Identifying the sources of school segregation

Hessel Oosterbeek Sándor Sóvágó Bas van der Klaauw*

Abstract

We develop a framework that decomposes school segregation into five additive sources: i) choice restrictions, ii) noise, iii) residential sorting, iv) preference heterogeneity and v) capacity constraints. We apply this framework to segregation by ethnicity and by social background in secondary schools in Amsterdam. This is a setting where students are free to choose the school they wish and school density is high. Combining register data with students' rank-ordered preference lists, we find that, despite substantial residential sorting, only 7% of school segregation by ethnicity can be attributed to residential sorting. Forty-two percent is accounted for by choice restrictions due to ability tracking and 46% to preference heterogeneity. Policy simulations show that minority reserves reduce school segregation only marginally whereas minority quotas have a more meaningful impact.

1 Introduction

Many cities nowadays have a rather diverse population, both in terms of ethnicity and social background. This diversity is typically not mirrored by the composition of

*This version: July 2018. Oosterbeek: University of Amsterdam, School of Economics, Roetersstraat 11, 1018 WB Amsterdam (h.oosterbeek@uva.nl); Sóvágó: VU University Amsterdam, Department of Economics, De Boelelaan 1105, 1081 HV Amsterdam, Netherlands (sovago.sandor@gmail.com). Van der Klaauw: VU University Amsterdam, Department of Economics, De Boelelaan 1105, 1081 HV Amsterdam, Netherlands (b.vander.klaauw@vu.nl). We gratefully acknowledge valuable comments from Mikael Lindahl, Magne Mogstad, Dinand Webbink and seminar and workshop participants in Amsterdam and Uppsala. Van der Klaauw acknowledges financial support from a Vici-grant from the Dutch Science Foundation (NWO).

schools which tend to be rather 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 negative consequences for inequality and integration of minorities more broadly (Stoica and Flache, 2014; Burgess and Platt, 2018).

To design policies that successfully reduce school segregation, knowledge about the driving forces of segregation is indispensable. While there is an understanding that different factors such as residential sorting, heterogeneity of preferences (Stoica and Flache, 2014) and the school assignment mechanism (Calsamiglia et al., 2017) play a role, the relative importance of different factors is yet unknown.

This paper develops a framework that identifies five additive sources of school segregation. The framework starts from the observation that school segregation is an immediate consequence of the assignment of students to schools. The assignment of students of schools is determined by students' choice sets, their preferences for schools, the capacities and priority rules of schools and the school assignment mechanism. Our framework allows students' preferences to be heterogeneous across ethnic and social groups.

The five sources of school segregation that we identify are: i) choice restrictions, ii) noise, iii) residential sorting, iv) preference heterogeneity and v) capacity constraints. With sufficient information about students' social background, their choice sets, their preferences for schools, distances and the actual assignment to schools, it is possible to quantify the importance of each of the five sources nonparametrically. We apply the framework to segregation by ethnicity and by social background in secondary schools in the city of Amsterdam, where the required information is available.

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 has a non-Western background (second or third generation immigrant), half of them originating from Morocco or Turkey, and therefore with a cultural and religious background quite different from that of the native population.[1] The population is also diverse in terms of educational attainment and household income. [Add information.] Amsterdam further constitutes 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 each student has a considerable number of schools that are realistic options. This creates a setting where the role of residential sorting is potentially small. Finally, almost all students living

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

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]

A feature of the Dutch education system that is relevant for an analysis of segregation in secondary schools is ability tracking. 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. Students cannot choose a school that does not offer the track that is assigned to them. Early tracking is not uncommon in continental Europe and also occurs in other countries including Austria, Germany, Hungary and Switzerland.

Starting in 2015, the secondary schools in Amsterdam use the student-proposing deferred acceptance mechanism to assign student 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.

We can identify the contribution of the five sources of school segregation using information on each student's ethnicity (social background), ability track, ROL, home address and actual placement. The contribution of restricted choices due to ability tracking results from first assigning students to tracks and then assuming no segregation within tracks (assign an equal share of disadvantaged students to each school within a track). The contribution of noise follows from randomly assigning students to schools within their track. To quantify the contribution of residential segregation we replace the top-ranked schools on the ROLs of disadvantaged students by the top-ranked schools on the ROLs of non-disadvantaged students who live in the same neighborhood. Residential segregation then plays a role to the extent that non-disadvantaged students living in neighborhoods with high fractions of disadvantaged students choose other schools than non-disadvantaged students living in neighborhoods with low fractions of disadvantaged students. The difference between segrega-

[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.

tion based on the replaced top-ranked schools of disadvantaged students and segregation based on the actual top-ranked schools of disadvantaged 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 0.48 (Dissimilarity Index), 42% is due to ability tracking, around 46% to preference heterogeneity and only 7% to residential sorting. Noise and capacity constraints play (almost) no role for school segregation by ethnicity. Segregation by household income equals 0.37 (DI), 61% of which can be attributed to ability tracking, 31% to preference heterogeneity, and 9% to noise. Residential sorting and capacity constraints play no role for school segregation by household income. The modest contribution of residential sorting for school segregation is surprising in light of the fact that residential sorting 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 disadvantaged students are less willing to travel than non-disadvantaged students and that students from different groups dislike schools with high shares of students from the other group.

We use our framework to simulate the effects of four policy options. The first policy is stricter ability tracking where not the decision of the primary school teacher but the score on a nationwide exit test is decisive. This reduces segregation by a small amount because some of the non-disadvantaged students can no longer apply to an elite school and are assigned to a comprehensive school. In a second policy simulation we reserve a given fraction of the seats of each school for disadvantaged students, which gives these students priority in a school over non-disadvantaged students as long as their share in the school is below the given fraction. This policy reduces school segregation only marginally. Next we simulate quota, where given fractions of the seats are secured for each group of students.[4] Quota reduce school segregation by a more meaningful amount than reserves. Finally we assess the effects on segregation of replacing the student-proposing deferred acceptance mechanism by the Boston (immediate acceptance) mechanism. In contrast to claims in the literature, we find that this replacement does not affect school segregation.

This paper contributes to a large and expanding literature on school segregation.

[4]With quota the secured seats remain empty if they are not occupied by students from the designated groups. With reserves these places can be taken by students from the other group.

This 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 briefly summarize this branch of the literature at the end of Section 2 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) or both (Card et al., 2008). Third, studies that examine how a specific intervention influences school segregation (Böhlmark et al., 2016; Baum-Snow and Lutz, 2011; Söderström and Uusitalo, 2010). While we will also analyze effects of specific interventions, our approach differs from the one in these studies in that these studies are interested in the effects of a specific cause, while we are interested in the causes of a specific effect (segregation) (cf. Gelman and Imbens, 2013).

Because students' preferences for schools form a central element in the framework we develop, this study is also related to the expanding literature on the estimation of students' school preferences. Recent examples include: Burgess et al. (2015), Glazerman and Dotter (2017), Pathak and Shi (2017) and Ruijs and Oosterbeek (2018).

The remainder of this paper is organized as follows. The next section presents the framework that divides school segregation into five additive sources and discusses how each of the sources can be identified. Section 3 provides institutional details of secondary school choice in Amsterdam. Section 4 describes the data. Section 5 presents and discusses the main results and Section 6 analyzes students' preferences in greater detail. Section 7 reports and discusses the results from the four policy simulations that we conducted. Section 8 summarizes and concludes.

2 Framework

The five additive sources of school segregation that our approach is able to separately identify are: i) choice restrictions, ii) noise, iii) residential sorting; iv) preference heterogeneity, and v) apacity constraints, In this section we describe these sources and how they can be measured.

In many school systems, students' choice sets are restricted. Choice restrictions contribute to school segregation if the restrictions vary systematically between students from different (ethnic/social) backgrounds. The key restriction on choice sets in the context of Dutch secondary schools is due to ability tracking at the transition from primary school to secondary school. In other contexts, choice sets can be restricted due to commuting zones, religious schools or the unaffordability of private education.

The contribution of choice restrictions can be measured by assigning each student to her assigned choice set and then eliminate segregation within choice sets by assigning equal fractions of disadvantaged students to each school. The resulting segregation index (Seg^{cr}) divided by the observed segregation index measures which share of school segregation is due to choice restrictions.

The contribution of noise follows from randomly assigning students to schools within their choice set. While in expectation this results in equal shares of disadvantaged students in each school in a choice set, random deviations will occur (cf. Allen et al., 2015). These deviations are more prevalent if average school size is small and if the fraction of disadvantaged students is close to zero or one. In practice we repeat the random assignment of students to schools within their choice set 100 times. The difference between the mean of the resulting segregation indices within a choice set t (Seg_t^{random}) divided by the within choice set observed segregation index (Seg_t^{obs}) measures the share of school segregation within a choice set that is due to noise.

Residential sorting is the third source of school segregation. Even without formal constraints on the set of schools students can choose from, the distances between students' home addresses and the locations of schools may influence school choices. If the home addresses of students with the same background are clustered, this may lead to school segregation if students tend to prefer schools not too far from where they live.

To measure the contribution of residential sorting we replace the most-preferred school of each disadvantaged student by a random draw from the most-preferred schools of non-disadvantaged students, who live in the same neighborhood and are assigned to the same choice set. This results in a large role of residential sorting if non-disadvantaged students living in neighborhoods with high fractions of disadvantaged students choose other schools than non-disadvantaged students living in neighborhoods with low fractions of disadvantaged students. We repeat the replacement of most-preferred schools of disadvantaged students 100 times. The difference between the mean of the resulting segregation indices (Seg_t^{rs}) minus Seg_t^{random}, divided by Seg_t^{obs} measures the share of segregation within a choice set that is due to residential sorting.

The fourth source of school segregation is heterogeneity in preferences for schools between disadvantaged and non-disadvantaged students. To measure the contribution of preference heterogeneity we compare the level of segregation that results if each student is assigned to her most-preferred school ($Seg_t^{\text{top-choice}}$), and the level of segregation that results if disadvantaged students are assigned to the most-preferred schools of their non-disadvantaged neighbors (Seg_t^{rs}).

Due to capacity constraints of schools not all students are assigned to their most-preferred school. How capacity constraints affect school segregation depends on the severity of these constraints, on possible priority rules that schools may use and on the school assignment mechanism. It has been hypothesized that a manipulable mechanism such as the Boston mechanism results in more segregation than a truth-telling mechanism such as deferred acceptance (Calsamiglia et al., 2017).[5] We measure the contribution of capacity constraints to segregation as the difference between Seg_t^{obs} and $Seg_t^{\text{top-choice}}$, divided by Seg_t^{obs}.

3 Context

This section describes briefly the context of our study, the choice for secondary schools in the city of Amsterdam. The first subsection explains that ability tracking occurs at entry in secondary school and that (almost) all schools are publicly funded. The second subsection 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 sources and present descriptive statistics.

3.1 Secondary education in the Netherlands

Our empirical application pertains to students who make the transition from primary education to secondary education in the Netherlands. At this stage, students are around 12 years old. The Netherlands has a tracked secondary education system, where tracks differ in how academically demanding they are. We distinguish four main tracks:

1. vocational - elementary
2. vocational - theory
3. college
4. university

[5] 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 2015, which is the first year that the student-proposing deferred acceptance mechanism is used.

The vocational tracks last four years and give access to subsequent vocational programs. The college track takes five years and gives access to professional colleges. The university track takes six years and gives access to university education.

Which track a student is allowed to enter is determined at the end of primary education by the primary school teacher.[6] [7] Secondary schools do not accept students in a higher track than the track decided by the primary school teacher. Parents who want to influence the track placement of their children have to do this through the primary school teacher.

Students in the Netherlands can freely choose among the schools that offer their assigned track. Schools can offer varying combinations of tracks. Some schools specialize and offer only one track, while other schools offer two or more adjacent tracks. Below we describe precisely how many schools in Amsterdam offer which combinations of tracks.

Virtually all schools in the Netherlands are publicly funded and there are no substantial tuition fees. All schools prepare their students for nationwide 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 ("very weak") for three years in a row are closed (if publicly run) or lose their public funding (if privately run).

3.2 School assignment in Amsterdam

In 2015 the secondary schools in Amsterdam decided to replace the centralized school assignment mechanism that they were using since 2005 by a new mechanism. The mechanism that was in place until 2014 was a version of the adaptive Boston mechanism. Each student applied to one school. All schools that had at least as many seats as applicants accepted all applicants immediately, and schools with more applicants

[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 also 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.

than seats first accepted the students with priority[8] and accepted other students on the basis of a lottery. Rejected students could then in a second round apply to schools that still had vacant seats after the initial round.

Because of discontent with the old system, schools decided in 2015 to adopt the student-proposing deferred acceptance mechanism (Gale and Shapley, 1962). An attractive feature of this mechanism is that truth telling is a weakly dominant strategy for students. This was not the case under the old system where choosing strategically is potentially beneficial. An important change for students is that instead of applying to just one school, under the new system they have to submit a rank-ordered preference list (ROL). The length of this list can be as long as the number of available schools. There are no default schools for students that submit a short list and who are not placed in one of the schools on their list. Because of the strategy proofness of the new system, it is optimal for students to submit a list according to their true preferences. With the introduction of the new system, this property was emphasized in the communication to parents and students.

Also after the introduction of the new system some priority rules were kept.[9] Ties between student in the same priority group are broken by lottery numbers. Typically the number of students with priority is relatively small, so that tie-breaking is only relevant for students without priority. In 2015 the clearinghouse gave each student 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).[10]

4 Data and descriptive statistics

4.1 Data sources

Data for this paper come from two sources: the student register of the city of Amsterdam, and register data from Statistics Netherland. Information from the two registers

[8] Based on having an older sibling attending the school or a specific pedagogical relationship between the primary school that was attended and the secondary school (i.e. Montessori, Dalton).

[9] Priority for students from Montessori and Dalton primary schools at Montessori and Dalton secondary schools was maintained. Some (but not all) schools kept giving priority to students with older siblings in the school.

[10] In the first year, the schools chose multiple tie breaking because this reduces the share of students who are placed in a school low on their preference list. In that year, the Pareto inefficiency of deferred acceptance with multiple tie breaking became very visible and led to many complaints. The next year, the schools therefore switched to single tie breaking. This reduces inefficiency but increases the fraction of students placed in a school low on their preference list.

are merged at the individual student level.

The student register provides data of all students who participated in the school assignment procedure of secondary schools in Amsterdam in the years 2015, 2016 and 2017. For each student, it has information about assigned track, the rank-ordered preference list of schools, actual placement, gender, the score on the nationwide exit test from primary school and home address. The information of the home address is combined with information about the locations of secondary schools, to construct distances between each student's home address and the schools that correspond with the assigned track. To this data we added school-level information about the exam scores of the students that graduated from the secondary school in the previous year. This information is available from the websites of the secondary schools and is a source of information that parents and students can use in the application process.

The register data from Statistics Netherlands contain information about the country of origin of parents and grandparents. Based on this, the data include an indicator for students having a non-Western migrant background which is defined as someone who has at least one parent or grandparent born in Turkey, Africa, Latin America or Asia (with the exception of Japan and Indonesia). The register data also contain information about parents' income.

With the combined data we can measure the ethnic and social composition of students in each track in each school. This forms the basis of the measurement of school segregation. We also construct the one-year lagged values of the share of students with a non-Western background, of the share of students from low-income families, and of the average test score on the nation-wide exit test from primary school. In our analysis of school demand we examine how these variables influence students' preferences for schools.

4.2 Descriptive statistics

This subsection presents descriptive statistics of students and schools in Amsterdam. This shows that the student population is diverse and that school density is high at each track level so that each student has at least several schools to choose from. It also presents descriptive information about school segregation by ethnic and social background.

Students

Table 1 presents summary statistics of student characteristics broken down 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 we see that there share is between three and 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 among students in the vocational-elementary track is close to 25 and increases to over 60 among students in the university track.

The eighth row shows that the boys/girls ratio is very similar across tracks. The averages of the test score on the nation-wide exit test from primary school, which is standardized by year, increase steeply from low to high tracks with the difference between the lowest and highest tracks equal to 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 rank-ordered preference lists that students submit is slightly over seven. This average length increases monotonically from the vocational-elementary track to the university track. In Section 6 we describe the school rankings of students in detail.

The next part of the table looks at the interaction of a non-Western background and household income in the bottom 50% of the distribution. These two sources of disadvantagedness are clearly positively correlated; two thirds of the students with a non-Western background come from a low-income family, while this is only the case for slightly more than 25% of the Western students.

The bottom rows report the numbers of students who come from a primary school in Amsterdam, participate in the school assignment procedure of secondary schools in Amsterdam and whose information from the school register can be matched with data from Statistics Netherlands. The largest group of students is the group that is assigned to the college track (29% over the three years of our data), followed by the university track (26%). The two vocational tracks are each assigned somewhat less

[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%).

than 25% of the students. The shares of the four tracks do not vary much across years.

Schools

Table 2 shows by year, how many schools offer which combinations of tracks. For example, in the first column we can read that 22 schools (10+7+2+3) offered the vocational-elementary track in 2015. Ten of these schools exclusively 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 offer the college track in 2015, there is only one school that does not combine this with other tracks. A take-away from this table is that there are only a few schools that offer the entire range of tracks.

Table 3 presents summary statistics of classes (tracks within schools), overall and broken down by track. The patterns for test scores, share of students with a non-Western background and share of low-income students mirror the pattern 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. This is in more detail shown in Figure **??**. The table also reports the average score of students on their final exam for secondary school 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, which is the average of the annual number of students entering a track in a school. Average enrollment is 65 students. The standard deviation of 40 indicates that there is quite some variation in enrollment across classes (the minimum observed in our data equals 5, the maximum 174).

The school district of Amsterdam consists of schools located within the boundaries of the city of Amsterdam. The boundaries of the city enclose a relatively small area of 219 squared kilometers[12]. School density is high: around 55 schools offer secondary education[13], the average of the average distance between a student's home address and the schools that are in her choice set, is 6.3 km, and the average distance to the closest school in students' choice sets is 1.1 km. Table 4 reports the average

[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.

[13]The exact number varies from year to year.

of the number of schools at the track level in 1/3/5/10/15 kilometer radiuses from the student's home address. Since Amsterdam is a very bicycle-friendly city and with an average cycling speed of 15 kilometers per hour, students in Amsterdam have on average 11.3 schools at their track level within 20 minutes from their home address.

Segregation

Table 5 reports measures of secondary school segregation and of residential segregation by ethnicity and by household income in Amsterdam. The segregation measures that we report are the Dissimilarity Index (D) and the Mutual Information Index (M). [14] Both indices range from zero (no segregation) to one (complete segregation). 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). M satisfies the strong school decomposability property (Frankel and Volij, 2011). This is useful in our framework to decompose segregation into within-track segregation and between-track segregation. With tracking, segregation can be considered at two different levels: at the level of schools and at the level of tracks within schools, to which we will refer as "classes".[15] [16].

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 and 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

[14] 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). 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.

[15] The following example illustrates this distinction. Assume there are three schools: A, B and C. School A offers all four tracks, school B only offers the two vocational tracks and school C only offers the college and university tracks. When segregation is assessed at the school level, the student compositions of the three entire schools are compared. When segregation is examined at the class level, the student compositions of eight $(4+2+2)$ school-track combinations are compared. Examining segregation at the class level within tracks, boils down to four separate comparisons each involving two school-track combinations.

[16] 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 level but not at the school level. Hence: $\text{Seg}(\text{Class})=\text{Seg}(\text{Track})+\sum_{t=1}^{T}w_t\cdot\text{Seg}_t(\text{Class})$, where w_t is the share of students assigned to track t. Alternatively, segregation at the class level can be decomposed into segregation between schools and segregation within schools: $\text{Seg}(\text{Class})=\text{Seg}(\text{School})+\sum_{s=1}^{S}w_s\cdot\text{Seg}_s(\text{School})$

0.6 is labelled "moderately segregated".

Panel B reports segregation within school tracks. Within-track segregation is highest in the college track with D equal to 0.408 for ethnicity and 0.271 for household income. Also in other 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 with the statistics in panel A, we conclude that segregation in secondary schools in Amsterdam is somewhat 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. The tables are based on decomposing the Mutual Information Index, for which the strong school decomposability property allows for a between-track and a within-track distinction.[17] Panels A report segregation indices resulting from the counterfactual assignments of students discussed in Section 2, 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 gives the results for the decomposition for the four school tracks together. This reveals a clear pattern: ability tracking explains 42% of observed 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 sorting and 8% (4% of the total) to noise. Capacity constraints do not contribute to observed segregation.

The first four columns in the table present segregation indices of counterfactual assignments within tracks, and the relative contributions of noise, residential sorting, preference heterogeneity and capacity constraints within tracks. Within each track, preference heterogeneity is the main determinant of segregation, accounting for around 80%. The role of noise is somewhat larger in the vocational-elementary and university tracks than in the vocational-theory and college tracks, reflecting that

[17] Tables **??** and **??** in Appendix A.2 report results for decompositions based on the Dissimilarity Index. Results are very similar to those presented in the main text.

student-school ratios are somewhat smaller in the first two than in the latter two. Residential sorting has almost no influence on segregation within the vocational-elementary track. Its impact goes up to 11% within the vocational-theory track, 13% within the college track and almost 19% within the university track.

While capacity constraints have no influence in segregation in the aggregate, this is not the case within tracks. Within the vocational-elementary track segregation increases due to capacity constraints, while within the university track segregation is attenuated by capacity constraints.

The results in Table 6 imply that the substantial residential segregation by ethnicity (as shown in panel C of Table 5) explains only around 7% of the also substantial school segregation by ethnicity. If students with a non-Western background would choose the same schools as native students living in the same neighborhoods, school segregation would be much lower. 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.

Results for the decomposition of school segregation by household income are in Table 7. Over 60% of school segregation by household income is accounted for by tracking. Of the remainder almost 80% (31% of the total) is due to preference heterogeneity and around 20% is due to noise. Residential sorting and capacity constraints have at the aggregate level no impact on 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.

6 Students' preferences for schools

Our finding that heterogeneous preferences are the most important source of school segregation by ethnicity and the second most important source of school segregation by household income, calls for a detailed comparison of the differences in school preferences between students from different ethnic and social backgrounds. This section presents a comparison based on the estimation of discrete choice models. The main findings from this analysis are that students from disadvantaged groups have a stronger distaste for traveling than other students and that students from different groups prefer schools with smaller shares of the other group.

To relate students' ROLs 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 correspond to the track that was assigned to them ($\mathcal{S}_\mathbf{i}$).

Because students submit their rank-ordered preference lists under the strategy-proof deferred acceptance 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.

Because truth telling is only a weakly dominant strategy under deferred acceptance, there is a concern that students' ROLs disguise true preferences. 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, so that there is no reason to include this school in the ROL. The second scenario occurs when a student ranks a school and perceives placement in that school as certain. In that case there is no reason for a truthful ranking of schools ranked lower on the ROL than this 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 is in their choice set. The second scenario may, however, occur. We will therefore also present estimates of students' preferences based on ROLs that are truncated at the first school on the list that is a "safe" school. We operationalize "safe" schools as schools that have more seats than accepted applicants.

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:

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

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 ethnic and social 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 and that the distaste for distance is larger for students with a non-Western background. The presented estimates are coefficients from the logit model, such that they can be interpreted as the change in the log-odds ratio from a one kilometer increase in the distance to school. Hence, 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.[18]

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 very similar to those in the top panel of the table, but the estimates for the interaction effect of distance and non-Western background are substantially smaller (closer to zero) than those in the top panel, although still significantly different from zero for all tracks.

Students from both groups (native and non-Western backgrounds) have a preference for schools that attract students that perform better on the exit exam from primary school, and schools whose graduating students perform better on the exit exam from secondary school. The appreciation for these characteristics is in almost all cases somewhat smaller for students with a non-Western background than for native students.

The key school attribute that student 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, whereas 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% ($= (1 - \exp(-0.1311)) \times 100\%$), whereas it increases the probability that a student with a non-Western background in the same track chooses that school by 7.7% ($= (1 - \exp(-0.1311 + 0.2054)) \times 100\%$).

Table 9 reports analogous estimates based on specifications where school charac-

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

teristics 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 and this distaste for traveling is somewhat stronger for low-income students than for others. The distaste for traveling is rather similar for students in the 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, while the interaction terms of these shares and the low-income indicators are (again with one exception) all positive.

One of the counterfactual allocations that we use in the decomposition of school segregation, replaces the ROLs of disadvantaged students by a draw from the ROLs of non-disadvantaged students living in the same neighborhood. A potential concern with this approach is that non-disadvantaged students who live in neighborhoods with high shares of disadvantaged students are more willing (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 A1 and A2 in Appendix A.1.

7 Policy experiments

This section assesses the effects on segregation of five policy measures:

- Minority reserves (Hafalir et al., 2013)
- Minority quotas (Abdulkadiroğlu, 2005)
- Different school assignment mechanisms (DA-STB vs. DA-MTB vs. adaptive Boston)
- Stricter tracking
- Relocation of schools

Minority reserve

Minority reserves give priority in the school assignment procedure to students from disadvantaged groups as long their share within a school is below a certain fraction. We operationalize this by giving priority to students from a non-Western background as long as their share in the school falls short of 54%, and – in a separate simulation – by giving priority to low-income students as long as their share in a school is below 50%. This is implemented, following the procedure proposed by Hafalir et al. (2013).[19]

Table **??** presents segregation indices based on these simulations.

Quota

Instead of reserves, affirmative action can also take the form of setting quotas. With a quota, a given share of the seats in a school can only be filled by students from a specific group (Abdulkadiroğlu, 2005). This policy fights school segregation quite aggressively, possibly leaving many school seats unfilled and some students unassigned. We consider two counterfactual policies. In one simulation we secure 54% (46%) of the seats for non-Western (native) students in each class. In another simulation we secure 50% (50%) of the seats for low-income (high-income) students in each class.

Table **??** presents segregation indices based on these simulations.

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 deferred acceptance mechanism (Calsamiglia et al., 2017). This could happen if students from different ethnic or social groups differ in their willingness and ability to strategize. Because the ROLs that students submitted under the DA mechanism do not reveal which schools they would have chosen 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 10. Panel A reports segregation indices for all track together and panel B reports segregation indices by track. Our reading of the figures in this table is

[19] This implies first creating copies of each school (minority and majority). then duplicating schools on students' ROL (minority $\geq$ majority) and finally give priority to minority students in minority schools.

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 that the DA mechanism is in place, 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 when DA instead of Boston would have been used in that year.

Stricter tracking

Until 2014 track placement depended 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 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 for this upgraded track.

There is a concern that due to this change, some students have been placed in a higher track than would otherwise have been the case. Especially non-disadvantaged parents may have convinced the primary school teacher to place their children in a higher track. This may have increased segregation. To assess this, we examine what segregation would be if track placement is based on performance on the primary school exit test. Notice, however, that many students may not have strong incentives to perform well on the test because downgrading is not possible.

The transition matrix in Table 11 shows at each track the percentages of students that would stay in that track or go to a higher or lower track when track placement would be based on their test score. At each track, except the lowest, around 30% of the students would be placed in a lower track if placement would be based on their test score. Much smaller percentages would be placed in higher tracks.

To find out which students benefit from primary school teachers' discretion in determining students' track, we regressed indicators for the test score exceeding the teacher's decision and the test score being below the teacher's decision, on the dummies for non-Western background and low income and their interaction. We condition on test score fixed effects. The results in Table 12 show that students with a non-Western background and low-income students are more likely to be assigned to a track, which is lower than the one based on their test scores (columns (1)–(3)) and that the same groups are less likely to be assigned to a track, which is higher than the one based on their test scores (columns (4)–(6)).

Table 13 shows that stricter tracking reduces school segregation, both by ethnicity and household income. Consistent with our framework, this reduction is due to a reduction of between-track segregation. This reduction is partially but not fully mitigated by an increase of within-track segregation. That is, the changes in segregation between tracks are larger than the changes in total segregation.

Relocation of schools

Many schools – especially at the college and university tracks levels – are located in or close to the city center. Given the larger distaste of traveling of disadvantaged students, relocation of some of these schools may be helpful to reduce segregation. This policy might also make non-disadvantaged students better off since many do not live in or close to the city center. To implement this policy, we relocated three schools that only offer the university track and three schools that offer the college track, from their current location in or close to the city center to the eastern, western and southern parts of the city.

In the simulations we assume that all schools – relocated and others – keep their (group-specific) fixed effects. Students' ROLs then change due to the changes in the distances to schools. According to the results in Table **??**, the relocation of the six schools from the city center to more peripheral locations reduces school segregation by ethnicity from $M = 0.232$ to $M = 0.xxx$ (panel A) and school segregation by low-income status from $M = 0.139$ to $M = 0.xxx$ (panel B). The table has the same structure as Tables 6 and 7. The breakdown by sources of segregation shows that the reduction on segregation is ...

8 Conclusions

We have used information about students' preferences for schools, to decompose school segregation by ethnicity and parental income in secondary education in Amsterdam, into five additive sources. Our key findings are that school segregation by ethnic/social groups is mainly due to ability tracking and to preference heterogeneity, and that residential sorting plays a minor role. Capacity constraints of schools and noise are even less important.

The finding that residential sorting only explains a small share of school segregation is surprising 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 not to transmit to school segregation.

Estimation of school demand models reveals that disadvantaged students are less willing to travel than non-disadvantaged students and that students of both groups have preference for schools with a larger share of their own group.

The findings of the decomposition of school segregation are reflected in the results from policy simulations.

References

Abdulkadiroğlu, Atila. 2005. "College admissions with affirmative action." *International Journal of Game Theory*, 33(4): 535–549.

Allen, Rebecca, Simon Burgess, Russell Davidson, and Frank Windmeijer. 2015. "More reliable inference for the dissimilarity index of segregation." *Econometrics Journal*, 18 40–66.

Baum-Snow, Nathaniel, and Byron F. Lutz. 2011. "School Desegregation, School Choice, and Changes in Residential Location Patterns by Race." *American Economic Review*, 101(7): 3019–3046.

Billings, Stephen, David J. Deming, and Jonah Rockoff. 2014. "School Resegregation, Educational Attainment and Crime: Evidence from the End of Busing in Charlotte-Mecklenburg." *Quarterly Journal of Economics*, 129(1): 435–476.

Böhlmark, Anders, Helena Holmlund, and Mikael Lindahl. 2016. "Parental choice, neighbourhood segregation or cream skimming? An analysis of school segregation after a generalized choice reform." *Journal of Population Economics*, 29 1155–1190.

Burgess, Simon, Ellen Greaves, Anna Vignoles, and Deborah Wilson. 2015. "What parents want: School preferences and school choice." *The Economic Journal*, 125(587): 1262–1289.

Burgess, Simon, and Lucinda Platt. 2018. "Inter-ethnic relations of teenagers in England's schools: the role of school and neighbourhood ethnic composition." May, CReAM Discussion Paper Series CPD 07/18.

Calsamiglia, Caterina, Francisco Martínez-Mora, and Antonio Miralles. 2017. "Sorting in public school districts under the Boston Mechanism." Unpublished working paper.

Card, David, Alexandre Mas, and Jesse Rothstein. 2008. "Tipping and the Dynamics of Segregation." *The Quarterly Journal of Economics*, 123(1): 177–218, DOI: http://dx.doi.org/10.1162/qjec.2008.123.1.177.

Card, David, and Jesse Rothstein. 2007. "Racial segregation and the black-white test score gap." *Journal of Public Economics*, 91(2158-2184): .

De Haan, Monique, Pieter A Gautier, Hessel Oosterbeek, and Bas Van der Klaauw. 2018. "The performance of school assignment mechanisms in practice."

Frankel, David M, and Oscar Volij. 2011. "Measuring school segregation." *Journal of Economic Theory*, 146(1): 1–38.

Gale, David, and Lloyd S. Shapley. 1962. "College admissions and the stability of marriage." *The American Mathematical Monthly*, 69(1): 9–15.

Gelman, Andrew, and Guido Imbens. 2013. "Why ask Why? Forward Causal Inference and Reverse Causal Questions." NBER Working Paper No. 19614.

Glazerman, Steven, and Dallas Dotter. 2017. "Market Signals: Evidence on the Determinants and Consequences of School Choice From a Citywide Lottery." *Educational Evaluation and Policy Analysis*, 39(4): 593–619.

Graham, Bryan S. 2018. "Identifying and Estimating Neighborhood Effects." *Journal of Economic Literature*, 56(2): 450–500.

Hafalir, Isa E., M. Bumin Yenmez, and Muhammed A. Yildirim. 2013. "Effective affirmative action in school choice." *Theoretical Economics*, 8(2): 325–363.

Ladd, H.F., E.B. Fiske, and N.M. Ruijs. 2011. *School Choice and School Improvement*. Chap. Does Parental Choice Foster Segregated Schools? Insights from the Netherlands 233–253, Cambridge: Harvard Education Press.

Owens, Ann, Sean F. Reardon, and Christopher Jencks. 2016. "Income Segregation Between Schools and School Districts." *American Educational Research Journal*, 53(4): 1159–1197.

Pathak, Parag A, and Peng Shi. 2017. "How Well Do Structural Demand Models Work? Counterfactual Predictions in School Choice." November, NBER Working Paper No. 24017.

Ruijs, Nienke, and Hessel Oosterbeek. 2018. "School choice in Amsterdam: Which schools are chosen when school choice is free?" *Education Finance and Policy*, Forthcoming.

Söderström, Martin, and Roope Uusitalo. 2010. "School Choice and Segregation: Evidence from an Admission Reform." *Scandinavian Journal of Economics*, 112(1): 55–76.

Stoica, Victor Ionut, and Andreas Flache. 2014. "From Schelling to Schools: A comparison of a model of residential segregation with a model of school segregation." *Journal of Artificial Societies and Social Simulation*, 17(1): 1–10.

Yamaguchi, Kazuo. 2017. "Decomposition analysis of segregation." *Sociological Methodology*, 47(1): 246–273.

Tables

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	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)
2015	1,408	1,526	1,826	1,646	6,406
2016	1,482	1,466	1,783	1,578	6,309
2017	1,192	1,393	1,870	17,48	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.

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	56	55

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

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	70.06	47.52	78.45	67.13	65.07
	(27.56)	(42.87)	(39.73)	(42.80)	(40.92)
2015	23	28	25	26	102
2016	22	33	26	28	109
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.

Table 4: Average number of school with certain radiuses, by track

	Vocational (elementary)	Vocational (theory)	College	University	Total
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

Notes: The table presents average number of schools in choice set within a 1/3/5/10/15 km radius from students' home addresses.

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 1	0.338	0.093	0.201	0.032
Vocational 2	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).

Table 6: The determinants of school segregation: ethnicity

	Vocational 1	Vocational 2	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 2 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: The determinants of school segregation: household income

	Vocational 1	Vocational 2	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 2 describes the counterfactuals. Panel B translates the results of panel A into the relative contribution of different sources of segregation to total segregation

Table 8: Students' school preferences by ethnicity

	(1) Vocational 1	(2) Vocational 2	(3) College	(4) 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)
Avg. test score (t-1)	0.253***	0.842***	1.441***	1.016***
	(0.087)	(0.036)	(0.073)	(0.051)
Avg. test score (t-1) × Non-western	0.188*	-0.286***	-0.802***	-0.044
	(0.101)	(0.044)	(0.100)	(0.100)
Avg. exam score (t-1)	0.420***	0.765***	1.026***	1.879***
	(0.076)	(0.059)	(0.036)	(0.031)
Avg. 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. Standard errors clustered on the student-level are in parentheses.

Table 9: Students' school preferences by household income

	(1) Vocational 1	(2) Vocational 2	(3) College	(4) 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)
Avg. test score (t-1)	0.595***	0.745***	1.204***	1.109***
	(0.080)	(0.032)	(0.078)	(0.052)
Avg. test score (t-1) × Low-income	-0.297***	-0.172***	-0.527***	-0.379***
	(0.096)	(0.042)	(0.106)	(0.100)
Avg. exam score (t-1)	0.433***	0.682***	0.991***	1.860***
	(0.068)	(0.052)	(0.036)	(0.031)
Avg. 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. Standard errors clustered on the student-level are in parentheses.

Table 10: Segregation and the school 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 segregation year-by-year. The school district used the 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.

Table 11: Transition matrix between students' assigned track and counterfactual track based on their test score

Track	Revised track (based on test scores)				
	Vocational 1	Vocational 2	College	University	Total
Vocational 1	90.3	8.9	0.8	0.0	100
Vocational 2	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).

Table 12: The determinants of primary school teachers' discretion in their tracking advice

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 student × non-western			-0.013*			-0.031***
			(0.007)			(0.012)
Constant	-0.027***	-0.021***	-0.038***	0.053***	0.044***	0.077***
	(0.002)	(0.002)	(0.003)	(0.003)	(0.003)	(0.004)
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 students' test score. Robust standard errors are in parenthesis.

Table 13: Class segregation when tracking is based on students' test score

	Ethnicity		Household income	
	Dissimilarity	Mutual Information	Dissimilarity	Mutual Information
A. *Tracking based on advice*				
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 grades*				
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 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 alternatives (rows 2 and 4).

Figures

A Additional results

A.1 Willingness to travel and neighborhood composition

Table A1: Willingness to travel and neighborhood composition: ethnicity

	(1) Vocational 1	(2) Vocational 2	(3) College	(4) 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 the 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 A2: Willingness to travel and neighborhood composition: household income

	(1) Vocational 1	(2) Vocational 2	(3) College	(4) 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 the 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.2 The determinants of school segregation: dissimilarity