregation, capacity constraints and noise play only a minor role. Policy simulations indicate that even hard quota reduce segregation by only a modest amount, while it is costly in terms of student welfare. *JEL*-codes: I21, I24, I28.

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1 Introduction

Many cities nowadays have populations that are diverse by ethnicity and by social background. This diversity is often not mirrored by the composition of schools, which tend to be segregated. School segregation is considered to be undesirable because it may increase achievement gaps between students from different backgrounds (Card and Rothstein, 2007; Billings et al., 2014), and may even have adverse consequences for inequality and integration of minorities more broadly (Stoica and Flache, 2014; Burgess and Platt, 2018; Billings et al., 2019).

To design policies that can reduce school segregation, knowledge about its driving forces is indispensable. While there is an understanding that factors such as residential segregation, heterogeneity of preferences (Stoica and Flache, 2014) and the school assignment mechanism (Calsamiglia et al., 2017) play a role, the contribution of different factors to total school segregation has until now not been quantified.

This paper uses rich data from the secondary-school match in the city of Amsterdam to quantify the contributions of five additive sources of school segregation. In addition to residential segregation, preference heterogeneity and the school assignment mechanism, we distinguish ability tracking and noise due to small school$\times$track size, as sources of school segregation. We merged the data on the school match to register data. The resulting dataset provides information about students' ethnicity and social background, their ability track, their preferences for schools, distances between students' homes and schools, and the actual assignment to schools. With this data we can determine the importance of each of the five sources. A feature of our framework is that we do not need to make any parametric or functional form assumption but can rely on nonparametric simulation techniques.

Amsterdam provides a particularly interesting setting to study the sources of school segregation. Its population is diverse. Slightly over 50% of the school-aged population have a non-Western background (first, second or third generation immigrant). Half of them originate from Morocco or Turkey and thus with a different cultural and religious background than the native population.[1] The population is also diverse in social background.

Amsterdam further forms an interesting setting because students are free to choose the school they wish. There are no catchment areas and tuition fees are low. The city is relatively small and school density is high such that students have a considerable number of schools where they can realistically choose from. This creates a setting where the role of residential segregation is potentially small. Finally, almost all stu-

[1] A third large group are students with a Surinamese background (9%).

dents living in Amsterdam are covered by the same publicly-funded school system. The market share of private schools is less than one percent and these schools mainly serve the children of expats in international schools. Attending a school outside the district, although possible in theory, is a rare event.[2] This makes our study different from studies that analyze segregation in public schools systems in settings where a large share of students are not included because they enroll in private schools.

For the analysis of segregation in secondary schools in Amsterdam, ability tracking is a relevant feature of the Dutch education system. When students move from primary school to secondary school (around the age of 12), they are assigned to one of four tracks (vocational-elementary, vocational-theory, college, university) based on the decision of their primary-school teacher. This decision is informed by a nationwide testing system that follows students from age 5 onwards. Students cannot choose a school that does not offer their assigned track. Early tracking is common in continental Europe. It occurs in countries like Austria, Germany, Hungary and Switzerland. The main argument behind tracking is the belief that homogeneous classrooms permit better targeted instruction and that this improves learning outcomes of all students (cf. Hanushek and Woessmann, 2006). Other countries, including the US, also have ability tracking in the form of "gifted and talented" classes and other selective programs. Minority students are typically underrepresented in such classes and programs.

Starting in 2015, the secondary schools in Amsterdam use the student-proposing deferred acceptance (DA) mechanism to assign students to secondary schools.[3] As part of the process, each student submits a rank-ordered list (ROL) of preferences for schools. The length of the ROL is unrestricted and there is no default school in case a student does not submit a list. The mechanism is strategy proof so that it is in each student's best interest to submit a list that reports her true preferences. With the introduction of the new mechanism, this property is clearly, explicitly and repeatedly communicated to parents and students.[4]

We can identify the contribution of the five sources of school segregation using information on each student's ethnicity (household income), ability track, ROL, home address and actual placement. The contribution of ability tracking results from assign-

[2]Of the more than 18,000 students in our dataset living in Amsterdam, only 353 (less than 2%) opted for a school outside of the city.

[3]Before 2015 the schools used a version of the adaptive Boston mechanism; see De Haan et al. (2018) for a comparison of the old and the new mechanisms.

[4]Truth telling is actually a *weakly* dominant strategy, meaning that there may exist other strategies that lead to the same assignment. An example is that a student does not have to rank a school for which the admission probability equals zero. We discuss this issue further in Section 6.

ing students to tracks (as if each track is just one school). The contribution of noise follows from randomly assigning students to schools within their track. To quantify the contribution of residential segregation we construct a counterfactual where we replace the top-ranked schools on the ROL's of non-Western (low-income) students by the top-ranked schools on the ROL's of native (high-income) students who live in the same neighborhood.[5] Residential segregation then plays a role to the extent that native (high-income) students living in neighborhoods with high fractions of non-Western (low-income) students choose other schools than native (high-income) students living in neighborhoods with low fractions of non-Western (low-income) students. The difference between segregation based on the counterfactual top-ranked schools of non-Western (low-income) students and segregation based on the actual top-ranked schools of non-Western (low-income) students captures the contribution of preference heterogeneity. Finally, the difference between segregation based on students' top-ranked schools and segregation based on their actual placement is due to schools' capacity constraints, priority rules and the school assignment mechanism.

Our main finding is that of the total segregation by ethnicity of 0.23 (Mutual Information Index M; 0.48 when measured by the Dissimilarity Index D), 42% is due to ability tracking, 46% to preference heterogeneity and only 7% to residential segregation. Noise and capacity constraints play (almost) no role for school segregation by ethnicity. Segregation by household income equals 0.14 (M; $D = 0.37$), 61% of which can be attributed to ability tracking, 31% to preference heterogeneity, and 9% to noise. Residential segregation and capacity constraints play no role for school segregation by household income. The modest contribution of residential segregation to school segregation is particularly interesting in light of the fact that residential segregation itself is substantial.

To shed light on the heterogeneity in school preferences between students from different backgrounds, we present estimates of students' preferences for school attributes and willingness to travel. This reveals that non-Western (low-income) students value a higher quality of graduating students and of incoming students less than native (high-income) students. Students from each group are attracted to schools with a larger share of students from their own group. While this paper is not the first to document heterogeneity in school preferences between students from different backgrounds , we are the first to connect it to school segregation and quantify its importance for that (Hastings et al., 2009; Abdulkadiroğlu et al., 2017a).

In the final part of the paper, we simulate the effects of different policies aimed at

[5] We use the term "native" as shorthand for native Dutch and immigrants from a Western country.

reducing segregation. First, we assess the effects of two forms of affirmative action. In one form of affirmative action, a certain number of places in a school can only be assigned to students from a designated group (minority quota). Places that are not taken by students from that group remain empty. In the other form of affirmative action, disadvantaged students have priority in a school as long as their fraction in the school is below a certain fraction (minority reserves). Reserves only reduce segregation by a marginal amount. Quota have a more meaningful impact on segregation but this comes at the cost of reducing student welfare.

Second, we simulate the effects of stricter ability tracking. Instead of letting teachers decide on track assignment, we make the score on a nationwide exit test from primary school decisive. This policy reduces segregation by a small amount because some of the native (high-income) students can no longer apply to an elite school and are assigned to a comprehensive school. Third, we assess the effects on segregation of replacing the DA mechanism by the Boston (immediate acceptance) mechanism. In contrast to claims in the literature, this replacement does not affect school segregation. We finally assess whether the relocation of some popular schools from the city center to neighborhoods with high shares of non-Western (low-income) students, reduces segregation. The results show that while the relocated schools become more mixed, not much changes overall because other schools become somewhat more segregated.

This paper contributes to a large and expanding literature on school segregation. This literature falls into three broad categories. First, studies that address the properties of different segregation measures (Frankel and Volij, 2011; Allen et al., 2015; Yamaguchi, 2017). We build on this branch of the literature at the end of Section 3 where we introduce the school segregation measures that we use in this study.

Second, studies that present descriptive analyses of differences in segregation between cities (Ladd et al., 2011), changes in segregation over time (Owens et al., 2016; Reardon et al., 2000) or both (Card et al., 2008). The decomposition analyses that these studies conduct are quite different from ours. Reardon et al. (2000) for example, decompose multiracial school segregation in metropolitan areas into segregation between various combinations of racial groups (white vs minority and black vs hispanic vs asian) and geographical units (central city vs suburbs and within and between districts). The results of such a decomposition are informative but are unrelated to the sources of segregation that we uncover.

Third, studies that examine how a specific intervention influences school segregation (Böhlmark et al., 2016; Baum-Snow and Lutz, 2011; Kessel and Olme, 2018a,b; Söderström and Uusitalo, 2010). While we also address effects of specific interventions, we do so in a framework that separates all the contributing factors. This provides a better understanding of the (in)effectiveness of different interventions. Another way to characterize our approach is that we are after the causes of an effect (segregation), whereas the aforementioned studies are after the effect of a cause (cf. Gelman and Imbens, 2013).

Our analysis of preference heterogeneity is related to the expanding literature on the estimation of students' school preferences. An important contribution to this literature is the study by Hastings et al. (2009), who find that non-disadvantaged parents are more likely to choose better schools, while disadvantaged families must trade off preferences for better schools against preferences for a predominantly minority school. More recent contributions include: Burgess et al. (2015), Glazerman and Dotter (2017), Pathak and Shi (2017), Abdulkadiroğlu et al. (2017b), Agarwal and Somaini (2018) and Ruijs and Oosterbeek (2019).

The rest of this paper is organized as follows. The next section provides institutional details of secondary school choice in Amsterdam. Section 3 explains in more detail the five sources of school segregation and how we quantify these. Section 4 describes the data. Section 5 presents and discusses the main results. Section 6 analyzes students' preferences in greater detail. Section 7 reports the results from the four policy simulations. Section 8 summarizes and concludes.

2 Context

This section describes the context of our study, the choice for secondary schools in the city of Amsterdam. First, it explains that ability tracking occurs at entry in secondary school and that (almost) all schools are publicly funded. Next, it describes how students in Amsterdam are assigned to secondary schools. Information about the composition of the student population and the supply of school is given in Section 4 where we describe the data.

2.1 Secondary education in the Netherlands

When students in the Netherlands make the transition from primary school to secondary school, they are around 12 years old. At this stage, students are assigned to tracks which differ in how academically demanding they are. We distinguish four tracks: vocational - elementary, vocational - theory, college and university. The two vocational tracks last four years and give access to subsequent vocational programs. The college track takes five years and gives access to professional colleges (applied universities). The university track takes six years and gives access to university education.

Which track a student enters is determined by the primary-school teacher.[6,7] Students can freely choose among the schools that offer their assigned track. Schools do not accept students in a track above their assigned level. Schools can offer varying combinations of tracks. Some schools specialize and offer only one track. Other schools offer two or more adjacent tracks. Below we report how many schools in Amsterdam offer which combinations of tracks.

Because some schools offer multiple tracks, we can distinguish between segregation at the school level and segregation at the school×track level. We refer to latter type of segregation as class segregation since students who are in the same track in the same school are potentially in the same class. We report results for both types.

Virtually all schools in the Netherlands are publicly funded and there are no substantial tuition fees. Schools with a large share of disadvantaged students receive extra funding from the government. Consequently schools with a large fraction of disadvantaged students do not have fewer resources than other schools. All schools prepare their students for nationwide exit exams at the end of secondary education. The Dutch Education Inspectorate assesses the quality of schools and publishes its findings on the Internet. Schools that receive the lowest quality score for three years in a row are closed.

2.2 School assignment in Amsterdam

Since 2015 secondary schools in Amsterdam use the student-proposing DA mechanism to assign students to schools (Gale and Shapley, 1962). An attractive feature of this mechanism is that truth telling is a weakly dominant strategy for students. Under this system students submit a rank-ordered preference list (ROL) of schools. The length of this list can be as long as the number of available schools. There are no de-

[6]Primary-school teachers actually assign their student to one out of eight different levels: i) vocational basic, ii) vocational basic/cadre, iii) vocational cadre, iv) vocational theory, v) vocational theory/college, vi) college, vii) college/university, viii) university. To keep the presentation conceivable we have merged levels i) to iii) into vocational elementary, levels iv) and v) into vocational theory and levels vi) and vii) into college. In practice students with any of the mixed levels ii), v) and vii) can only choose from schools that offer the lowest of the two tracks that form the mixed levels.

[7]In addition to the decision by the teacher there is a nationwide exit test. Until 2014, the results of this test were available when the teacher took her decision and before students applied to schools. Track placement was based on the teacher's decision and the test result. Since 2015, the test is administered later in the year after the teacher already took her decision and after the school assignment procedure. Students that perform better on the test than corresponds to the teacher's decision can be upgraded. Downgrading of students who perform (much) worse on the test than corresponds to the teacher's decision, is not possible.

fault schools for students who submit a short list and are not placed in a school on their list. Because of the strategy proofness of the system, it is optimal for students to submit a list according to their true preferences. This property is emphasized in the communication to parents and students.

There are only a few priority rules, based on older siblings in the school, a parent employed by the school or a specific pedagogical relationship between primary and secondary schools (Montessori or Dalton). Ties between students in the same priority group are broken by lottery numbers. The number of students with priority is typically quite small, so that tie breaking is only relevant for students without priority. In 2015 each student had a different lottery number for each school (as if each school conducted its own lottery; multiple tie breaking). After 2015, each student received the same lottery number for all schools (single tie breaking).

3 Framework

Our starting point is the observation that the level of school segregation follows immediately from the assignment of students to schools. School assignment in Amsterdam is the result of a procedure in which students submit their ROL's given their track level, and schools submit their capacities and priority rules. The DA mechanism matches supply and demand. This procedure comprises the five sources of school segregation that we distinguish. These sources are:

- ability tracking;
- noise;
- residential segregation;
- preference heterogeneity;
- capacity constraints.

This section describes the counterfactuals assignments we construct to quantify the contribution to observed school segregation of each of these five sources. A feature of the decomposition method we develop is that we do not need to make any parametric or functional form assumption.[8]

[8] An alternative (parametric) approach can be based on estimates of demand models as presented in Section 6. Different counterfactual assignments can then be constructed by imposing restrictions on certain parameters.

Ability tracking

Due to ability tracking, students can only choose from the schools that offer the track level to which they are assigned. This leads to school segregation to the extent that students from different ethnic/social groups are differentially assigned to different tracks. The value of the school segregation index (SI) resulting from this source is equal to the level of segregation at the track level: $SI(\text{Track})$.

Although segregation due to ability tracking is specific to a school system with early ability tracking, we notice that other school systems impose other restrictions on students' choice sets that potentially affect school segregation. Examples include restrictions due to commuting zones, restricted access to religious schools and private schools being unaffordable for many.

The four remaining sources of school segregation are all measured within tracks, and can be aggregated over tracks.

Noise

The first source of within-track segregation we need to distinguish is noise due to the relatively small school×track size. Even if students are randomly assigned to schools within their track, not all school will have the exact same share of disadvantaged students. This is akin to sampling variation (cf. Allen et al., 2015). This source is more prevalent if average school size is small and if the fraction of disadvantaged students is close to zero or one.

To calculate the contribution of this source to total segregation, we construct the counterfactual in which students are randomly assigned to schools within their track. We repeat this 100 times. We refer to the average of the resulting levels of within-track segregation as $SI_t(s^{\text{random}})$. Subscript t indicates the track within which segregation is measured and s^{random} indicates that within their track students are randomly assigned to schools.

Residential segregation

The second source of within-track segregation is residential segregation. This source abstracts from differences in school preferences between students from different ethnic/social groups and solely captures that students from different groups are concentrated in different neighborhoods.[9]

[9]Our approach allows for between-neighborhood heterogeneity in preferences.

To measure school segregation due to residential segregation we construct a counterfactual where the ROL of each disadvantaged student is replaced by a random draw from the ROL's of non-disadvantaged students who live in the same neighborhood (4-digit postal code) and are assigned to the same choice set. We repeat the replacement of ROL's of disadvantaged students 100 times. We refer to the average of the resulting levels of within-track segregation as $SI_t(s_1^{\text{ndn}})$. s_1^{ndn} indicates that disadvantaged students are assigned to the top choice (s_1) from the ROL of their non-disadvantaged neighbor (ndn).

This procedure results in a large role of residential segregation if non-disadvantaged students living in neighborhoods with high fractions of disadvantaged students have other ROL's than non-disadvantaged students living in neighborhoods with low fractions of disadvantaged students.

Preference heterogeneity

The next source of within-track segregation is heterogeneity in preferences for schools between students from different groups. To measure the contribution of this source of segregation we construct the counterfactual in which all students are assigned to their top choices. We refer to the resulting segregation as $SI_t(s_1)$. The difference between this level of segregation and segregation based on residential segregation ($SI_t(s_1^{\text{ndn}})$) captures differences in school preferences between disadvantaged and non-disadvantaged students living in the same neighborhoods.

Capacity constraints

The final source of within-track segregation is that schools may have capacity constraints. How capacity constraints affect school segregation depends on the severity of these constraints, on possible priority rules that schools use and on the school assignment mechanism. It also depends on the schools that students rank below their top choices. It has been hypothesized that a manipulable mechanism such as the Boston mechanism results in more segregation than a truth-telling mechanism such as DA (Calsamiglia et al., 2017).[10] To measure the contribution of capacity constraints to segregation we compare segregation based on observed placement, $SI_t(s^{\text{observed}})$, and segregation in the counterfactual scenario where all students are assigned to their most-preferred schools, $SI_t(s_1)$.

[10] In Section 7 we assess this hypothesis by comparing school segregation in Amsterdam in 2014, which is the last year that the Boston mechanism was in place, and later years in which the DA mechanism is used.

Segregation measures

To separate segregation due to ability tracking from the within-track sources of segregation, it is convenient to use a segregation measure that satisfies the strong school decomposability property. With this property, segregation within tracks can be aggregated by weighing with the shares of students within tracks. The mutual information index (M) has this property; see Frankel and Volij (2011). The expression for M is $h(S) - \sum_{s=1}^{S} \pi_s h(s)$, where $h(S)$ is the entropy of the school district S, $h(s)$ is the entropy of school s and π_s is the share of students in school s. Entropy of a unit equals $h = q \log_2(1/q) + (1-q)\log_2(1/(1-q))$, with q the share of disadvantaged students in the unit.

Decomposing M into between-track segregation and within-track segregation requires that units do not belong to multiple tracks. This requirement is fulfilled at the class (tracks within schools) level but not at the school level. For the main analysis, we will therefore report results using the mutual information index and focus on segregation at the class level.

We will also report results using the dissimilarity index (D), and at the school level. The expression for D is $\frac{1}{2}\sum_{i=1}^{n}\left|\frac{P_{Li}}{P_L} - \frac{P_{Hi}}{P_H}\right|$, where P_{Li} is the number of disadvantaged students in school (class) i, P_{Hi} is the number of non-disadvantaged students in school (class) i, P_L is the total number of disadvantaged students, P_H is the total number of non-disadvantaged students, and n is the number of schools (classes).

D and M both range from zero (no segregation) to one (complete segregation). The value of D can be interpreted as the proportion of disadvantaged students who would need to move to another school to obtain perfect integration, relative to the proportion that would need to move to another school under a status quo of perfect segregation (Graham, 2018). The value of M does not have such an intuitive interpretation.

To summarize:

- Total segregation at the school×track level (M(Class)) is the sum of between-track segregation (M(Track)) and the weighted average of within-track segregation:

$$M(\text{Class}) = \underbrace{M(\text{Track})}_{\text{between track}} + \sum_{t=1}^{T} w_t \cdot \underbrace{M_t(\text{Class})}_{\text{within track}},$$

  where the weights w_t equal to the shares of students assigned to each track.
- Within-track segregation due to noise equals $M_t(s^{\text{random}})$
- Within-track segregation due to residential sorting equals: $M_t(s_1^{\text{ndn}}) - M_t(s^{\text{random}})$

- Within-track segregation due to preference heterogeneity equals $M_t(s_1) - M_t(s_1^{\text{ndn}})$.
- Finally, within-track segregation due to capacity constraints equals $M_t(s^{\text{observed}}) - M_t(s_1)$.

4 Data and descriptive statistics

4.1 Data sources

The data come from two sources: the student register of the city of Amsterdam and register data from Statistics Netherlands. The two registers are merged at the student level.

The student register provides data of all students who participated in the secondary-school match in Amsterdam in the years 2015, 2016 and 2017. For each student, it has information about assigned track, the ROL, actual placement, gender, the score on the nationwide exit test from primary school and home address. Home addresses combined with school locations, result in distances between each student's home address and all schools in the assigned track. We added school-level information of exam scores of students graduating in the previous year. This information is publicly available from the websites of secondary schools.

The register data have information about the country of origin of (grand)parents. Based on this, an indicator is constructed for students who have a non-Western background. This is defined as someone who has at least one (grand)parent born in Turkey, Africa, Latin America or Asia (except for Japan and Indonesia). The register data also contain information about parents' income. Low-income students come from families with household income below the national median (in the year of observation).

The combined data allows us to measure the ethnic and social composition of students in each track in each school. This is the basis for the measurement of school segregation. We also construct for each class (tracks within schools) the one-year lagged values of the share of students with a non-Western background, the share of students from low-income families, and the average test score on the nation-wide exit test from primary school. In our analysis of school demand we examine how these variables are related to students' school preferences.

4.2 Descriptive statistics

This subsection presents descriptive statistics of students and schools in Amsterdam. The student population is diverse, and school density is high at each track level. Each student has at least several schools to choose from. We also present descriptive information about school segregation by ethnic and social background.

Students

Table 1 presents summary statistics of student characteristics by track. According to the first row, the share of students with a non-Western background is unequally divided over tracks. Where the overall share of these students is 54%, it ranges from 77% in the vocational-elementary track to 29% in the university track. The next three rows show the shares for the three non-Western groups with backgrounds from Turkey (8%), Morocco (20%) and Suriname (9%).[11] For each of these groups, the share is three to four times higher in the vocational-elementary track than in the university track.

The rows on household income indicate a steep increase in household income from low tracks to high tracks. The average percentile of household income of students in the vocational-elementary track is close to 25 and increases to over 60 for students in the university track.

The next row shows that the share of girls is very similar across tracks. The average test score on the exit test from primary school increases steeply from low to high tracks. The difference between the lowest and highest tracks equals 2.4 standard deviations. Test score information is not available for 11% of the students. This fraction is similar across tracks.

The average length of the ROL's is slightly over seven. This average increases from the vocational-elementary track to the university track. In Section 6 we analyze the school rankings of students in detail.

The next part of the table looks at the interaction of ethnic background and household income. These two characteristics are positively correlated. Two thirds of the students with a non-Western background come from a low-income family. This is only the case for a bit more than 25% of the Western students.

The bottom rows report the numbers of students who: i) come from a primary school in Amsterdam, ii) took part in the Amsterdam secondary-school match, and iii) whose school register information can be matched with data from Statistics Netherlands. Twenty-nine percent of the students enroll in the college track and 26% in the university track. The remaining students are divided over the two vocational tracks. The shares of the four tracks do not vary much across years.

[11] The remaining 17% of students with a non-Western background come from 111 different countries, including Ghana (2.3%), Egypt (1.8%), Nederlands Antilles (1.4%), and Pakistan (1%).

Table 1: Summary statistics: student characteristics

	Vocational (elementary)	Vocational (theory)	College	University	Total
Non-western student	0.77	0.67	0.48	0.29	0.54
	(0.42)	(0.47)	(0.50)	(0.46)	(0.50)
Turkey	0.13	0.11	0.06	0.03	0.08
	(0.33)	(0.32)	(0.24)	(0.16)	(0.27)
Morocco	0.29	0.27	0.19	0.09	0.20
	(0.45)	(0.44)	(0.39)	(0.29)	(0.40)
Suriname	0.15	0.10	0.06	0.04	0.09
	(0.36)	(0.31)	(0.24)	(0.19)	(0.28)
Household income (percentile)	24.92	34.28	46.75	60.66	42.92
	(20.45)	(27.34)	(32.15)	(32.84)	(31.98)
Household income (missing)	0.04	0.03	0.03	0.02	0.03
	(0.21)	(0.17)	(0.16)	(0.14)	(0.17)
Low-income family	0.73	0.60	0.43	0.27	0.49
	(0.45)	(0.49)	(0.50)	(0.45)	(0.50)
Female	0.50	0.52	0.51	0.50	0.51
	(0.50)	(0.50)	(0.50)	(0.50)	(0.50)
Test score	-1.36	-0.36	0.36	1.04	0.00
	(0.71)	(0.52)	(0.44)	(0.34)	(1.00)
Test score (missing)	0.13	0.10	0.10	0.12	0.11
	(0.33)	(0.31)	(0.30)	(0.33)	(0.31)
Length of ROL	4.10	5.67	8.28	10.28	7.30
	(1.82)	(2.38)	(3.46)	(3.97)	(3.88)
Non-western – low-income	0.59	0.46	0.31	0.15	0.36
	(0.49)	(0.50)	(0.46)	(0.36)	(0.48)
Non-western – high-income	0.19	0.21	0.17	0.14	0.17
	(0.39)	(0.41)	(0.38)	(0.35)	(0.38)
Western – low-income	0.14	0.14	0.13	0.12	0.13
	(0.35)	(0.34)	(0.33)	(0.32)	(0.34)
Western – high-income	0.09	0.19	0.40	0.59	0.33
	(0.28)	(0.40)	(0.49)	(0.49)	(0.47)
Students in 2015	1,408	1,526	1,826	1,646	6,406
Students in 2016	1,482	1,466	1,783	1,578	6,309
Students in 2017	1,192	1,393	1,870	1,748	6,203
Total	4,082	4,385	5,479	4,972	18,918

Notes: The table reports mean values of student characteristics by track, with standard deviations in parentheses. Non-Western student equals one if the student has at least one parent or grandparent that was born in Turkey, Africa, Latin America or Asia (with the exception of Japan and Indonesia), zero otherwise. Household income is the mean of the percentile rank in the household income distribution. Low-income family is an indicator equal to one if family income is below the median, zero otherwise. Test score is the standardized score on the nationwide exit test from primary school. Length of ROL is the number of schools that a student included on the rank-ordered preference list. The bottom panel reports numbers of students by year and track.

Schools

Table 2 shows by year, how many schools offer which combinations of tracks. For example, in the first column we read that in 2015, 22 schools (10+7+2+3) offered the vocational-elementary track. Ten of these schools only offered this track. Seven schools combine this track with the vocational-theory track. Two schools offer it together with the vocational-theory track and the college track. And three schools offer all four tracks. In contrast, of the 25 schools (2+3+4+8+1+7) that offered the college track in 2015, only one school offered only that track. A takeaway from this table is that there are only a few schools that offer the entire range of tracks.

Table 2: Schools' track supply

	2015	2016	2017
Vocational (elementary)	10	7	6
Vocational (elementary – theory)	7	10	8
Vocational (elementary) – College	2	1	1
Vocational (elementary) – University	3	3	4
Vocational (theory)	5	6	4
Vocational (theory) – College	4	3	3
Vocational (theory) – University	8	9	11
College	1	1	2
College – University	7	8	8
University	7	7	7
Total	54	55	54

Notes: The table presents the number of schools offering specific combinations of tracks (rows) by year (columns).

Table 3 presents summary statistics of classes (tracks within schools), overall and by track. The patterns for test scores, share of students with a non-Western background and share of low-income students mirror the patterns from Table 1. The difference is that the statistics in this table are averaged over the averages or shares of classes, while the statistics in Table 1 are averaged over students. The standard deviations indicate that not only between but also within tracks there is a fair amount of variation in the composition of classes in terms of ethnicity, social background and test scores. The table also reports the average exam score of students graduating from secondary school in the year prior to the year in which the students in our sample apply for secondary schools. Exams are track specific and graded on a scale from 1 to 10, where 5.5 is the passing score.

Finally, the table reports average enrollment measured at the track level. Average enrollment is 65 students. The standard deviation of 40 indicates quite some variation across classes. The minimum in our data is 5, the maximum 174.

Table 3: Summary statistics: class characteristics

	Vocational (elementary)	Vocational (theory)	College	University	Total
Share non-Western student (t-1)	0.75	0.65	0.51	0.37	0.56
	(0.17)	(0.28)	(0.27)	(0.28)	(0.29)
Share low-income (t-1)	0.74	0.58	0.47	0.36	0.53
	(0.11)	(0.22)	(0.18)	(0.24)	(0.24)
Average test score (t-1)	-1.39	-0.37	0.38	1.00	-0.03
	(0.26)	(0.33)	(0.15)	(0.13)	(0.89)
Average exam score (t-1)	6.44	6.24	6.28	6.38	6.33
	(0.31)	(0.24)	(0.19)	(0.35)	(0.29)
Enrollment (number of students)	70.06	47.52	78.45	67.13	65.07
	(27.56)	(42.87)	(39.73)	(42.80)	(40.92)
Schools in 2015	23	28	25	26	102
Schools in 2016	22	33	26	28	109
Schools in 2017	21	33	34	32	120
Total	66	94	85	86	331

Notes: The table reports mean values of class characteristics by track, with standard deviations in parentheses. Share of non-Western students is the share of students in a class with a non-Western background. Share low-income is the share of students in a class from a low-income family. Average test score is the average score on the nationwide exit test in primary school of the students entering the class. Average exam score is the average exam score of the students graduating from the track in a secondary school. All these variables are measured with a one year lag. The test score is standardized at the cohort level and therefore comparable between tracks. The exam score is track specific. Enrollment is the number of students that enrolls in a track in a school. For all variables the share of missing values is below 5% except for the exam score where the maximum share of missing values is 14%, which is due to newly established schools from which no students graduated yet.

The school district of Amsterdam consists of the schools located within the city's boundaries. These boundaries enclose a relatively small area of 219 squared kilometers.[12] School density is high. There are 54–55 schools that offer secondary education. The mean average distance between a student's home address and all schools offering her track is 6.3 km. The average distance to the closest school offering students' track is 1.1 km. The top panel of Table 4 reports the average of the number of schools at the track level in 1/3/5/10/15 kilometer radiuses from students' home addresses. Amsterdam is a bicycle-friendly city. With a modest speed of 15 km/hr, students have on average 11.3 schools offering their track within 20 minutes of their home address.

Table 4: School characteristics with certain radiuses, by track

	Vocational (elementary)	Vocational (theory)	College	University	Total
A. *Number of schools*					
Schools within 1 km	0.60	0.76	0.81	1.26	0.87
Schools within 3 km	3.18	4.71	5.23	7.54	5.28
Schools within 5 km	6.84	10.67	11.54	15.24	11.30
Schools within 10 km	16.49	23.81	22.72	26.01	22.49
Schools within 15 km	19.74	27.54	24.97	27.88	25.20
B. *Average range of within-class share of non-Western students (t-1)*					
Schools within 1 km	0.04	0.08	0.09	0.08	0.08
Schools within 3 km	0.26	0.42	0.43	0.52	0.42
Schools within 5 km	0.42	0.70	0.67	0.80	0.66
Schools within 10 km	0.59	0.99	0.91	0.99	0.88
Schools within 15 km	0.62	1.00	0.93	1.00	0.90
C. *Average range of within-class share of low-income students (t-1)*					
Schools within 1 km	0.03	0.06	0.06	0.08	0.06
Schools within 3 km	0.18	0.31	0.31	0.46	0.32
Schools within 5 km	0.27	0.56	0.50	0.71	0.52
Schools within 10 km	0.41	0.99	0.71	0.87	0.75
Schools within 15 km	0.43	1.00	0.74	0.89	0.77

Notes: The table presents average school characteristics in choice set within a 1/3/5/10/15 km radius from students' home addresses. Panel A presents the number of schools. Panel B presents the average range of the within-class share of non-Western students. Panel C presents the average range of the within-class share of low-income students.

The other panels of Table 4 report the average difference between the maximum and minimum shares of non-Western (panel B) and low-income students (panel C) in the schools within a 1/3/5/10/15 kilometer distance. This shows that within 5 kilo-

[12]For comparison, London, New York City and Berlin are much larger with sizes of respectively 1572 km^2, 1214 km^2 and 892 km^2.

meter from their home address, students could, on average, choose between schools that differ 0.66 (0.52) in the share of non-Western (low-income) students. These spreads are not much smaller than the city-level spreads in these shares.

Segregation

Table 5 reports measures of secondary-school segregation and residential segregation by ethnicity and household income in Amsterdam.

Table 5: Segregation in Amsterdam

	Ethnicity		Household income	
	Dissimilarity	Mutual Information	Dissimilarity	Mutual Information
A. *Placement*				
School	0.458	0.211	0.342	0.122
Class	0.481	0.232	0.372	0.139
B. *Placement within track*				
Vocational elementary	0.338	0.093	0.201	0.032
Vocational theory	0.386	0.145	0.220	0.052
College	0.408	0.190	0.271	0.077
University	0.290	0.100	0.215	0.053
C. *Residence*				
District	0.325	0.108	0.184	0.031
Postcode	0.448	0.193	0.307	0.095

Notes: The table presents segregation by ethnicity and household income. Panel A presents school- and class-level segregation based on students' placement. Panel B shows within track segregation for each track at the class-level. Panel C presents residential segregation at the district (7) and 4-digit postcode-level (72).

For school segregation by ethnicity, D equals 0.458 at the school level and 0.481 at the class level. For school segregation by household income, the respective figures are 0.342 and 0.372. Hence, segregation at the school level and at the class level are not very different. This is not surprising given that many schools specialize in a limited number of tracks. Segregation by ethnicity is stronger than segregation by household income. Graham (2018) refers to a classification where a value of D between 0.3 and 0.6 is labelled as "moderately segregated".

Panel B reports segregation within school tracks. Within-track segregation is highest in the college track. In all tracks, segregation by ethnicity falls in the moderately segregated interval.

For comparison, panel C reports indices for residential segregation. Across the seven districts of the city, segregation – measured by D – by ethnicity equals 0.325

and by income 0.184. These numbers go up when the city is sliced into the 72 postal code units. For ethnicity, D equals 0.448 and for income 0.307. Comparing panels A and C, we see that secondary-school segregation is a bit higher than residential segregation.

5 Results

Tables 6 and 7 report the results of the decomposition of segregation into the five additive sources. Table 6 pertains to segregation by ethnicity. Table 7 to segregation by household income.[13] The decomposition uses the Mutual Information Index, for which the strong school decomposability property allows for a between-track and within-track distinction.[14] Panels A report indices resulting from the counterfactual assignments of students discussed in Section 3. Panels B present these results in terms of the relative contribution of each of the five sources of segregation.

The final column of Table 6 decomposes segregation by ethnicity for all tracks together. Ability tracking explains 42% of total segregation. Of the remaining 58%, 80% (46% of the total) is accounted for by preference heterogeneity. Only 12% (7% of the total) can be attributed to residential segregation and 8% (4% of the total) to noise. Capacity constraints do not contribute to segregation.

The first four columns in the table present segregation indices of counterfactual assignments within tracks. It also reports the relative contributions of different sources to within-track segregation. Within each track, preference heterogeneity is the main source of segregation. It accounts for around 80%. The role of noise is larger in the vocational-elementary and university tracks than in the other tracks. This reflects that student-school ratios are smaller in these tracks. Residential sorting has almost no influence on segregation within the vocational-elementary track. Its impact goes up to 11% in the vocational-theory track and to 13% in the college track and almost 19% in the university track.

While capacity constraints have no influence on total segregation, they do within tracks. In the vocational-elementary track segregation increases due to capacity constraints. While in the university track capacity constraints attenuate segregation.

The results in Table 6 imply that the substantial residential segregation by ethnicity (as shown in panel C of Table 5) explains only a small share of the also substantial

[13]The results in the tables are based on data aggregated over years. Differences in results between years are minimal.

[14]Tables A1 and A2 in Appendix A.1 report results for decompositions based on the Dissimilarity Index. Results are similar to those presented in the main text.

school segregation by ethnicity. School segregation would be much lower if students with a non-Western background would choose the same schools as native students living in the same neighborhoods. In Section 6 we present evidence that this is not due to native students in neighborhoods with a high share of students with a non-Western background being more willing to travel than native students in neighborhoods with a low share of students with a non-Western background.

Table 6: The determinants of school segregation: ethnicity

	Vocational (elementary)	Vocational (theory)	College	University	Total
A. *Determinants of class-level segregation*					
Segregation between tracks					0.098
Segregation within tracks					
Noise	0.013	0.012	0.010	0.014	0.108
Residential sorting	0.014	0.028	0.036	0.033	0.124
Highest-ranked class	0.082	0.148	0.185	0.112	0.233
Placement	0.093	0.145	0.190	0.100	0.232
B. *Relative contribution to total segregation*					
Tracking					42.1
Within tracks	40.0	62.2	81.9	42.9	57.9
Decomposition within tracks					
Noise	13.5	8.5	5.4	14.3	7.7
Residential sorting	1.1	11.0	13.3	18.8	12.0
Preference heterogeneity	74.1	83.2	78.5	79.2	80.4
Capacity constraints	11.3	−2.6	2.8	−12.3	−0.2

Notes: Panel A of the table reports values of the Mutual Information Index of school segregation at the class level by ethnicity for different counterfactual assignments. Section 3 describes the counterfactuals. Panel B translates the results of panel A into the relative contribution of different sources of segregation to total segregation.

Table 7 shows results for the decomposition of school segregation by household income. Over 60% of school segregation by household income is accounted for by ability tracking. Of the remainder almost 80% (31% of the total) is due to preference heterogeneity and around 20% to noise. Residential sorting and capacity constraints have no impact on overall school segregation by household income. Very similar patterns are found for segregation within tracks. The larger part is due to to preference heterogeneity, at a distance followed by noise. Residential sorting explains a small share of the segregation by household income in the college and university tracks. This is partially undone by a desegregating effect of capacity constraints.

Table 7: The determinants of school segregation: household income

	Vocational (elementary)	Vocational (theory)	College	University	Total
A. *Determinants of class-level segregation*					
Segregation between tracks					0.085
Segregation within tracks					
Noise	0.009	0.017	0.010	0.010	0.098
Residential sorting	0.009	0.015	0.018	0.015	0.098
Highest-ranked class	0.030	0.050	0.078	0.059	0.141
Placement	0.032	0.052	0.077	0.053	0.139
B. *Relative contribution to total segregation*					
Tracking					61.2
Within tracks	22.9	37.2	55.0	37.8	38.8
Decomposition within tracks					
Noise	29.8	32.6	13.1	19.7	22.6
Residential sorting	−2.9	−4.5	10.8	9.6	0.3
Preference heterogeneity	67.0	68.5	77.9	82.1	79.3
Capacity constraints	6.1	3.4	−1.8	−11.4	−2.2

Notes: Panel A of the table reports values of the Mutual Information Index of school segregation at the class level by household income for different counterfactual assignments. Section 3 describes the counterfactuals. Panel B translates the results of panel A into the relative contribution of different sources of segregation to total segregation.

6 Students' preferences for schools

The previous findings call for a further exploration of the differences in school preferences between students from different backgrounds. This section presents such an exploration based on the estimation of discrete choice models. Students from all groups are more likely to express a preference for schools with a higher quality of graduating and of incoming students. This association is, however, weaker for disadvantaged students than for non-disadvantaged students. Students from each group express a preference for schools with a larger share from their own group.

To relate the ROL's of students to characteristics of students and schools we assume that indirect utility of student i for school (class) s depends on the distance between the home address and the school (d_{is}), distaste for traveling (β), school fixed effects (η_s), and a random utility component (ε_{is}):

$$u_{is} = (d_{is}\beta^L + \eta_s^L) \times L + (d_{is}\beta^H + \eta_s^H) \times H + \varepsilon_{is}, \quad s \in \mathcal{S}_\mathbf{i}$$

where distaste for traveling and school fixed effects are allowed to differ between students from different backgrounds, indicated by L and H. Students can only choose from the schools that offer their assigned track ($\mathcal{S}_\text{i}$).

Because students submit their ROL's under the strategy-proof DA mechanism, we will in our benchmark analysis assume that a student's ROL reports her true ordering of preferences for schools. This implies that $u_{is} > u_{is'}$ if school s is ranked above school s', and that $u_{is} > u_{is''}$ if school s is included in the ROL and school s'' is not.

Under DA, truth telling is only a weakly dominant strategy. There is therefore a concern that students may disguise their true preferences (Fack et al., Forthcoming). There are two plausible scenario's for that. The first occurs when a student perceives that her chance to be admitted to a school is equal to zero. In that case there is no reason to include this school in the ROL. The second scenario occurs when a student ranks a school and believes that placement at that school is certain. In that case there is no reason for a truthful ranking of schools ranked below this "safe" school. The first scenario is irrelevant in our setting because students always have a substantial chance to be admitted to the school they rank first, provided it offers their track. The second scenario may, however, occur. We will therefore also present estimates of students' preferences based on ROL's that are truncated below the first "safe" school on the list. We operationalize "safe" schools as schools that have more seats than accepted applicants in the previous year.

Assuming that ε_{is} is an i.i.d. draw from a type-I extreme value distribution, the resulting model is a rank-ordered logit model. Estimation of β's and η_s's is feasible using maximum likelihood. The likelihood contribution of student i from group $G \in \{L, H\}$ who can choose from n schools and ranks k schools in the order $s_1, s_2, \ldots, s_k$, is:

$$\mathcal{L}_i = \prod_{j=1}^{k} \frac{\exp(d_{is_j}\beta^G + \eta^G_{s_j})}{\sum_{m=j}^{n} \exp(d_{is_m}\beta^G + \eta^G_{s_m})}.$$

In addition to the specification with group-specific school fixed effects, we will also present results from specifications where the school fixed effects are replaced by school characteristics. This gives insights in the school characteristics that students value and how this valuation differs between students from different groups.

Panel A of Table 8 reports estimates from specifications that include distance to school, the interaction of distance to school and an indicator for non-Western background and class times year fixed effects. Estimates are presented for each of the four tracks separately. The results indicate that students in all tracks dislike a longer distance between their home address and a school. The distaste for distance is larger for students with a non-Western background. The presented estimates are coefficients from the logit model. These can be interpreted as the change in the log-odds ratio from a one kilometer increase in the distance to school. The estimate of -0.273 in the first column means that the probability to choose a school that is one kilometer further from the student's home is 23.8% ($= (1 - \exp(-0.273)) \times 100\%$) lower.[15,16]

Panel B of Table 8 reports estimates from specifications that include distance to school, school characteristics and interactions of school characteristics and an indicator for a student having a non-Western background. The main effects for distance are similar to those in the top panel of the table. The estimates for the interaction effect of distance and non-Western background are smaller (closer to zero) than those in the top panel. They are, however, still significantly different from zero for all tracks.

Students from both groups prefer schools that attract students performing better on the exit test from primary school. They also prefer schools whose graduating students perform better on the exit exam from secondary school. The appreciation for these characteristics is often somewhat smaller for students with a non-Western background than for native students.

The key school attribute that students from different backgrounds value differently is the ethnic composition of schools. Native students value a high share of non-Western students in a school negatively. Students with a non-Western background tend to value this positively. An increase of the share of non-Western students in a school of 10 percentage points, reduces the probability that a native student in the college track chooses that school by 12.2% ($= (1 - \exp(-0.1311)) \times 100\%$). The same increase of the share of non-Western students increases the probability that a student with a non-Western background in that track chooses that school by 7.7% ($= (1 - \exp(-0.1311 + 0.2054)) \times 100\%$).[17] These estimates are not causal in a *ceteris paribus* sense. Instead, they capture the effect of the share of of non-Western students *and* everything that is correlated with that share. This includes in particular the extent to which the facilities and guidance that a school offers are tailored to the needs of students from different backgrounds, and the cultural distance between the school and the home environment.

[15] Note that the effect is expressed in percentages, not in percentage points.

[16] The differences in willingness to travel between native and non-Western students is not due to residential segregation. When we interact distance with postcode fixed effects the findings continue to hold.

[17] Hastings et al. (2009) report a similar pattern of preference heterogeneity.

Table 8: Students' school preferences by ethnicity

	Vocational (elementary)	Vocational (theory)	College	University
A. *School demand w/ class FEs*				
Distance (km)	−0.273***	−0.311***	−0.300***	−0.328***
	(0.010)	(0.007)	(0.005)	(0.005)
Distance (km) × Non-western	−0.110***	−0.098***	−0.146***	−0.131***
	(0.011)	(0.009)	(0.009)	(0.010)
Class x Year FEs	Yes	Yes	Yes	Yes
B. *School demand w/o class FEs*				
Distance (km)	−0.264***	−0.303***	−0.306***	−0.306***
	(0.009)	(0.006)	(0.004)	(0.004)
Distance (km) × Non-western	−0.077***	−0.058***	−0.050***	−0.048***
	(0.011)	(0.008)	(0.007)	(0.008)
Share of non-western students (t-1)	−0.697***	−0.841***	−1.311***	−1.533***
	(0.142)	(0.050)	(0.067)	(0.036)
Share of non-western students (t-1) × Non-western	2.581***	1.611***	2.054***	1.062***
	(0.171)	(0.066)	(0.101)	(0.081)
Share of low-income students (t-1)	−0.634***	−0.719***	−0.626***	0.410***
	(0.196)	(0.056)	(0.105)	(0.050)
Share of low-income students (t-1) × Non-western	0.546**	0.394***	−0.420***	−0.044
	(0.234)	(0.070)	(0.156)	(0.098)
Average test score (t-1)	0.253***	0.842***	1.441***	1.016***
	(0.087)	(0.036)	(0.073)	(0.051)
Average test score (t-1) × Non-western	0.188*	−0.286***	−0.802***	−0.044
	(0.101)	(0.044)	(0.100)	(0.100)
Average exam score (t-1)	0.420***	0.765***	1.026***	1.879***
	(0.076)	(0.059)	(0.036)	(0.031)
Average exam score (t-1) × Non-western	−0.033	−0.181**	−0.492***	−0.406***
	(0.087)	(0.071)	(0.056)	(0.059)
# Students	4,082	4,385	5,479	4,972
# Alternatives (min.)	24	26	28	38
# Alternatives (max.)	29	46	49	52

Notes: The table presents the estimates for students' school preferences by students' ethnicity. Panel A includes class × year fixed effects. Panel B includes lagged class-specific characteristics, such as the share of non-western students, the share of low-income students, the lagged average test score of the incoming cohort, and the lagged average exam score of the graduating cohort. Alternatives are tracks within schools but also special classes with an emphasis for sports, arts, et cetera. Standard errors clustered on the student-level are in parentheses.

Table 9 reports analogous estimates based on specifications where school characteristics are interacted with a dummy that equals one if a student is from a low-income household. According to the results in Panel A, students from both social groups dislike a longer distance to school. The distaste for traveling is somewhat stronger for low-income students than for others. The distaste for traveling is rather similar for students in different tracks.

Turning to panel B, we see that students from both social groups prefer schools with a higher average test score for the incoming students and a higher average exam score for the graduating students. Low-income students value these school characteristics less than high-income students. The main effects for the shares of non-Western students and low-income students are (with one exception) all negative. The interaction terms of these shares and the low-income indicators are (again with one exception) all positive.[18]

[18]Tables A3 and A4 in Appendix A.2 present estimates based on ROL's that are truncated at the first "safe" school. These estimates are very similar to those presented in the main text.

Table 9: Students' school preferences by household income

	Vocational (elementary)	Vocational (theory)	College	University
A. *School demand w/ class FEs*				
Distance (km)	-0.319^{***}	-0.334^{***}	-0.324^{***}	-0.342^{***}
	(0.009)	(0.006)	(0.005)	(0.005)
Distance (km) × Low-income	-0.053^{***}	-0.068^{***}	-0.097^{***}	-0.091^{***}
	(0.010)	(0.009)	(0.009)	(0.011)
Class x Year FEs	Yes	Yes	Yes	Yes
B. *School demand w/o class FEs*				
Distance (km)	-0.299^{***}	-0.327^{***}	-0.324^{***}	-0.312^{***}
	(0.008)	(0.006)	(0.004)	(0.004)
Distance (km) × Low-income	-0.036^{***}	-0.030^{***}	-0.035^{***}	-0.059^{***}
	(0.010)	(0.008)	(0.007)	(0.009)
Share of non-western students (t-1)	0.472^{***}	-0.387^{***}	-0.802^{***}	-1.384^{***}
	(0.147)	(0.049)	(0.068)	(0.038)
Share of non-western students (t-1) × Low-income	1.033^{***}	0.989^{***}	1.258^{***}	0.682^{***}
	(0.175)	(0.067)	(0.107)	(0.081)
Share of low-income students (t-1)	-0.674^{***}	-0.608^{***}	-0.899^{***}	0.377^{***}
	(0.192)	(0.049)	(0.103)	(0.050)
Share of low-income students (t-1) × Low-income	0.575^{**}	0.166^{**}	-0.057	0.070
	(0.232)	(0.067)	(0.159)	(0.099)
Average test score (t-1)	0.595^{***}	0.745^{***}	1.204^{***}	1.109^{***}
	(0.080)	(0.032)	(0.078)	(0.052)
Average test score (t-1) × Low-income	-0.297^{***}	-0.172^{***}	-0.527^{***}	-0.379^{***}
	(0.096)	(0.042)	(0.106)	(0.100)
Average exam score (t-1)	0.433^{***}	0.682^{***}	0.991^{***}	1.860^{***}
	(0.068)	(0.052)	(0.036)	(0.031)
Average exam score (t-1) × Low-income	-0.059	-0.104	-0.416^{***}	-0.375^{***}
	(0.081)	(0.067)	(0.057)	(0.060)
# Students	4,082	4,385	5,479	4,972
# Alternatives (min.)	24	26	28	38
# Alternatives (max.)	29	46	49	52

Notes: The table presents the estimates for students' school preferences by household income. Panel A includes class × year fixed effects. Panel B includes lagged class-specific characteristics, such as the share of non-western students, the share of low-income students, the lagged average test score of the incoming cohort, and the lagged average exam score of the graduating cohort. Alternatives are tracks within schools but also special classes with an emphasis for sports, arts, et cetera. Standard errors clustered on the student-level are in parentheses.

The counterfactual allocation that we construct to assess the importance of residential segregation, replaces the ROL's of disadvantaged students by a draw from the ROL's of non-disadvantaged students living in the same neighborhood. A possible concern with this approach is that non-disadvantaged students who live in neighborhoods with high shares of disadvantaged students are less unwilling to travel than non-disadvantaged students who live in neighborhoods with low shares of disadvantaged students. Results from school demand models with interactions of distance and the share of disadvantaged students living in the neighborhood, annihilate this concern. The coefficients of these interaction terms are even significantly negative; see Tables A5 and A6 in Appendix A.3.

7 Policy experiments

This section assesses the effects of four policies aimed at reducing segregation: affirmative action, stricter ability tracking, different school assignment mechanisms and relocation of schools. These assessments do not exploit policy reforms or other sources of exogenous variation, and may therefore appear somewhat mechanical. We think, however, that the results are informative about the magnitude of the effects that can be expected from these policies. As we will discuss below, the effects that we find are likely to be upper bounds of the true effects. These are informative since none of the policies that we assess, reduces segregation by more than 15% (from 0.48 to 0.41).

Affirmative action

Affirmative action in the school assignment process can take two forms. One form is quotas where given shares of the places in a school can only be filled by students from a specific group (Abdulkadiroğlu, 2005). This policy fights school segregation quite aggressively, possibly leaving some seats unfilled and some students unassigned. A milder form is reserves where disadvantaged students have priority in a school as long as their share is below a certain fraction (Hafalir et al., 2013).

We operationalize reserves by giving priority to non-Western (low-income) students as long as their share in the class falls short of the track-specific share of non-Western (low-income) students.[19] For quotas, we secure seats for non-Western (low-

[19] This is implemented, following the procedure proposed by Hafalir et al. (2013). This implies first creating copies of each school (minority and majority), then duplicating schools on students' ROL's (ranking the minority version of a school above its majority version) and finally giving priority to minority students in the minority versions of schools.

income) students proportional to their track-specific share.[20]

Panel A of Table 10 shows that quotas reduces the dissimilarity index of segregation by ethnicity by 15%, from 0.481 to 0.406. Reserves have less bite and reduce the dissimilarity index of segregation by ethnicity only by 4%, from 0.481 to 0.461. Segregation by household income is less affected by quotas and reserves. Quotas reduce the dissimilarity index of this form of segregation by around 5%, and reserves leave the index basically unchanged.

Panel B of Table 10 reports results for each track separately. These show that quotas reduce segregation by ethnicity in all tracks except vocational-elementary by a sizable amount. Quotas also reduce segregation by household income in the college and university tracks by a nontrivial amount. Reserves have much less impact, and even increase the levels of segregation in the vocational tracks.

To assess the impact of quotas and reserves on student welfare, Table 11 reports the shares of students who win and lose from the policies. This is reported separately for non-Western and native students and for low-income and high-income students. Quotas based on ethnicity make 26% of the students worse off, while only 10.4% of the students benefit. The share of losers is larger among native students than among the non-Western students, whereas similar shares of both groups benefit. The table also shows how many rank positions winners on average improve and how many rank positions losers on average fall on their ROL's. Native students who are harmed by ethnicity quotas, are on average placed two positions lower on their ROL's. The welfare effects of quotas based on income show a similar pattern. Among high-income students a larger share is harmed by the policy and similar shares of low-income and high-income students benefit from it. High-income losers fall on average two positions on their ROL's.

Also reserves lead to a sizable share of native (high-income) students who are harmed. Reserves based on ethnicity (income) harm 23% (22%) of these students and they fall on average 1.8 (1.7) positions on their ROL's. Tables A7 and A8 in Appendix A.4 report welfare effects of quotas and reserves by track. This shows that most of the students who are affected by affirmative action study in the college and university tracks.

Our evaluation of affirmative action keeps students' ROL's fixed. In reality, affirmative action may change students' rankings of schools. Given the results from the school demand models, such changes are unlikely to exacerbate the reduction in segregation. Majority schools that become more diverse will be ranked lower by non-

[20] These simulations assume that priority on the basis of ethnic background is permitted. Fryer et al. (2008) and Ellison and Pathak (2016) analyze the additional costs of color-blind affirmative action.

Table 10: School segregation and affirmative action

	Ethnicity		Household income	
	Dissimilarity	Mutual Information	Dissimilarity	Mutual Information
A. *Placement (class-level)*				
Placement	0.481	0.232	0.372	0.139
Minority quota	0.406	0.174	0.351	0.122
	[0.403, 0.408]	[0.172, 0.176]	[0.349, 0.353]	[0.120, 0.123]
Minority reserve	0.461	0.224	0.368	0.140
	[0.458, 0.464]	[0.221, 0.226]	[0.365, 0.371]	[0.138, 0.142]
B. *Placement within track*				
B1. *Vocational (elementary)*				
Placement	0.338	0.093	0.201	0.032
Minority quota	0.320	0.097	0.196	0.036
	[0.313, 0.326]	[0.092, 0.100]	[0.190, 0.201]	[0.034, 0.039]
Minority reserve	0.367	0.116	0.228	0.046
	[0.360, 0.372]	[0.113, 0.121]	[0.221, 0.235]	[0.043, 0.050]
B2. *Vocational (theory)*				
Placement	0.386	0.145	0.220	0.052
Minority quota	0.296	0.103	0.187	0.047
	[0.291, 0.303]	[0.100, 0.108]	[0.181, 0.192]	[0.044, 0.050]
Minority reserve	0.401	0.167	0.246	0.065
	[0.393, 0.410]	[0.161, 0.174]	[0.240, 0.253]	[0.062, 0.069]
B3. *College*				
Placement	0.408	0.190	0.271	0.077
Minority quota	0.249	0.092	0.192	0.046
	[0.243, 0.256]	[0.087, 0.097]	[0.186, 0.198]	[0.044, 0.049]
Minority reserve	0.372	0.167	0.255	0.071
	[0.362, 0.379]	[0.162, 0.173]	[0.247, 0.263]	[0.068, 0.075]
B4. *University*				
Placement	0.290	0.100	0.215	0.053
Minority quota	0.162	0.056	0.129	0.031
	[0.156, 0.170]	[0.052, 0.060]	[0.123, 0.135]	[0.028, 0.034]
Minority reserve	0.281	0.092	0.207	0.047
	[0.271, 0.290]	[0.088, 0.095]	[0.198, 0.216]	[0.045, 0.050]

Notes: The table presents indices of school segregation under the actual placement and counterfactual school assignment mechanisms, such as Deferred Acceptance (DA) with minority quotas and DA with minority reserves. Quotas and reserves mimic the share of minority students within each track. 95% confidence intervals are in brackets. The confidence intervals are based on the 2.5 and 97.5 percentiles of 100 random draws and they reflect uncertainty stemming from random lotteries (multiple tie breaking).

disadvantaged students, who may try to switch to schools whose majority status was unaffected by the policy. Our evaluation also keeps the student population fixed. In reality, this may also change. Students whose welfare is strongly reduced by the policy may opt for a school outside the district, thereby reducing the shares of native and high-income students. Although this may reduce segregation among the students that remain in the district, this can hardly be considered a successful policy.

Table 11: Affirmative action and student welfare

	Ethnicity			Household income		
	Non-western	Western	Total	Low-income	High-income	Total
A. *Minority quota*						
Winners (%)	9.0	11.9	10.4	9.9	12.6	11.3
Indifferent (%)	73.9	51.8	63.6	78.3	60.9	69.5
Losers (%)	17.1	36.2	26.0	11.8	26.5	19.3
Average rank – policy	1.35	2.08	1.68	1.24	1.75	1.50
Average rank – placement	1.23	1.54	1.37	1.25	1.49	1.37
Average rank of winners – policy	1.31	1.72	1.53	1.29	1.59	1.46
Average rank of winners – placement	2.94	4.14	3.59	3.06	3.89	3.54
Average rank of losers – policy	2.64	3.51	3.21	2.41	3.21	2.97
Average rank of losers – placement	1.10	1.23	1.18	1.08	1.20	1.17
Unassigned students (%) – policy	1.3	2.1	1.6	0.6	1.1	0.9
Unassigned students (%) – placement	1.3	1.1	1.2	1.2	1.2	1.2
B. *Minority reserve*						
Winners (%)	11.4	13.6	12.4	11.9	12.8	12.4
Indifferent (%)	84.7	63.0	74.6	84.5	65.4	74.8
Losers (%)	3.9	23.3	12.9	3.6	21.7	12.8
Average rank – policy	1.11	1.63	1.35	1.10	1.58	1.34
Average rank – placement	1.23	1.54	1.37	1.25	1.49	1.37
Average rank of winners – policy	1.19	1.57	1.38	1.19	1.54	1.37
Average rank of winners – placement	2.79	4.05	3.44	2.92	3.91	3.45
Average rank of losers – policy	2.20	2.95	2.83	2.17	2.92	2.81
Average rank of losers – placement	1.05	1.18	1.15	1.04	1.18	1.16
Unassigned students (%) – policy	0.2	0.8	0.5	0.2	0.8	0.5
Unassigned students (%) – placement	1.3	1.1	1.2	1.2	1.2	1.2

Notes: The table presents the welfare effect of implementing a minority quota (Panel A) and a minority reserve (Panel B) relative to students' actual placement. Minority quota/reserve assigns winners (losers) to a more (less) favorable school relative to their actual placement. Average ranks exclude unassigned students.

Stricter tracking

Until 2014 track placement was based on the judgment of the primary-school teacher and on students' performance on a nationwide exit test from primary school. In 2015 the test days were moved to a later period in the year. Due to this, the performance of students on the test is no longer used as input for track placement, and track placement is solely determined by the primary-school teacher. Only when students perform much better on the test than corresponds to the teacher's decision, track placement can be revised. Upgraded students can, however, only choose from schools that still have vacant places at that stage.

There is a concern that due to this change, some students are placed in a higher or lower track than would otherwise be the case. High-income native parents may convince primary-school teachers to place their children in a higher track. At the same time, teachers may assign low-income and non-Western students to a track below their capacity because they anticipate that these students will not get enough support from their parents. Such biased placements increase segregation due to ability tracking. To assess the magnitude of this, we calculate the level of segregation if track placement is based on performance on the primary school exit test, which is an objective measure of student achievement. We notice, however, that many students have no reason to perform well on the test because downgrading is not possible.

The transition matrix in Table 12 shows for each track the percentages of students that would stay in that track or go to a higher or lower track when track placement is based on their test score. Around 30% of the students from each track (except the lowest) would go to a lower track. Much smaller percentages would go to a higher track.

Table 12: Transition matrix between students' assigned track and counterfactual track based on their test score

Track	Revised track (based on test scores)				
	Vocational (elementary)	Vocational (theory)	College	University	Total
Vocational (elementary)	90.3	8.9	0.8	0.0	100
Vocational (theory)	31.7	56.7	11.2	0.4	100
College	3.1	26.1	63.8	7.1	100
University	0.1	1.8	26.5	71.6	100
Total	27.8	23.1	28.2	21.0	100

Notes: The table presents the transition matrix between students' track (rows) and students' counterfactual track based on their test scores (columns).

To find out whether primary-school teachers use their discretion differentially for students from different groups, we regressed indicators for the test score exceeding the teacher's decision and the test score being below the teacher's decision, on dummies for non-Western and low income and their interaction. We condition on test score fixed effects. The results in Table 13 show that students with a non-Western background and low-income students are more likely to be assigned to a track below the one based on their test scores (columns (1)–(3)) and that the same groups are less likely to be assigned to a track above the one based on their test scores (columns (4)–(6)). This confirms the concern that especially high-income native students are benefiting from the discretion of teachers. Consistent with this, Table 14 shows that stricter tracking reduces school segregation, both by ethnicity and by household income. This reduction is due to a reduction of between-track segregation. The reduction in between-track segregation is partially mitigated by an increase of within-track segregation. As a result, the overall effect is modest, with 5–9% reductions in the value of D.

Table 13: The determinants of primary-school teachers' discretion in their tracking decision

Dependent variable	Test score exceeds advice			Advice exceeds test score		
	(1)	(2)	(3)	(4)	(5)	(6)
Non-western student	0.053***		0.049***	−0.105***		−0.097***
	(0.004)		(0.005)	(0.006)		(0.008)
Low-income student		0.044***	0.037***		−0.091***	−0.081***
		(0.004)	(0.005)		(0.006)	(0.009)
Low-income × non-western student			−0.013*			−0.031***
			(0.007)			(0.012)
Test score FE	Yes	Yes	Yes	Yes	Yes	Yes
# Students	18,918					

Notes: Columns (1)–(3) present the estimates of a linear probability model where the outcome is an indicator of having a track that is lower than the one implied by students' test score. Columns (4)–(6) present the estimates of a linear probability model where the outcome is an indicator of having a track that is higher than the one implied by students' test score. All regressions are conditional on test score fixed effects. Robust standard errors are in parenthesis.

Table 14: School segregation when tracking is based on students' test score

	Ethnicity		Household income	
	Dissimilarity	Mutual Information	Dissimilarity	Mutual Information
A. *Tracking based on advice*				
Segregation between tracks	0.326	0.098	0.300	0.085
Highest-ranked class	0.485	0.233	0.378	0.141
B. *Tracking based on test score*				
Segregation between tracks	0.287	0.075	0.260	0.066
Highest-ranked class	0.460	0.212	0.344	0.120

Notes: The table compares class-level segregation between the current tracking system (based on primary-school teachers' advice, Panel A) and a counterfactual tracking system where students' track is based on their test score (Panel B). The table compares segregation between tracks (rows 1 and 3), and segregation based on students' highest-ranked class (rows 2 and 4).

Different school assignment mechanisms

It has been suggested that manipulable school assignment mechanisms such as the Boston mechanism may lead to more segregation than strategy-proof mechanisms such as the DA (Calsamiglia et al., 2017). This happens if students from different ethnic or social groups differ in their willingness and ability to strategize. Because the ROLs that students submit under the DA mechanism do not reveal which schools they would choose under the Boston mechanism, we cannot construct the counterfactual assignment based on the data from 2015–2017. Instead, we resort to a direct comparison of observed segregation in 2014 when secondary schools in Amsterdam used the adaptive Boston mechanism, and 2015 to 2017 when DA was used.

Indices (D and M) for segregation by ethnicity and household income by year, are reported in Table 15. Panel A reports segregation indices for all tracks together and panel B reports indices by track. Our reading of these figures is that there is no evidence that school segregation was higher when the Boston mechanism was in place than when DA was in place. The patterns of the indices during the three years under the DA mechanism, do not point to an upward trend in school segregation. There is therefore no reason to assume that school segregation in 2014 would have been much lower if DA instead of Boston would have been used in that year.

Relocation of schools

Many schools that are popular with non-disadvantaged students are located in the city center. Many disadvantaged students live at some distance from the city center. Given these students' distaste for traveling, relocation of some popular schools

Table 15: School segregation and the assignment mechanism

	Ethnicity		Household Income	
	Dissimilarity	Mutual Information	Dissimilarity	Mutual Information
A. *Placement (class-level)*				
Boston (2014)	0.492	0.254	0.369	0.145
DA-MTB (2015)	0.477	0.240	0.376	0.141
DA-STB (2016)	0.475	0.229	0.373	0.142
DA-STB (2017)	0.490	0.228	0.366	0.133
B. *Placement within track*				
B1. *Vocational (elementary)*				
Boston (2014)	0.362	0.096	0.192	0.034
DA-MTB (2015)	0.401	0.126	0.172	0.024
DA-STB (2016)	0.303	0.074	0.225	0.036
DA-STB (2017)	0.309	0.076	0.198	0.036
B2. *Vocational (theory)*				
Boston (2014)	0.336	0.137	0.205	0.050
DA-MTB (2015)	0.395	0.144	0.233	0.053
DA-STB (2016)	0.361	0.139	0.192	0.043
DA-STB (2017)	0.395	0.151	0.221	0.054
B3. *College*				
Boston (2014)	0.474	0.238	0.293	0.090
DA-MTB (2015)	0.432	0.214	0.276	0.084
DA-STB (2016)	0.391	0.170	0.290	0.073
DA-STB (2017)	0.393	0.186	0.251	0.071
B4. *University*				
Boston (2014)	0.333	0.122	0.239	0.059
DA-MTB (2015)	0.308	0.109	0.239	0.070
DA-STB (2016)	0.278	0.094	0.210	0.040
DA-STB (2017)	0.285	0.097	0.201	0.047

Notes: The table presents class-level segregation year-by-year. The school district used the (adaptive) Boston mechanism (immediate acceptance) in 2014, deferred acceptance with multiple tie breaking (DA-MTB) in 2015, and deferred acceptance with single tie breaking (DA-STB) in 2016–2017.

seems a promising policy to reduce segregation. This policy may also benefit non-disadvantaged students since many of them do not live in the city center. To implement this policy, we relocated three popular schools offering the university track and three popular schools offering the college track, from their current location in the city center to parts with higher densities of disadvantaged students.

In the simulations we assume that all schools keep their group-specific fixed effects. Students' ROL's then change due to changes in the distances to schools. We use the multinomial logit model to compute group-specific market shares, i.e. aggregate probabilities to be the first choice. As expected, the share of native (high-income) students choosing these relocated schools goes down. The share of non-Western (low-income) students choosing these relocated schools goes up. Total segregation (based on most-preferred schools) is unchanged because the reduction in segregation between relocated school and other schools is undone by higher segregation within the relocated schools; see Table 16. Our assumption that schools keep their group-specific fixed effects, is likely to overestimate the effect of the relocation on the reduction of segregation. High income native students are likely to value the relocated schools less and will rank other majority schools higher thereby partially undoing any initial reduction in segregation.

Table 16: School segregation and the relocation of schools

	College		University	
	Original	Relocation	Original	Relocation
A. *Ethnicity*				
Highest-ranked class	0.185	0.188	0.112	0.116
Segregation between groups	0.019	0.002	0.000	0.009
Segregation within groups				
- schools with fixed location	0.204	0.211	0.123	0.109
- relocated schools	0.043	0.095	0.026	0.077
B. *Household income*				
Highest-ranked class	0.078	0.085	0.059	0.058
Segregation between groups	0.011	0.005	0.000	0.002
Segregation within groups				
- schools with fixed location	0.085	0.091	0.067	0.060
- relocated schools	0.011	0.043	0.008	0.020

Notes: The table presents the Mutual Information Index when schools are relocated. Due to the strong school decomposability property, segregation is the sum of segregation between groups and the weighted average of within-group segregation.

8 Conclusions

We have used rich information from the Amsterdam secondary-school match to decompose school segregation by ethnicity and income into five additive sources. For this decomposition we do not need to make any distributional or parametric model assumption. Our key finding is that school segregation by ethnic/social groups is mainly due to ability tracking and preference heterogeneity. Residential segregation, capacity constraints of schools and noise play only a minor role. Although preference heterogeneity has been documented by others before, we are the first to demonstrate its importance for school segregation.

The finding that residential segregation only explains a small share of school segregation is interesting in light of the city's high degree of residential segregation. The combination of free school choice, high school density and a compact city where most student cycle to school, apparently suffices for residential segregation to not affect school segregation.

None of the four policies that we assessed is attractive. Minority quota reduce segregation the most (by 15%) but this comes at the cost of reducing student welfare. The welfare loss might trigger some students to move to another municipality. Our findings imply that the more promising policies to reduce school segregation are those that reduce segregation due to ability tracking or influence preference heterogeneity. Policies that reduce segregation due to ability tracking should focus on earlier educational stages. To reduce differences in school preferences of students from different groups, we need to know where these differences come from. Our school demand estimates indicate that students from each group prefer schools with a larger share of their own group and other (unobserved) attributes that are correlated with it. A deeper understanding of these attributes (e.g. facilities tailored to group-specific needs, cultural distance) seems important to make further progress.

According to the demand model estimates disadvantaged students are less willing to travel and value a higher quality of incoming or graduating students less than advantaged students. We do not know to what extent these differences capture genuine differences in preferences or mainly reflect differences in information about (the importance of) school quality. If the latter is the case, an information treatment might be a more promising policy to reduce segregation.

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A Appendices

A.1 The determinants of school segregation: dissimilarity

This Appendix presents the determinants of the dissimilarity index. The counterfactual assignments are the same as in the main text. Since the dissimilarity index does not have the strong school decomposability property, the calculation of the relative contributions differs from the main text. When we decompose total segregation, noise corresponds to the random assignment of students *unconditional* on their track. Tracking corresponds to the difference of two random assignments: random assignment of students *conditional* on their track and random assignments of students *unconditional* on their track. The relative contributions within tracks are calculated as in the main text.

Table A1: The determinants of school segregation (dissimilarity): ethnicity

	Vocational (elementary)	Vocational (theory)	College	University	Total
A. *Determinants of class-level segregation*					
Noise	0.095	0.112	0.093	0.099	0.100
Tracking	0.117	0.108	0.092	0.120	0.329
Residential sorting	0.126	0.170	0.161	0.161	0.358
Highest-ranked class	0.311	0.384	0.412	0.308	0.485
Placement	0.338	0.386	0.408	0.290	0.481
B. *Relative contribution to total segregation*					
Tracking					47.6
Noise	34.6	28.0	22.5	41.4	20.8
Residential sorting	2.7	16.1	16.9	14.1	6.0
Preference heterogeneity	54.7	55.4	61.5	50.7	26.4
Capacity constraints	8.0	0.5	−1.0	−6.2	−0.8

Notes: Panel A of the table reports values of the Dissimilarity Index of school segregation at the class level by ethnicity for different counterfactual assignments. Section 3 describes the counterfactuals. Panel B translates the results of panel A into the relative contribution of different sources of segregation to total segregation

Table A2: The determinants of school segregation (dissimilarity): household income

	Vocational (elementary)	Vocational (theory)	College	University	Total
A. *Determinants of class-level segregation*					
Noise	0.095	0.112	0.093	0.099	0.100
Tracking	0.092	0.120	0.095	0.103	0.313
Residential sorting	0.107	0.108	0.122	0.114	0.309
Highest-ranked class	0.192	0.213	0.284	0.223	0.378
Placement	0.201	0.220	0.271	0.215	0.372
B. *Relative contribution to total segregation*					
Tracking					57.3
Noise	45.8	54.5	35.1	47.9	26.9
Residential sorting	7.5	−5.5	10.0	5.1	−1.1
Preference heterogeneity	42.3	47.7	59.8	50.7	18.5
Capacity constraints	4.5	3.2	−4.8	−3.7	−1.6

Notes: Panel A of the table reports values of the Dissimilarity Index of school segregation at the class level by household income for different counterfactual assignments. Section 3 describes the counterfactuals. Panel B translates the results of panel A into the relative contribution of different sources of segregation to total segregation

A.2 Students' preferences for schools: robustness

This Appendix presents alternative (rank-ordered logit) estimates of students' preferences for schools. These alternative specifications assume that schools that ranked lower than the most-preferred "safe school" are unranked. Safe schools were not oversubscribed in the previous year.

Table A3: Students' school preferences by ethnicity – robustness

	Vocational (elementary)	Vocational (theory)	College	University
A. *School demand w/ class FEs*				
Distance (km)	-0.326^{***}	-0.359^{***}	-0.344^{***}	-0.365^{***}
	(0.013)	(0.010)	(0.007)	(0.006)
Distance (km) × Non-western	-0.134^{***}	-0.154^{***}	-0.245^{***}	-0.152^{***}
	(0.015)	(0.014)	(0.016)	(0.014)
Class x Year FEs	Yes	Yes	Yes	Yes
B. *School demand w/o class FEs*				
Distance (km)	-0.319^{***}	-0.357^{***}	-0.328^{***}	-0.323^{***}
	(0.013)	(0.010)	(0.007)	(0.005)
Distance (km) × Non-western	-0.096^{***}	-0.116^{***}	-0.108^{***}	-0.061^{***}
	(0.015)	(0.013)	(0.012)	(0.012)
Share of non-western students (t-1)	-2.110^{***}	-1.360^{***}	-1.555^{***}	-1.270^{***}
	(0.191)	(0.091)	(0.056)	(0.042)
Share of non-western students (t-1) × Non-western	3.353^{***}	2.052^{***}	1.679^{***}	0.952^{***}
	(0.246)	(0.115)	(0.089)	(0.089)
Share of low-income students (t-1)	-1.269^{***}	-0.067	-2.441^{***}	-1.971^{***}
	(0.435)	(0.159)	(0.148)	(0.090)
Share of low-income students (t-1) × Non-western	1.767^{***}	0.810^{***}	1.498^{***}	0.516
	(0.525)	(0.194)	(0.256)	(0.181)
Avg. test score (t-1)	0.705^{***}	1.047^{***}	1.782^{***}	2.900^{***}
	(0.134)	(0.060)	(0.119)	(0.084)
Avg. test score (t-1) × Non-western	0.515^{***}	-0.087	-0.753^{***}	-1.078^{***}
	(0.153)	(0.073)	(0.160)	(0.160)
Avg. exam score (t-1)	0.416^{***}	0.782^{***}	1.077^{***}	1.850^{***}
	(0.141)	(0.094)	(0.051)	(0.032)
Avg. exam score (t-1) × Non-western	-0.029	-0.015	-0.200^{**}	-0.057
	(0.161)	(0.109)	(0.093)	(0.068)
# Students	4,082	4,385	5,479	4,972
# Alternatives (min.)	24	26	28	38
# Alternatives (max.)	29	46	49	52

Notes: The table presents the estimates for students' school preferences by students' ethnicity. Panel A includes class × year fixed effects. Panel B includes lagged class-specific characteristics, such as the share of non-western students, the share of low-income students, the lagged average test score of the incoming cohort, and the lagged average exam score of the graduating cohort. Alternatives are tracks within schools but also special classes with an emphasis for sports, arts, et cetera. Standard errors clustered on the student-level are in parentheses.

Table A4: Students' school preferences by household income – robustness

	Vocational (elementary)	Vocational (theory)	College	University
A. *School demand w/ class FEs*				
Distance (km)	−0.374***	−0.395***	−0.375***	−0.378***
	(0.013)	(0.010)	(0.007)	(0.006)
Distance (km) × Low-income	−0.070***	−0.110***	−0.179***	−0.106***
	(0.015)	(0.014)	(0.015)	(0.014)
Class x Year FEs	Yes	Yes	Yes	Yes
B. *School demand w/o class FEs*				
Distance (km)	−0.354***	−0.409***	−0.348***	−0.329***
	(0.012)	(0.009)	(0.007)	(0.005)
Distance (km) × Low-income	−0.056***	−0.051***	−0.096***	−0.069***
	(0.014)	(0.013)	(0.013)	(0.013)
Share of non-western students (t-1)	−1.002***	−0.721***	−1.187***	−1.120***
	(0.209)	(0.081)	(0.055)	(0.043)
Share of non-western students (t-1) × Low-income	1.659***	1.179***	1.086***	0.565***
	(0.257)	(0.110)	(0.089)	(0.092)
Share of low-income students (t-1)	−0.231	0.333**	−2.561***	−2.056***
	(0.424)	(0.140)	(0.149)	(0.093)
Share of low-income students (t-1) × Low-income	0.383	0.400**	1.562***	0.739***
	(0.515)	(0.183)	(0.254)	(0.173)
Avg. test score (t-1)	1.454***	0.975***	1.598***	2.887***
	(0.110)	(0.054)	(0.111)	(0.084)
Avg. test score (t-1) × Low-income	−0.503***	0.007	−0.604***	−1.101***
	(0.136)	(0.069)	(0.155)	(0.159)
Avg. exam score (t-1)	0.269**	0.779***	1.080***	1.878***
	(0.130)	(0.078)	(0.052)	(0.032)
Avg. exam score (t-1) × Low-income	0.170	−0.125	−0.098	−0.188***
	(0.153)	(0.097)	(0.093)	(0.068)
# Students	4,082	4,385	5,479	4,972
# Alternatives (min.)	24	26	28	38
# Alternatives (max.)	29	46	49	52

Notes: The table presents the estimates for students' school preferences by household income. Panel A includes class × year fixed effects. Panel B includes lagged class-specific characteristics, such as the share of non-western students, the share of low-income students, the lagged average test score of the incoming cohort, and the lagged average exam score of the graduating cohort. Alternatives are tracks within schools but also special classes with an emphasis for sports, arts, et cetera. Standard errors clustered on the student-level are in parentheses.

A.3 Willingness to travel and neighborhood composition

This Appendix presents rank-ordered logit estimates of students' preferences for schools by neighborhood composition. The estimates show that non-disadvantaged students who live in neighborhoods with high shares of disadvantaged students are more willing to travel than non-disadvantaged students who live in neighborhoods with low shares of disadvantaged students.

Table A5: Willingness to travel and neighborhood composition: ethnicity

	Vocational (elementary)	Vocational (theory)	College	University
A. *Native students*				
Distance to school (km)	-0.199^{***}	-0.284^{***}	-0.264^{***}	-0.320^{***}
	(0.026)	(0.017)	(0.011)	(0.010)
Distance to school (km) × Share of non-Western students	-0.160^{***}	-0.086^{***}	-0.133^{***}	-0.047^{*}
	(0.045)	(0.032)	(0.027)	(0.026)
Class × Year FEs	Yes	Yes	Yes	Yes
# Students	934	1,453	2,857	3,512
B. *Non-Western students*				
Distance to school (km)	-0.252^{***}	-0.283^{***}	-0.193^{***}	-0.241^{***}
	(0.023)	(0.020)	(0.018)	(0.021)
Distance to school (km) × Share of non-Western students	-0.191^{***}	-0.169^{***}	-0.330^{***}	-0.265^{***}
	(0.033)	(0.029)	(0.029)	(0.037)
Class × Year FEs	Yes	Yes	Yes	Yes
# Students	3,148	2,932	2,622	1,460

Notes: The table presents rank-ordered logit estimates for students' school preferences by the share of non-Western students living in the same neighborhood (4-digit postcode). Panel A presents the estimates for native students, Panel B corresponds to non-Western students. All specifications include class × year fixed effects. Standard errors clustered on the student-level are in parenthesis.

Table A6: Willingness to travel and neighborhood composition: household income

	Vocational (elementary)	Vocational (theory)	College	University
A. *High-income students*				
Distance to school (km)	-0.202^{***}	-0.233^{***}	-0.218^{***}	-0.317^{***}
	(0.029)	(0.018)	(0.012)	(0.012)
Distance to school (km) × Share of low-income students	-0.233^{***}	-0.262^{***}	-0.308^{***}	-0.098^{***}
	(0.054)	(0.038)	(0.030)	(0.030)
Class × Year FEs	Yes	Yes	Yes	Yes
# Students	1,112	1,765	3,108	3,618
B. *Low-income students*				
Distance to school (km)	-0.141^{***}	-0.228^{***}	-0.132^{***}	-0.255^{***}
	(0.024)	(0.021)	(0.020)	(0.025)
Distance to school (km) × Share of low-income students	-0.406^{***}	-0.305^{***}	-0.512^{***}	-0.298^{***}
	(0.042)	(0.037)	(0.039)	(0.051)
Class × Year FEs	Yes	Yes	Yes	Yes
# Students	2,970	2,620	2,371	1,354

Notes: The table presents rank-ordered logit estimates for students' school preferences by the share of low-income students living in the same neighborhood (4-digit postcode). Panel A presents the estimates for high-income students, Panel B corresponds to low-income students. All specifications include class × year fixed effects. Standard errors clustered on the student-level are in parenthesis.

A.4 Welfare effects of affirmative action by track

This Appendix presents the welfare effects of affirmative action policies by track.

Table A7: Minority quota and student welfare by track

	Ethnicity			Household income		
	Non-western	Western	Total	Low-income	High-income	Total
A. *Vocational (elementary)*						
Winners (%)	5.0	5.4	5.1	5.2	5.1	5.2
Indifferent (%)	90.8	81.5	88.7	91.8	87.8	90.7
Losers (%)	4.1	13.1	6.2	3.0	7.1	4.1
Average rank – policy	1.11	1.22	1.13	1.09	1.16	1.11
Average rank – placement	1.08	1.08	1.08	1.08	1.09	1.08
B. *Vocational (theory)*						
Winners (%)	6.9	6.6	6.8	7.7	8.3	7.9
Indifferent (%)	75.0	70.8	73.6	79.4	81.2	80.1
Losers (%)	18.1	22.6	19.6	13.0	10.5	12.0
Average rank – policy	1.33	1.44	1.36	1.23	1.21	1.22
Average rank – placement	1.15	1.17	1.16	1.15	1.17	1.16
C. *College*						
Winners (%)	11.8	11.0	11.4	13.5	12.1	12.7
Indifferent (%)	60.8	46.2	53.2	68.5	56.7	61.8
Losers (%)	27.4	42.8	35.4	17.9	31.1	25.4
Average rank – policy	1.61	2.48	2.06	1.39	2.02	1.75
Average rank – placement	1.39	1.68	1.54	1.42	1.63	1.54
D. *University*						
Winners (%)	16.8	16.6	16.7	18.2	17.4	17.6
Indifferent (%)	58.4	40.6	45.8	63.7	46.3	51.1
Losers (%)	24.8	42.8	37.5	18.1	36.2	31.3
Average rank – policy	1.46	2.24	2.01	1.33	1.96	1.78
Average rank – placement	1.41	1.70	1.61	1.48	1.66	1.61

Notes: The table presents the welfare effect of implementing a minority quota relative to students' actual placement. Minority quota assigns winners (losers) to a more (less) favorable school relative to their actual placement. Average ranks exclude unassigned students.

Table A8: Minority reserve and student welfare by track

	Ethnicity			Household income		
	Non-western	Western	Total	Low-income	High-income	Total
A. *Vocational (elementary)*						
Winners (%)	5.6	4.6	5.4	5.7	4.3	5.3
Indifferent (%)	92.6	89.9	92.0	92.6	90.4	92.0
Losers (%)	1.8	5.5	2.7	1.7	5.3	2.7
Average rank – policy	1.08	1.15	1.09	1.07	1.15	1.09
Average rank – placement	1.08	1.08	1.08	1.08	1.09	1.08
B. *Vocational (theory)*						
Winners (%)	9.9	6.1	8.6	10.0	6.5	8.6
Indifferent (%)	85.5	82.8	84.6	86.6	81.7	84.6
Losers (%)	4.6	11.1	6.8	3.5	11.9	6.8
Average rank – policy	1.09	1.23	1.14	1.08	1.25	1.14
Average rank – placement	1.15	1.17	1.16	1.15	1.17	1.16
C. *College*						
Winners (%)	15.6	13.4	14.4	16.4	12.4	14.2
Indifferent (%)	78.7	58.9	68.3	77.7	62.3	68.9
Losers (%)	5.9	27.7	17.3	5.9	25.2	
Average rank – policy	1.18	1.90	1.55	1.17	1.83	1.54
Average rank – placement	1.39	1.68	1.54	1.42	1.63	1.54
D. *University*						
Winners (%)	19.7	19.4	19.5	21.2	19.0	19.6
Indifferent (%)	76.7	51.0	58.6	74.9	52.4	58.6
Losers (%)	3.6	29.6	22.0	3.9	28.6	21.9
Average rank – policy	1.06	1.71	1.52	1.07	1.67	1.51
Average rank – placement	1.41	1.70	1.61	1.48	1.66	1.61

Notes: The table presents the welfare effect of implementing a minority reserve relative to students' actual placement. Minority quota assigns winners (losers) to a more (less) favorable school relative to their actual placement. Average ranks exclude unassigned students.