Single-Sex Primary Schools and Student Achievement: Evidence from Admission Lotteries*

Soledad Giardili†

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Abstract

In the last decade, single-sex education has experienced a major revival. However, whether same-gender schooling is an appropriate strategy to boost academic achievement is still an open question. I leverage randomized assignment of 4 and 5 years old children to schools in Malta to estimate the causal effect of single-sex education on short and mid-run outcomes. To alleviate concerns of endogenous school inputs, I compare students within the same school sector, in which coeducational and single-sex schools look alike in all dimensions except for the gender composition of the student population. I find that attending a single-sex primary school produces large and significant test score gains, for both boys and girls, at the end of primary school. Further, single-sex schooling at childhood has lasting effects on the choice of curriculum track at secondary school. Students make less gendered subject choices and are less likely to enrol in vocational subjects. Survey evidence suggests that the single-sex school effect is mediated through higher student school satisfaction, lower levels of classroom disruption and teachers' use of guided instruction.

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†School of Economics and Finance, Queen Mary University of London, Mile End Rd, E1 4NS. Email: s.giardili@qmul.ac.uk.

1. Introduction

Among a number of school inputs with potential to improve students' academic performance, single-sex education has recently attracted greater attention. This is partly due to the fact that gender-homogeneous schools and classrooms have climbed in the United States over the last decade in an attempt to raise the educational achievement of boys and girls.[1] Furthermore, its relatively low implementation cost —reshuffling students across classrooms or schools— makes this strategy very attractive.

Although the concept is not new, the rationale behind single-sex education is. Proponents of single-sex education argue that gender-homogeneous environments improve student outcomes by tailoring instruction according to gender-specific needs, improving classroom behaviour, and making gender stereotypes less salient (e.g., girls being labelled as less talented in math). Yet, there is little credible empirical evidence that attending single-sex schools improves students' educational outcomes. Moreover, the few studies available are based on high school or university students and there is no evidence at early school stages, where the aforementioned benefits may be particularly relevant.

This paper fills this gap in the literature by assessing the impact of single-sex education among children of primary school age. The empirical evidence on the effects of single-sex education found for adolescents or young adults may not hold for students at early ages. Early and middle childhood are key stages of an individual's physical and cognitive development (Eccles, 1999; Heckman, Pinto, and Savelyev, 2013). During this period, children develop new life habits and social roles and thus, this is where the foundation of gender gaps is laid (Ruble and Martin, 1998). It is also the period in which school inputs are most effective in improving students' cognitive development (Chetty et al., 2011; Heckman, Pinto, and Savelyev, 2013).

Evaluating single-sex education posts a challenge due to a lack of detailed data and natural experiments. Typically, students who choose to attend a single-sex school differ in important unobserved ways from those that choose a coeducational (coed) school. Further, even when it is possible to control for the sorting of students, estimates could be biased due to the fact that single-sex schools may differ in other dimensions from their coed counterparts, beyond classroom gender composition.

[1] In the U.S., the debate on single-sex education came back to the forefront after the amendments to the No Child Left Behind Act in 2006 that allowed government schools experimenting with single-sex education. By 2014, there were at least 133 single-sex schools and 794 public coeducational schools offering single-sex classes (Klein et al., 2018).

I leverage admission lotteries and rich administrative school records in Malta to quantify the short and medium-term effects of attending a single-sex school on students' academic outcomes. The Maltese setting offers a unique opportunity to disentangle the effect of single-sex schooling. First, admission into catholic primary schools is based on a centralized lottery system that creates an exogenous allocation of students to single-sex and coed schools. Second, due to institutional reasons, these schools are strongly homogeneous in a wide range of important dimensions (e.g., curriculum design, teacher qualifications, class size, etc.). I bring to bear unique school-level data to provide empirical evidence on this matter.

I start by studying the impact of single-sex education on children's scores on a national standardized test at the end of primary school and find large positive effects in all subjects areas. The effects on test scores are around 0.70σ for English and Maltese, and of 0.55σ for mathematics. To put this in perspective, the yearly equivalent of these overall effects is four to five times higher than the "per-pupil" effect found in class size studies (Jepsen, 2015). The effect sizes are also about half the effect size found in lottery-based studies for charter schools in Boston (Abdulkadiroğlu et al., 2011 and Angrist et al., 2012). Interestingly, I find that single-sex education benefit both boys and girls. Students show better average performance in all subjects, but particularly in those in which they do not traditionally have a comparative advantage. Girls' performance on math is 0.2σ higher than their performance in English and Maltese, while the boys' performance for the language subjects is twice the effect size for math.

The main effects are not driven by parents with strong preferences for single-sex schools. To measure preferences over the single-sex school attribute, I estimate a discrete choice model exploiting information on the school ranking submitted by the parents when applying to the lotteries. My results contrast with existing lottery-based studies which usually find that the effects are concentrated among those assigned to schools ranked high in their preferences.

I also examine whether attending a single-sex primary school affects the choice of subjects taken at secondary school. It is a well-established fact that there is a substantial gender difference in major choices and occupations (OECD, 2016) and this may be explained by the choice of curriculum track in secondary school (Card and Payne, 2017). In theory, single-sex schooling should reduce the intake of gender-typical courses, especially for girls, by making gender less salient, lowering competition (Riordan, 1990), and boosting academic self-concept (Sullivan, 2009; Kessels and Hannover, 2010; Sax, Shapiro, and Kevin, 2011). However, the existing literature on single-sex education does not find evidence that female high school students take more science courses compared to their counterparts in coeducational

settings (Jackson, 2012), or that they are more likely to join a university with a STEM college major (Park, Behrman, and Choi, 2018). One possible explanation is that interventions at adolescent age or later, such as single-sex school environment, come too late (Cunha and Heckman, 2007; Cunha, Heckman, and Schennach, 2010). Gender stereotypes are internalized early in life through teachers and parents (see, for example, Gunderson et al., 2012; Alan, Ertac, and Mumcu, 2018; Carlana, 2019) and traditional norms and beliefs about gender are presumably less likely to be challenged at these higher educational levels.

All Catholic secondary schools in Malta are single-sex and, at the end of Year 8, the second year at secondary school, students have to choose two elective subjects among a set of academic and vocational courses that supplement the national core curriculum. As in the case of primary schools, admission to secondary schools is orthogonal to individual characteristics. This is because there are only two paths to get into a catholic secondary school and both are ultimately determined by a lottery. Firstly, some primary schools have an associated secondary school in which case admittance is granted. Secondly, those attending a catholic primary without continuation, or those coming from the state sector, are admitted through a lottery system.[2] This characteristic, combined with the fact that the subject choice set offered to students does not differ greatly across schools, allows me to test whether students at single-sex secondary schools differ in their choice of subjects depending on the type of primary school attended. Because all students are exposed to single-sex education after coming from different primary schools, it is possible to think about this exercise as a test on whether single-sex school in high school comes too late in terms of affecting gendered course-taking patterns and preferences for STEM. The results are consistent with the idea that single-sex education at primary school age renders gender less salient, and thus students' choice of subjects is less gender-typical. Female students who attended a girls-only primary school do take more science compared to female students coming from a coeducational primary, while boys take less science. The effect on "prevalently female" courses (like hospitality and health and social care) is negative, although imprecisely estimated. Last, single-sex education reduces, on average, the likelihood of choosing vocational subjects as electives for both genders. Given that academic courses match university entrance requirements more than vocational courses, my findings suggest that attending a single-sex primary school increases the odds of boys and girls entering university.

Taken together, my results suggest that attending a single-sex school increases

[2]The transition from primary to secondary schools within the catholic sector is discussed in detail in Appendix Section E.

student learning and also has significant lasting effects on important determinants of career choice, such as the curriculum track decision. One possible explanation of these findings is that teachers and schools are able to specialize when they serve gender-homogeneous groups. Teachers may adopt pedagogical practices (types of examples used, the ability level to which the class is pitched) and discipline methods that best suit students of a given gender. Another (not mutually exclusive) mechanism behind the single-sex school effect could be related to the students' responses to the gender composition of the classroom, the direct gender peer effect. The presence of the opposite sex may be a distracting or an intimidating factor affecting the students' beliefs about their own academic abilities.

I study the mechanisms mediating the single-sex school effect using teacher and student survey data. I find that, compared to teachers in coed schools, teachers in girls-only or boys-only schools are significantly more likely to use teacher-guided instructions (i.e., children received instruction with examples and explanations). They are also more likely to report that the school employs and enforces clear rules of conduct. Given that I don't find significant differences among predetermined characteristics of the teachers, I interpret these results as teachers reacting differently to different gender composition environments. I then link lottery participants to survey data on students' school experiences, such as academic self-perceptions and bullying. I find that students who were drafted to attended a single-sex school report higher levels of school satisfaction and teacher-student relationship, compared to those who were not drafted.

This paper connects with a broader literature on school gender-composition. Some studies exploiting the natural variation in the share of female students in adjacent cohorts find that both male and female students perform better in predominately female classes (e.g., Hoxby, 2000; Lavy and Schlosser, 2011), but that a larger proportion of female peers increases the gender gap in STEM entry (Brenoe and Zoelitz, 2018).[3] Other studies based on randomized experiments are less conclusive (Whitmore, 2005), or find that gender homogeneity in classroom groups, measured by the number of surrounding desk mates of the same gender, is beneficial for both male and female students (Lu and Anderson, 2015). Nevertheless, there may be substantial differences between a learning environment with a high share of female students and one with only female students.

This study is most closely related to those evaluating the impact of single-sex

[3]Interestingly, Lavy and Schlosser (2011) further show that the positive effect are consistent with the "bad apple" theory of Lazear (2001). As girls are less likely to show disruptive behaviour, a higher proportion of girls in the classroom improves discipline and the teacher-student relationship.

education, which has become an active area of research in economics in recent years. Empirical studies exploiting the random or quasi-experimental assignment of students to coed and single-sex high schools (or classes) suggest positive effects of single-sex education for academic performance and educational achievements (Jackson, 2012; Park, Behrman, and Choi, 2013; Lee et al., 2014; Choi, Moon, and Ridder, 2014; Eisenkopf et al., 2015; Dustmann, Ku, and Kwak, 2018; Booth, Cardona-Sosa, and Nolen, 2018; Jackson, 2019).[4] However, besides the increase in academic performance, single-sex schooling has not been found to increase the likelihood that female students choose STEM programs (Jackson, 2012; Park, Behrman, and Choi, 2018). None of these studies evaluates the effect of single-sex school at childhood. The empirical evidence on single-sex education at the primary school level is almost non-existent, with the exception of Doris, O'Neill, and Sweetman (2013) who compare 9-years old students' performance in math across different school types in Ireland, addressing selection bias by controlling for pupil and teacher characteristics. They find suggestive evidence that boys perform better in single-sex schools, but there is no such evidence for girls.

This paper also makes a contribution to the literature that uses lotteries in school contexts. Admission lotteries have been used to study the impact of attending high performing schools (e.g., Rouse, 1998; Angrist et al., 2002; Abdulkadiroğlu, Pathak, and Walters, 2018) and charter schools (e.g., Hoxby and Murarka, 2008; Angrist et al., 2010; 2012; Dobbie and Fryer, 2015). Many of these studies use school-specific lotteries for a small share of slots after distance-based priority slots are secured for local students. This paper is different in a number of important dimensions. First, I leverage centralized admission lotteries (with no distance priority) for schools that serve 30 percent of the country's student population. Second, I work with lotteries for the whole island of Malta so my analysis is not affected by students moving out of the district, which is a typical problem in many lottery-based studies (where different assumptions produce conflicting estimates). Third, an additional characteristic of the Maltese setting is that students at catholic schools are comparable to the national student population, making the extrapolation of results less of an issue. This is because at least 40% of the population participates in each lottery and applicants

[4]Half of these studies (Park, Behrman, and Choi, 2013; Lee et al., 2014; Choi, Moon, and Ridder, 2014; Dustmann, Ku, and Kwak, 2018) are based on Seoul, South Korea, because students are randomly allocated across high schools within school districts. The details of the assignment rule are kept confidential and there is suggestive evidence that the student allocation actually follows a distance-based rule (Sohn, 2016). Besides the potential sorting of parent into school districts, this may also add selection bias through the endogenous sorting of parents into residential neighbourhoods within each district.

come from everywhere on the island.[5] Last, the single-sex schools analyzed here are particularly relevant for the country's accountability mandate as these schools are state-funded and part of the mainstream education system.

The remainder of the paper is organized as follows. Section 2 describes in detail the institutional background and the admission lottery system use by catholic schools. Section 3 outlines the data sources and the sample, while Section 4 provides summary statistics about the lottery applicants and the schools. Section 5 outlines the lottery-based estimation framework and presents the empirical results on end-of-primary test scores and the choice of subjects at secondary school. Section 6 provides evidence on the underlying mechanisms and Section 7 concludes.

2. Institutional Setting

2.1. Malta Education System

Due to its colonial inheritance, Malta education and examination systems closely follow the British model.[6] Compulsory education covers two levels, primary and secondary education, and students take national and externally graded exams at the end of each stage. The primary school cycle runs from Year 1 to Year 6 (ages 5-11). The secondary school cycle is of five years duration, running from Year 7 to Year 11 (ages 12-16). Bilingualism is considered as the basis of the educational system. Maltese and English, the two official languages, are taught at all levels within compulsory education. Although kindergarten is not mandatory, attendance is the facto universal.[7] Entry to each education level in is on a birth-year basis, meaning that enrolment to Year 1 is determined by the calendar year a child turns 5 years old. The school year runs from late September to mid June and there are three mainstream education providers: the Government (state schools), the Church (catholic schools) and the Independent sector (private schools).

Most of the students in Malta attend schools either from the state or the catholic sector. Independent schools are an expensive alternative, so catholic schools are

[5]Note that admission lotteries do not necessarily draw applicants from the general student population and there is no reason to assume that those who sign up for a school slot are coming from a random process. Thus comparing lottery winners and losers, in this and any other lottery-based study, may reveal little about the effect of schools on non-participant. However, extrapolation of the results is less of an issue if the amount of participants is quite high, as in the Maltese case.

[6]Malta was a British colony for 150 years, getting independence in 1964. It is the smallest country in the European Union by both population and area, and the most densely populated.

[7]Participation rates in 2014 were 95.4 percent and 97.7 percent for kindergarten I and kindergarten II, respectively (OECD Stats EU-SILC, 2014).

mainly attended by students that otherwise would attend their local state school.[8] As of 2015, the distribution of students across primary schools was 56% for state-run schools, 31% for catholic schools and 13% for independent schools. Practically every town and village in Malta has its own primary state school, while catholic schools are mainly concentrated in the Northern and Southern harbours (Figure 1).

Another distinct characteristic of the primary schools within the catholic sector is that they are of different types: 4 schools are coed, 10 are girls-only schools and 7 are boys-only schools. All state and private schools are coeducational.[9] When comparing the quality of schools across types, single-sex schools stand out. Figure 2 plots estimates of a proxy of school quality for single-sex and coed schools coming from regression of students end-of-primary test score on a full set of year and school fixed effects. While students at coed schools perform below the national average, those at single-sex schools are disproportionately on the right side of the distribution.

While admission to primary state schools is based on the student home' address,[10] catholic schools use a centralized lottery to ration seats. Since the nineties, Malta introduced several measures and educational reforms in order to democratize access and increase parental school choices.[11] As a consequence, the Catholic sector became embedded in the mainstream public school system. They ceased charging tuition fees, implemented the National Curriculum and the National Minimum Conditions Regulations (which establish standards of hygiene, safety and classroom dimensions and amenities), and became funded by the national government.[12] The agreement also prohibited catholic schools to select students on faith grounds or any other trait, so the Secretariat for Catholic Education (hereafter Secretariat), the central office of Church schools, adopted a lottery system in order to deal with student admissions.[13]

[8] Average tuition fee in private schools was around 3600 euros annually (14 percent of the average household disposable income) by the 2014-2015 school year according to Malta Today (2015).

[9] Until recently, except for the independent sector, the system of secondary education in Malta was single-sex. Since 2014, state-run secondary schools are gradually transitioning to mixed-gender schools, while catholic schools remains gender-homogeneous.

[10] Principals may accept students coming from a different town if the parents request it and the resources of the school allow it, though in conversations with the staff at the Ministry of Labor and Education those turn out to be exceptional cases.

[11] See Cutajar (2007) for an overview of the educational reforms in Malta, specially after independence.

[12] The government fully funded the budgeted salaries of the staff and gives additional 10 percent to cover other operational expenses. Catholic schools do have the right to ask for voluntary donations and parents pay for the school supplies.

[13] The island of Gozo, the second-largest island of the archipelago with 8 percent of the Maltese population, implements a separated admission lottery for the 4 catholic primary schools in the island. Gozitan lotteries are not part of the sample used in this paper.

2.2. Catholic Schools Admission Lottery

In January each year, parents submit an application on a paper form they pick up from the Secretariat or any catholic school. In the application, parents need to provide basic demographic information and a ranking of schools. The rank-order list (ROL) of schools is unrestricted, which means that parents can rank as many schools as they like from the ones available for a particular intake grade and year. There is no requirement for participating in the lottery, that is, parents do not need to satisfy any criteria to make their child a candidate, and it is costless.[14] Lotteries are held around April/May and there is one admission lottery per traditional intake grade, which are kindergarten and Year 1.[15]

Different schools differ in the school grade they start admitting students. For example, most coed catholic schools start serving student since Kindergarten 1 (KG1), while all single-sex school do it from Kindergarten 2 (KG2) or Year 1. However, this does not mean that coed schools participate exclusively in KG1 lottery only. Class sizes is capped at 15 and 20 for KG1 and KG2, respectively, and to 30 students for Year 1 onwards. Consequently, coed schools participate in each grade lottery, topping up classrooms (and single-sex school with traditional intake grade in KG2 also participates in Year 1 lotteries following the same logic).

Student matching mechanism.—The Secretariat uses a random serial dictatorship (RSD) to match students to schools. This is a centralized single-offer allocation mechanism in which single random lottery numbers act as a tie-breaking variable by placing students in a queue, and then processes students in that order. Then, assignment to schools proceeds as follows: the first student in the queue obtains her most preferred school as stated in the application form, the subsequent student obtains her top choice among schools with slots remaining, and so on until no seat remains in any school. Although boys and girls are placed in the same queue, the number of available slots in each school are set by gender beforehand. Obviously, there is no decision about the student gender in single-sex schools and coeducational school split slots evenly. This means that, even though there is a unique lottery draw for all applicants (in a particular year for a particular grade), the assignment mechanism can be though as two separated assignment mechanism, one for each gender.

[14]There was no charge for applying up to 2010. Administrative cost were introduced in 2011 of about 10 euros by that time.

[15]Places at higher grades are only made available when a student leaves, which is a very infrequent event. These slots are allocated at the discretion of the school principals.

In 2011 the allocation mechanism was slightly modified. Instead of requiring parent to submit a rank order list of schools with the application, they have to attend a public event where the final allocation of schools is decided. In this public event, parents are sequentially called to select a school following the order determined by their lottery number. After each decision, the corresponding slot is not available for the subsequent candidate. Despite of the change in the design, note that the final allocation of students to schools is identical to the one that the mechanism used before 2011 would have generated.[16]

A random serial dictatorship is the easiest mechanism to implement in an allocation problem and is strategy-proof. By only using the preference over schools information when it is the applicant's turn to make the choice, the best strategy for an applicant is to report truthfully. This mechanism also has the property of being fair (equal treatment of equals), since each student has the same chance to appear in each position in the queue (Pathak, 2011).

School Priorities.—Schools also ration their seats using priorities. Importantly, priorities are not school-specific (i.e., do not vary across schools). The priority groups are arranged in lexicographic order based on the following traits: applicants with already-enrolled siblings; children from church-run homes; children of employees; special cases (low-income family, single-mother); and children with special educational needs (SEN). Due to national regulations, the number of SEN students is capped at two slots per classroom, so a separate lottery is held for them. Based on preferences, slots at each school are first allocated to students belonging to these priority groups, while the rest of the vacancies are filled by the single lottery number as described above.

3. Data

This section provides an overview of each data source and the criteria used to select the sample. Appendix A shows the survey questions an additional details on variable definition.

The first dataset is the lottery data, which combines administrative data with information extracted from the lottery application forms.[17] The application form

[16]The main difference in term of data is that, with the change, I can not observed parents full set of preferences over schools.

[17]Data collection for this paper involved the scanning and digitization of the individual application forms (Appendix Figure A1). The preservation of the lottery data was not a priority after the admission process was completed and prevents me to get information before 2008 and for the

data contain student's full name, gender, date of birth, parent's name, father or mother ID, home address, sibling relation, special educational need status and the preference order of schools. The administrative data contain records of school capacity, the student priority grouping, lottery numbers and lottery outcomes (i.e., identifying which applicants were the successful candidates and to which school they were matched).

I exclude from the lottery data applicants that have granted access through priority (e.g., those who got a slot because they have an older sibling already enrolled). Therefore, I keep only those in the marginal priority group, which are the applicants for which lottery number alone determine whether they get an offer (randomized applicants). As applicants with special education needs were also randomized, they are part of the analysis sample.[18,19]

I use KG2 and Year 1 lotteries, which are the intake grades of single-sex schools, for the cohort of applicants born in 2005 and 2006. Additionally, I include a Year 4 lottery used to fill up three new boys-only schools. This exceptional lottery only affected the 2005 cohort.[20] Admission lotteries are competitive. Every year and for every intake grade, there are about 1.000 applicants and, on average, one out of four receives a single-sex offer. This can be seen in Table 1, which reports information about the year of the lottery, the number of applicant (total and randomized), and the share that received an offer to attend a single-sex catholic school.

The lottery data allows me to follow the cohorts born in 2005 and 2006 at every year in which they could participate in an admission lottery. For example, if a child does not receives a lottery offer in KG2 and reapplies the following year to the Year 1 lottery, then I observe lottery participation and lottery outcomes in both instances. As will be discussed in the next section, observing the full application patterns of student is important for the identification strategy.

I link the lottery data to the End of Primary Benchmark (Benchmark) exam data, a test administered on a national basis by the Department of Curriculum

KG2-2009 lottery.

[18]SEN lotteries are included except for those with no losers (i.e., degenerate lotteries). Lotteries held for students with special educational needs are small, specially for girls and, except one, there is no variation in the instrument as all the girls got an offer.

[19]The sample should also be restricted to applicants to the relevant sector, i.e., those that apply to single-sex schools by ranking them anywhere in the application form, and exclude those than only rank coed schools. This is of little concern here since, among the randomized applicants, only 10 parents have exclusively chosen coed schools in their submitted ROL of schools.

[20]Three of the seven boys-only schools opened in 2011, with rolling-up in Year 1 and Year 4. In order to quickly fill the schools, lotteries were held at Year 1 and Year 4 for 3 consecutive years starting from 2011. The last Year 4 lottery was held in 2013 and everyone born in 2005 was eligible to apply.

Management. The Benchmark is a standardized examination for Year 6 students, at the end of their primary cycle. The assessment measures speaking, listening, reading comprehension and writing skills in English and Maltese, and mental and written skills in mathematics. The test scores were standardized by subject and year to have mean zero and unit variance among all test-takers. The overall match rate between randomized students and the Benchmark is 82 percent. Several reasons explain not achieving a perfect match, which are described in detail in Appendix B. I assess the quality of the matching procedure by testing if the match rate differ by lottery status. Results of this exercise suggest that lottery winners are not more likely to be matched than lottery losers (0.002 , SE = 0.015).

I also collected information on students' choice of curriculum track that covers the last three years of secondary education. At the age of thirteen, Year 8 students have to choose two elective subjects among a set of academic and vocational courses that supplement the national core curriculum. Elective subjects cover a wide range of fields from home economics or hospitality, which are prevalently female courses, to chemistry or physical education, which are prevalently male courses. In practice, this curriculum track largely affects the afterwards choice of college major (Calleja, 2008).[21] A number of characteristics of the catholic secondary education guarantee that students face a similar decision among the set of elective subjects independently of whether they attended a single-sex or coed primary school. First, all schools offer the same three science courses (physics, chemistry and biology). Second, it is possible to observe in all cases a wide number of topics that span very similar fields. Finally, conditional on gender, the available subjects are quite similar irrespective of the type of primary school education. Appendix E describes in more details this setting and the transition from primary to secondary school within the catholic sector.

Finally, I use survey data from the Progress in International Reading Literacy Study (PIRLS) 2016. PIRLS is an international assessment conducted by the International Association for the Evaluation of Educational Achievement (IEA) and designed to measure trends in reading comprehension skills among 10-year old students. The survey includes, besides some students and teachers background data, information about the home literacy environment, the school curriculum and curriculum implementation and the instructional practices. The target population in Malta consists of students enrolled in Year 5 of compulsory primary education in

[21] For instance, admission to medicine school requires A-levels in biology or chemistry, and students are strongly encouraged to take these elective courses if they aim to enroll in any medicine-related fields at university.

2016, a year before the Benchmark examination.[22] The PIRLS sample comprised the whole population of 10-year-olds in 2016, which correspond to 2006 cohort in the lottery data. I match both dataset using student full name and date of birth.[23]

4. Applicants and School Characteristics

Applicants Representativeness.—Given the spatial concentration of catholic schools in the island, it could be the case that these schools serve students who are disproportionately located in surrounding neighbourhoods. I find that this is not the case as applicants come from everywhere in the island. In order to show this, I link each applicant address to their census locality and compute the number of applicant per locality in the KG2 and Year 1 lotteries held in 2010. Then, I compare the number of applicants per locality with the census population counts of children of corresponding ages (4 and 5, respectively). Figure 3 shows the results of this exercise. Panel A shows that the KG2 lottery contains 40 percent of the 4 years old population, while Panel B shows that the Year 1 lottery contains 28 percent of the 5 years old population.[24] The applicant data appears quite representative as the census population can explain 84 percent and 77 percent of the variation in the applicant population for each intake grade. Further, the figure shows that this relationship is well approximated by a linear function. This implies that, on average, localities are proportionally represented among the pool of applicants.[25]

Parents Ranking of Schools.—There is no catholic school undersubscribed. When submitting the ROL, 50 percent of the applicants rank all feasible schools. Among those that rank a fewer number of schools, the typical is to rate 6 out of 10 schools. The distribution of applicants across proportion of schools ranked is shown in Figure 4. The ranking of schools also reveals that parents prefer, in general, single-sex over coed schools, and this holds independently of the applicant's gender. Figure 5 shows average ranking per school for girls and boys separately. Note that the lower the

[22]PIRLS assesses students in their fourth year of schooling, which corresponds to the fourth grade in most countries. In Malta, however, PIRLS is administered to students in their fifth grade. This is because the statutory school starting age is five and so Year 5 test better match the assessment to the achievement level of students.

[23]Access to student date of birth was subject to approval by the IEA Amsterdam. Students surname and name was retrieved from the Benchmark.

[24]Using applicants participating in lotteries held in other calendar years yield quite similar results.

[25]Appendix Table C1 also shows that the applicant population (independently of the lottery outcome) is also equally distributed across the four quarter of birth, as the distribution of the general population is. There is also no difference between the share of the applicant and the general population that have a popular surname.

value, the more preferred is a school. Preferences play a central role in lottery-based studies at isolating the random components of the data-generating mechanism. The empirical strategy in Section 5 will discuss this further.

Balance.—Table 2 presents summary statistics and test for balance among lottery winner and losers.[26] To formally test for the quality of the lotteries, I regress different predetermined variables on a dummy variable indicating whether the applicant won the lottery, where winning the lottery means that the applicant is offered a slot in a single-sex school. All regressions control for lottery fixed effect (interaction of year and grade of application, SEN status and gender) in order to make use of the within-lottery randomness only. Point estimates and standard errors of this test are reported in column 3. Lottery winners and losers are similar on the range of predetermined observable characteristics. Note that differences are not only statistically insignificant but also substantively small in magnitude. The F-statistics fails to reject the null that the covariates, taken as a whole, are significant (p-value 0.775).[27]

School Inputs.—Although the catholic sector is part of the mainstream public education system in Malta, there are a number of dimensions in which catholic schools differ from the state-run schools. The former are privately managed, have more discretion over the hiring and dismissal of teachers, the school text and pedagogical approaches, and may extend activities beyond the core curriculum. There are also substantial differences in average class sizes. Due to the fact that there is practically one state primary school per locality, the student population at some of those schools is relatively low, potentially leading to greater individualized instruction, while catholic schools operate under full capacity.[28,29]

[26]This balance table (as well as the ones included in the appendix) excludes the KG2-2009 sample, as the application form was not found.

[27]Balance regressions were also performed for the single-sex offer within the sample of lottery winners for a catholic school slot and for the catholic offer. The results, reported in Appendix Table C2, are similar to those described here. There is also not significant differences between randomized and non-randomized applicants. If student admitted inside and outside of lotteries are different in ways related to student outcomes, the inferences of this study to that population will be limited. The comparison of students who got admission to single-sex schools through priority (i.e., whose lottery numbers had no impact on admission) and those entering because they were randomized are reported in Appendix Table C3.

[28]The average class size at state primary schools is 17.1 (SD 3.69) students, well below the established regulatory threshold of 30 (or 26 in cases where there is at least a students with special educational needs). In catholic schools the average size of the class is 25.4 (SD 0.87) students.

[29]Surprisingly, the religious instruction seems not to be the overriding factor that differentiate these two school sectors. Roman Catholic religion is taught in all state-run schools and for the same amount of hours per week as in the catholic schools. Parents do have the right to opt-out but very

On the contrary, for historical and institutional reasons, the Catholic sector seems to comprise a more homogeneous set of schools. I use rich administrative data on teachers and school characteristics to test this empirically. Columns 1 and 2 of Table 3 report mean values of schools staff characteristics (Panel A), teacher characteristics (Panels B) and other school-level characteristics (Panel C) for coed and single-sex catholic schools, respectively. Column 3, which reports the difference in mean covariate value, shows that coed and single-sex schools are statistically indistinguishable. For example, teacher in both school types are predominantly female (96%), ruling out the student-teacher gender effect widely explored in the educational literature.[30] There is no difference in teachers age (∼37 years old), qualification (∼83% declare to have a bachelor degree) and years of experience (∼10 years). There is also no difference in teacher wages, as one would expect given they are mainly determined by teacher's years of experience and education levels.

I also find statistically indistinguishable school-level characteristics between single-sex and coed catholic schools. There is no difference in the total number of hours per year of instruction, nor in the number of hours per week dedicated to each subject (∼5 hours per week for English, Maltese and math). Single-sex and coeducational catholic schools do not seems to differ in terms of geographical location neither, which may trigger a differential access to resources. Last, there is no difference in class size (∼25.5), which is consistent with the information that catholic schools works in full capacity.[31] Appendix Table C4 shows the single-sex school breakdown for girls-only and boys-only catholic schools.

few choose to do it (2% during the 2008-2009 scholastic year and 6% during 2015-2016).

[30]For example, Bettinger and Long (2005); Dee (2007); Paredes (2014); Antecol, Eren, and Ozbeklik (2015) and Lim and Meer (2017). A potential concern when evaluating the effect of single-sex education is that the high proportion of same-gender teachers in girls-only and boys-only schools may confound the interpretation of the results. Same-gender teachers may provide better role models, especially for girls, and may have some advantages in managing student discipline and classroom order, especially for boys and thus, the single-sex school effect may simply be reflecting the teacher-student gender matches. Park, Behrman, and Choi (2018) and Lee et al. (2014) address this issue for students in single-sex schools in Korea. Park, Behrman, and Choi (2018) find that the gender matching between students and math teachers are significantly related with test scores and STEM outcomes for male students in boys-only schools. They do not find an effect for teachers in other subjects or for female students in girls-only schools. Lee et al. (2014) also find little evidence that the boys-only school effect varies by the gender composition of the teachers.

[31]The maximum number of student allowed in each primary class is thirty. This number is reduced by two for each students with a statement of needs in the class. The average class size of 26 student is consistent with the regulation that allow only two SEN students per class.

5. The Effect of Single-Sex Primary Schools

5.1. Identification Strategy

To identify the effect of attending a single-sex primary school, I exploit the random allocation of students to single-sex and coeducational schools within the catholic sector. The identification strategy relies on two facts. First, the lottery numbers generate exogenous variation in the type of school offered to the student. In practice, this allocation is exogenous when comparing applicants who face the same risk of assignment to a single-sex school. Second, as discussed in the previous section, single-sex and coed schools catholic schools are similar in many observable dimensions. Thus, differences in students performance are mainly attributable to the homogeneous-gender composition rather than other characteristics of the schools. The estimating equation takes the following form:

$$y_i = \beta_1 SingleSex_i + \beta_2 Catholic_i + \gamma' R_i + \delta' X_i + \phi_{t(i)} + \varepsilon_i, \tag{1}$$

where y_i is the academic outcome of student i. The term $SingleSex_i$ is an indicator equal to 1 if the student attends a single-sex primary school and zero if not.[32] The term $Catholic_i$ is an indicator equal to one if the student attends a catholic school (either single sex or coed) and zero otherwise. The vector X_i represents a set of applicants' baseline covariates that (such as locality), although not necessary for identification, are included to increase precision. The dummies R_i, described below, are indicators for lottery-specific *risk sets*. The term $\phi_{t(i)}$ are time fixed effects that capture shocks in the test year that may affect all students, while ϵ_i is the error term. I interpret equation (1) as describing the average achievement that would be revealed by assignment to single-sex education in an experiment that holds catholic education fixed. Our coefficient of interest is β_1.

Ordinary least squares (OLS) estimates of equation (1) would capture the average causal effect of single-sex schooling under full compliance. In practice, administrative assignment may fail to conform fully to a randomized design as some students may not comply with the treatment that the lottery assigns to them. For example, students who are offered a single-sex school slot may decide to deviate from assignment and attend their local state school. Analogously, students not offered a slot may manage to get admission by the discretion of the principals or gaining sibling priority when

[32] Given that all single-sex schools are catholic, this term is equivalent to the interaction between a catholic indicator and the single-sex indicator. For notation brevity, I use the simplified notation.

a younger sibling wins a lottery. As this would potentially bias OLS estimates, the variables $SingleSex_i$ and $Catholic_i$ are instrumented with lottery offers. The excluded instruments are Z_i^{ss} and Z_i, which represent single-sex and catholic offer indicator, respectively.[33]

Risk sets.—To operationalize the identification strategy it is necessary to accommodate reapplications and parental preferences over schools. In relation to reapplication patterns, take for example the basic setting faced for the cohort of students born in 2005. There are three lottery participation possibilities. They may participate in the lottery for KG2 only; they may participate in the Year 1 lottery only; or they may participate on both KG2 and Year 1 lotteries (in two consecutive years). So these participation patterns defines three possible groups. The same applies for the cohort of students born in 2006. Because parental characteristics may differ according to this application pattern, I solve the selection controlling for group membership, meaning that the identification comes from lottery-induced variation within groups.[34] This is in the spirit of the self-revelation approach of Dale and Krueger (2002) and standard in the lottery-based literature.

On the other hand, wining-losing probabilities are not independent of the revealed preferences and one would like to compare parents who submitted a similar ranking of preferred schools. In practice, there are different ways of leveraging lottery assignments independent of potential outcomes. One may focus on offers at student's first-choice school (Abdulkadiroğlu, Hu, and Pathak, 2013; Deming, 2011; Deming et al., 2014; Hastings, Kane, and Staiger, 2009) or condition on the full set of schools ranked (Pop-Eleches and Urquiola, 2013; Lucas and Mbiti, 2014). Note that the last case is only possible when the number of observations is large relative to the number of schools. However, when the number of schools is large, there is an obvious dimensionality constraint given by the extreme large number of school-rank combinations one may find in the data. To deal with this issue, one can impose ad hoc solutions of the type conditioning to the three top choices or, alternatively, control

[33]In practice, given that each lottery in which a student participates is a valid instrument for single-sex schooling, I leverage here all the lotteries each cohort participates. Thus Z_i^{ss} and Z_i correspond to a set of indicator for lottery offers at different grades. I examine the robustness of the results by considering defining the instruments as the outcome of the first lottery only.

[34]Parents seems to be persistent in attempting to get a place at catholic schools, with round 70 percent of rejected first-time applicants reapplying a second time. I empirically investigate the presence of observable differences in parental characteristics across applicants with different application patterns and find no statistically significant difference. This is shown in Appendix Figure D1. Because the baseline data is limited, I remain agnostic about the possibility that unobserved characteristics may be significantly different and report results with students' application pattern adjustment.

for the simulated conditional probability of getting admission (propensity score) as proposed by Abdulkadiroğlu et al. (2017).[35] This method has two advantages, on the one hand it reduces the dimensionality problem and, on the other hand, it maximizes the number of individuals that contributes to the estimation of the average treatment effect. Intuitively, the propensity score can be calculated by drawing lottery numbers and running the allocation mechanism many times (while keeping constant applicants preferences and school priorities and slots), and computing the resulting average assignment rates. I follow their analytic formula to generate for each applicant a probability of receiving an offer from a single-sex school. The drawback is that I lose observations given the changes in the lottery system from 2011 onward, where the Secretariat cease asking parent the rank order list of schools.

5.2. Impact on End-of-Primary Test Scores

Table 4 shows the estimated single-sex school effect on English, Maltese and math test scores. I report results using all the lotteries affecting cohorts 2005 and 2006 (columns 1-3), and for the subset of lotteries with parents preferences over schools (columns 4-6). The first stage column (1 and 4) indicates that, on average, receiving a singe-sex offer increase the probability of attending a single-sex school by at least 60 percent. The reduced form estimates, reported in columns 2 and 5, indicate that being offer a single-sex slot is associated with an increase in test scores of all subjects. The 2SLS estimates, reported in columns 3 and 6, reveal that student at single-sex schools perform significantly better than those at coed schools in all the subjects. Point estimates are largely consistent across the individual subjects, on the order of 0.63σ for English, 0.74σ for Maltese and 0.55σ for math, when conditioning on propensity score.[36]

To put these results in perspective, the yearly equivalent of these overall effects

[35] Abdulkadiroğlu et al. (2017) evaluate the efficiency gains obtained by controlling for the propensity score relative to, for example, schools ranked first using Denver centralized school assignment. Moreover, they show that the propensity score is applicable to any centralized mechanisms satisfying the equal treatment of equals (ETE) property.

[36] The results also reveal (not shown) that students in coed catholic schools performed worse (compared to student in coed state schools) in all of the core subjects. The point estimates for *Catholic* are consistently negative (and significant in some cases). This is a puzzling result and hard to reconcile with the fact that all catholic schools are highly demanded every year. One possible explanation could be related to the smaller and more manageable class sizes at state schools. Another possible explanation could be that parents with a lucky lottery number for a catholic slot relax after securing admission, while parents of applicants that did not manage to get any catholic slot compensate by putting more effort. Cullen, Jacob, and Levitt (2006) provides empirical evidence on the substitutability between parental involvement and school quality in the education production function at Chicago Public Schools.

are in the range of 0.07 to 0.1 standard deviations. This is four to five times higher than the "per-pupil" effect found in class size studies (i.e., the effect of reducing the class size by one student) but less than half of the charter schools effect. These findings are consistent with the results documented in the literature on single-sex education for students at higher educational levels, of about $0.15 - 0.20\sigma$ after 3 years of attending a single-sex middle or high school (Jackson, 2019; Lee et al., 2014; Dustmann, Ku, and Kwak, 2018).

Results described above leverage all the lottery outcomes. Some studies that also deal with a high reapplication level use only the outcome of the first lottery an individual participates for the estimation of the treatment effect (see, for example, Angrist et al., 2010; Ketel et al., 2016). As a robustness test, I conduct the same analysis using as instrument the outcome of the first lottery alone. Results, reported in Table 5, are statistically indistinguishable from the main results except for the math outcome that is not significant.

5.3. Response Heterogeneity

Table 6 explores heterogeneity in the single-sex school effect across student gender. I find that both, boys and girls, have meaningful test score gains by attending a single-sex school. Column 5 shows that the effects for girls are statistically significant for the language subjects, with a size of about 0.40σ for English, 0.53σ for Maltese. Column 6 reports the results for boys, which are all statistically significant. Overall, the impacts appear to be larger for boys than for girls in the language subjects, and smaller for math. Overall, these findings show that single-sex education at childhood improves student performance but, in particular, for those subjects in which girls and boys do not traditionally have a comparative advantage. In addition, the finding that single-sex education benefit both, boys and girls, contrasts with the recent studies evaluating single-sex schools or classrooms at high school or university. For example, Jackson, 2012; and Booth, Cardona-Sosa, and Nolen, 2018 find significant effects only for female students, while Lee et al., 2014 and Jackson, 2019 find evidence only for male students.

Given that the assignment mechanism used by catholic schools is strategy-proof (i.e., applicants rank-order list of schools measure parents true preferences), I next examine treatment effect heterogeneity along preferences over single-sex schools. As explained in Subsection 2.2, parents are asked to rank schools in order of preference from their first to their last choice. They do not have limitations in the number of schools to rank and, on average, they rank 60 percent of the schools in their choice set. Multiple-ranked responses are superior to single (first) choice because, in the

later case, it is difficult to disentangle whether the stated choice is the result of a strong preference for some particular aspects of the choice or due to an unusual error term. With rank-order lists one can gather more information, because the same individual provides multiple outcomes by removing the prior chosen school from the subsequent choice set. In other words, if parents systematically choose schools who share a common attribute, one can infer that there is a strong preference for that attribute.[37]

I use a mixed rank-ordered logit model on parents ranking of schools data to infer the intensity of preferences over schools' attributes (McFadden and Train, 2000).[38] In particular, I estimate for each applicant i the weight ($\hat{\theta}_i$) their parents place on the single-sex attribute when choosing schools. The fact that this parameter depends only on baseline data and is independent of the lottery outcome, motivates the following second stage equation:

$$y_i = \gamma_1 SingleSex_i + \gamma_2(SingleSex_i\hat{\theta}_i) + \gamma_3 Catholic_i + \gamma_4' R_i + \gamma_5' X_i + \phi_{t(i)} + \mu_i. \quad (2)$$

The coefficient γ_2 indicates whether effects are larger or smaller as the weight over single-sex attribute increases. Note that the corresponding first-stage equations add the interaction between $\hat{\theta}_i$ and the instrument for identification.

Results of this test are shown in Figure 6. Although effect are imprecisely estimated they are informative of the heterogeneous treatment effect by preference for single-sex schooling. As expected, effects are weakly increasing with $\hat{\theta}_i$, specially for the language subjects. However, it is worth noting that the highest quartile seems not to drive the results in any of the test scores.

[37] Empirical studies on students' heterogeneous preferences over school attributes based on a demand system approach can be found in Hastings, Kane, and Staiger (2009) and Abdulkadiroğlu, Agarwal, and Pathak (2017).

[38] This mixed logit can approximate a random utility model of parental choices of the form: Assume $U_{is} = \beta_i' X_{is} + \epsilon_{is}$ is the expected utility for student i of attending school s, and that X_{is} represents a vector of attributes describing s (share of teachers with a bachelor degree, average wage, average teacher tenure, school proximity, being single-sex or a coed school). If parents choose among all possible schools in the choice set S_i based on whether it delivers the highest utility, then he probability of choosing school s in the first choice is given by $Prob(c_i^1 = s) = Prob(U_{is} - U_{ik} > 0)\, \forall k \neq s$. It is assumed that the following choices are made in a similar manner, except for the fact that the choice set excludes schools already chosen, until a preference order is obtained over all schools. Given this assumptions, the probability of parent i having a particular ranking of alternative schools is modeled by a rank-ordered logit as the product of of best choices. For example, for the case of three alternative schools we have $Pr_i(ranking\ s_a, s_b, s_c) = Pr(s_a\ 1st\ best) * Pr(s_b\ 2nd\ best)$. Parameters were estimated by maximum likelihood estimation (MLE) following Lancsar, Fiebig, and Hole (2017).

5.4. Impact on Option Subjects

Table 7 presents 2SLS estimates of the effects of single-sex school on the probability of taking at least one science subject, the probability that both subject options taken are science, the probability of taking at least one prevalently female subject, and the probability of taking at least one vocational subject. These estimates follow the same lottery-based specification in equation (1) using all randomized applicants born in 2005 and 2006. Column 1 shows result for the whole sample, while column 2 and 3 breakdown the overall effect by gender.[39] I present here results controlling for application pattern (as the first three columns in Table 6).[40]

Results are consistent with the idea that single-sex education renders gender less salient, and thus students choice of subjects is less gender-typical. Girls that attended a girls-only primary school are 21 percent more likely to choose all science subjects compared to girls coming from coed catholic schools (column 2). Similar point estimates, but on the opposite direction, applies for the probability of taking at least one prevalently female subject, though imprecisely estimated. Boys are 11 percent less likely to choose at least one science course compared to boys coming from a coed primary (column 3). Last, both female and male students are less likely to choose vocational subjects as electives. Given that academic courses match university entrance requirements more than vocational ones, these results suggest that attending a single-sex school increases the odds of boys and girls to enter university.

The effect of single-sex education on (less) gendered course taking documented here marks a departure from other studies that found no effect of single-sex schooling on STEM course selection (Jackson, 2012) and career choices (Park, Behrman, and Choi, 2018) for female students. One possible explanation of these null effects may be related to the timing of exposure to a gender-homogeneous learning environment. While Jackson (2012) and Park, Behrman, and Choi (2018) look at students assigned to different school types at secondary school, here I look at students exposed to single-sex education at childhood that are, arguably, more likely to be influenced by the environment.

A possible concern about the single-sex effect on later academic outcomes is that the characteristics of the attended secondary schools could be correlated with the type of school attended in primary level. This raises the question of whether the observed differences among single-sex and coed graduates is attributable to other

[39] Instead of running separate regression by gender as I did with test scores, I fully interacted the right hand side variables with a female indicator.

[40] Data collection is still in process and using only applicants in lotteries with preferences will produce relatively small samples. Hence, results must be interpreted carefully.

factors such as facing different curriculum alternatives. However, this is much less of a concern in this setting. Admission to catholic secondary schools is ultimately determined by lotteries, as in the case of primary schools. In addition, all schools provides a wide but very similar subject choice sets, that includes both vocational and more academically-oriented courses. Appendix E provides additional information regarding option subjects and the transition from primary to secondary within the catholic sector.

6. Mechanisms of Single-Sex Schools

In this section, I use student and teacher survey data to study the underlying mechanisms that led to the substantial impact of single-sex education on the academic achievement of boys and girls. The educational literature points out that the single-sex school effect operates through direct and indirect channels. On the one hand, gender peer effects may be at work as a results of the student interactions in the classroom (e.g., peers discipline or bullying incidents, self-concept of ability). On the other hand, there may be changes in the teacher behavior in single-sex schools. These indirect channels refer to the gender alignment in the teacher pedagogical practices, the discipline methods used, as well as the ability-level to which the class is pitched (Jackson, 2019). Although the survey data do not allow to fully explore and measure all the mediating factors behind the positive effects of single-sex education, it can provide important insights.

I evaluate teacher and student responses to school type using PIRLS 2016 questionnaires. The teacher survey covers Year 5 teachers only and not the whole school staff. The student survey covers the student cohort 2006. Hence, the results of this analysis should be taken with some caution as small sample sizes may lead to rather imprecise estimates. The estimates presented here are based on the main specification, so all comparisons are made among teachers (students) in single-sex and coed catholic schools. I split the single-sex school variable into two dummy variables, a girls-only and a boys-only school dummy, so estimates are deviations from teachers' (students') answers from coeducational schools. With the exception of absenteeism, all other measures are standardized to have mean zero and standard deviation of one. Appendix A provides a detailed description of how the outcomes examined in this section were constructed.

Teachers.—Teachers at single-sex schools show no systematic difference in their level of satisfaction with the profession and work compared to teachers at coed schools, but they do report a better quality of the teacher-student relationship. I

combined 5 items to measure teacher satisfaction: "I am content with my profession as a teacher", "I find my work full of meaning and purpose", "I am enthusiastic about my job", "My work inspires me" and "I am proud of the work I do", while the quality of teacher-student relationship is based on answers to the item "The students are respectful of the teachers". Results are shown in Panel A of Table 8. The first column reports estimates of the effect of girls-only schools on teacher responses while the second column reports estimates of boys-only schools. The effects on teacher satisfaction in both school types are large and negative but not statistically significant. There is, however, differences in the quality of the relationship between students and teachers. Teachers working in girls-only schools are more likely to report that students are respectful to them. The estimates for teachers working in boys-only schools are also positive, but not statistically different from zero.

Consistent with the hypothesis that boys are more disruptive than girls (Lavy and Schlosser, 2011), teachers in girls-only schools are less likely to report that students misbehave while the opposite is true for teachers at boys-only schools, though imprecisely estimated. The survey does not allow to differentiate if there are different discipline methods across school types, but teachers at girls-only schools are more likely to report that the school employs and enforces clear rules of conduct. The difference between teachers in boys-only schools and those in coeducational schools is not statistically significant. These results on classroom disruption and school discipline are reported in Panel B of Table 8. Classroom climate is captured by the teacher report on students' general behavior ("The students behave in an orderly manner") or if they report that disruptive students limits the teaching. School discipline is measured by two dummy variables related to the teacher agreement with the following statements: "This school has clear rules about student conduct" and "This school's rules are enforced in a fair and consistent manner".

Instructional practices in both girls-only and boys-only schools seem to be more teacher-guided, meaning that teachers are less likely to leave students to work independently on an assigned plan or goal. However, there is no evidence that teachers at single-sex schools aligned pedagogical practices according to the prevalent gender in the classroom (engaging students' interests, use multiple perspectives or link content to prior knowledge). Measures of teacher instructional practices are shown in Panel C of Table 8. It also shows that teachers in girls-only schools are more likely to report that they use individualized methods of teaching compared to their counterpart at coed schools, though not statistically significant. On the contrary, teachers at boys-only schools are marginally less likely to report giving individualized feedback and instructions. Last, in both single-sex school types, teacher report less use of ability-grouping methods for teaching (tracking). Although none of the effects

is statistically significant, the negative pattern is consistent with the argument that gender-homogeneous environments should produce less variation in student abilities withing a given class.

Complementary to school environment and teachers' instructional practices is that of the effect of single-sex school on the school emphasis on academic success. Teachers at girls-only schools reported significantly lower curriculum expertise while there is no such evidence for teachers at boys-only schools, as shown on Panel D of Table 8. Curriculum expertise is a index derived from how teachers characterized understandings of the school's curricular goals and their degree of success in implementing the school's curriculum. Teachers were also surveyed about their students' desire to do well in school and their ability to reach academic goals. Estimates are small and insignificant indicating that teachers' perception of students' performance are comparable across school types.[41]

School principals were also surveyed about the quality of the teacher-student relationship, classroom environment and school emphasis on academic success. Estimates using the principals sample confirm the main finding described in this section using the teacher survey. Overall, single-sex schools provides a better teacher-student relationship and classroom climate. The results using the principal survey data are reported in Appendix Table F2.

Students.—Students satisfaction with the school do not seems to differ according to the type of school attended. However, single-sex schooling do seem to impact other measures of student (dis)satisfaction, like truancy and bullying. This is shown in Panel A of Table 9. The student satisfaction index is derived from three survey questions which ask students how much they agree with the following statements: "I like being in school", "I feel like I belong at this school", and "I am proud to go to this school". Coefficients are in both cases positive but not statistically significant. Coefficients are both positive, much higher for girls than for boys, but not statistically significant. In relation to student absenteeism, girls in girls-only schools are 27 percent less likely to be absent from school than girls at coed schools. The point estimates for boys is much smaller (2 percent) and not statistically significant. Estimates also reveal that boys-only schools lead to a significant reduction on bullying incidents compared to coed schools.

Boys in single-sex schools are less likely to report that teachers are fair to them,

[41] If I exclude from the sample teachers working in the 3 schools that do not participate in the Benchmark, and thus do not contribute to the estimates on test scores, I get similar findings to the ones present here. Appendix Table F1 show the results of this exercise.

as can be seen in Panel B of Table 9. This is striking, given the higher quality of the teacher-student interaction as reported by the teachers and the higher level of schools satisfaction reported by the students. The point estimates for girls is positive but imprecisely estimated.

Consistent with the findings described above using teacher responses, estimates using students survey data show no evidence of a greater alignment of instructions at single-sex schools compared to coed schools. This is shown in Panel C of Table 9. The measure of alignment of pedagogical practices is derived using students answers to the statements: "My teacher gives me interesting things to read", "My teacher is easy to understand", and "My teacher does a variety of things to help us learn". The point estimates are positive for girls and negative for boys and, in both cases, not statistically different from zero.

Estimates of girls-only and boys-only schools across student self-assessment and confidence outcomes are, in general, not statistically significant. This is shown in Panel D of Table 9. All these questions refer to reading skills, the subject assessed by PIRLS. Despite the fact that reading is a subject where boys have no advantage compared to girls, boys in boys-only schools show higher self-confidence levels (measure by their agreement with statements like "Reading is harder for me than for many of my classmates" or "I am just not good at reading") that boys in coeducational schools.

Overall, the results describe here on mechanisms mediating the single-sex school effect using teacher and student survey data are consistent with recent findings in other contexts. For example, Lee et al. (2014) find that teachers in boys-only schools in Korea employ stricter discipline and teaching methods and that single-sex schooling reduces the number of male students bullied. They are also in line with the finding for Trinidad and Tobago reported in Jackson (2019), that show no evidence that the single-sex school effect is mediated by a greater alignment of instructional practices to the needs of each gender. Last, the fact that boys in single-sex schools reported higher self-confidence levels in reading is consistent with the evidence in Germany that single-sex learning environments reinforce academic self-concept of ability in atypical subjects (Kessels and Hannover, 2010).[42]

[42]In Appendix Table F3 I report OLS estimates of equation (1) taking the whole Year 5 student population in 2016 and not just the randomized lottery applicants. I find a similar pattern of a positive effect of single-sex education of students satisfaction of boys and girls and a greater self-confidence in reading for boys.

7. Conclusion

This paper investigates whether single-sex education at childhood age affects students test scores and subject take-up later at secondary school. I leverage random variation from admission lotteries used by the Catholic sector in Malta. I take advantage of rich administrative school data to show that the setting resemble an ideal educational experiment: schools are indistinguishable from each other in many important dimension (curriculum design, teacher quality, class size, etc.) and students allocation to single-sex or coeducational schools is determined by random lottery numbers.

I find that attending a single-sex school leads to significant achievement gains of around 0.70σ on end-of-primary English and Maltese test, and of 0.55σ on mathematics. Further, I find that the benefits of gender-homogeneous schools are positive for both boys and girls and that estimated effects are not driven by parents with strong preferences for single-sex education. I also find that the single-sex school effects are long-lasting. Female and male students that attended a single-sex primary schools prefer different curriculum tracks in secondary school. Girls choose more science courses that girls coming from a coed primary school. Boys choose less vocational and science-based courses.

Survey data reveal that the mechanisms mediating the single-sex school effect are related with a higher quality in the teacher-student relationship, teachers use of guided instruction, clear and strict discipline policies, a better school environment measured by bullying incidents and a decrease in truancy.

Overall, these findings suggest that single-sex education can improve student achievement and it worth noting that it could do so at little or no cost. However, in order to have a complete grasp of the nature and impact of same-gender learning environments further work is needed. Interventions such as single-sex education may be designed more effectively by having better understanding about the optimal timing and it consequences in non-academic outcomes.

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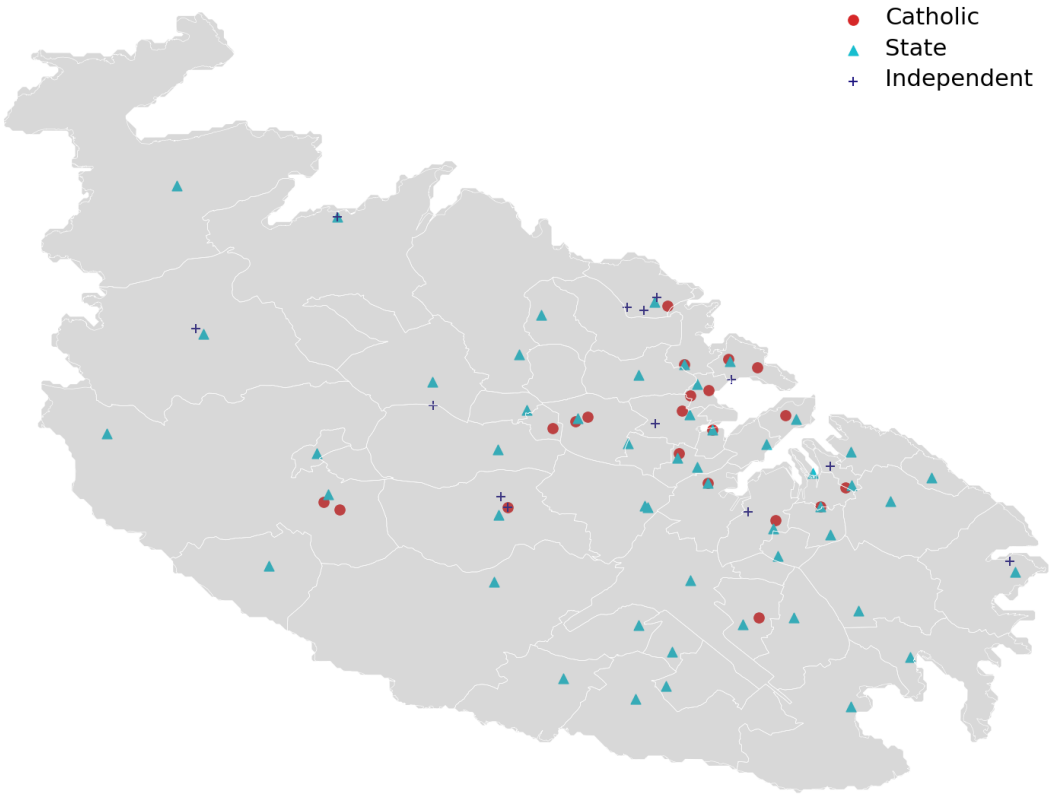
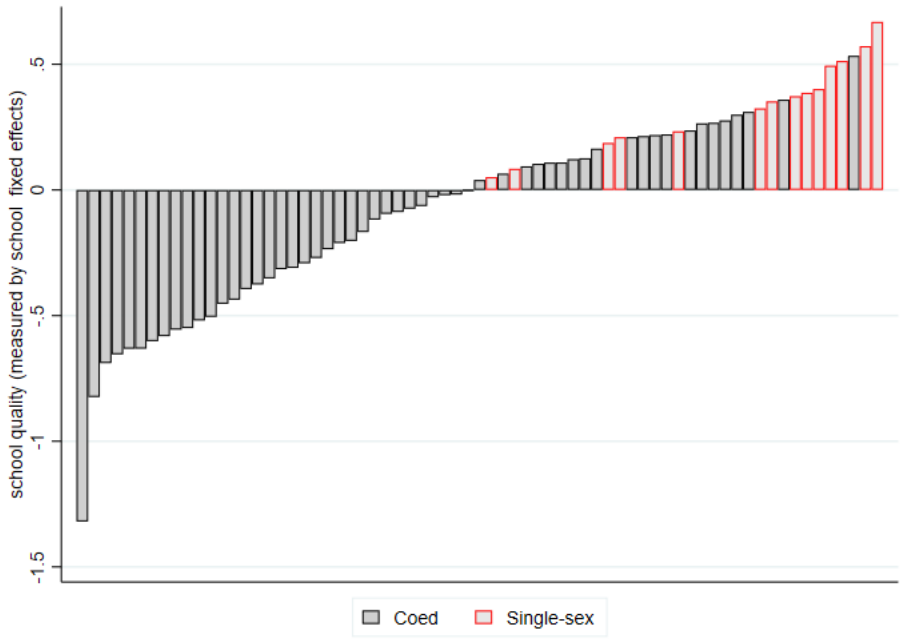
Figure 1. Location of Primary Schools in Malta



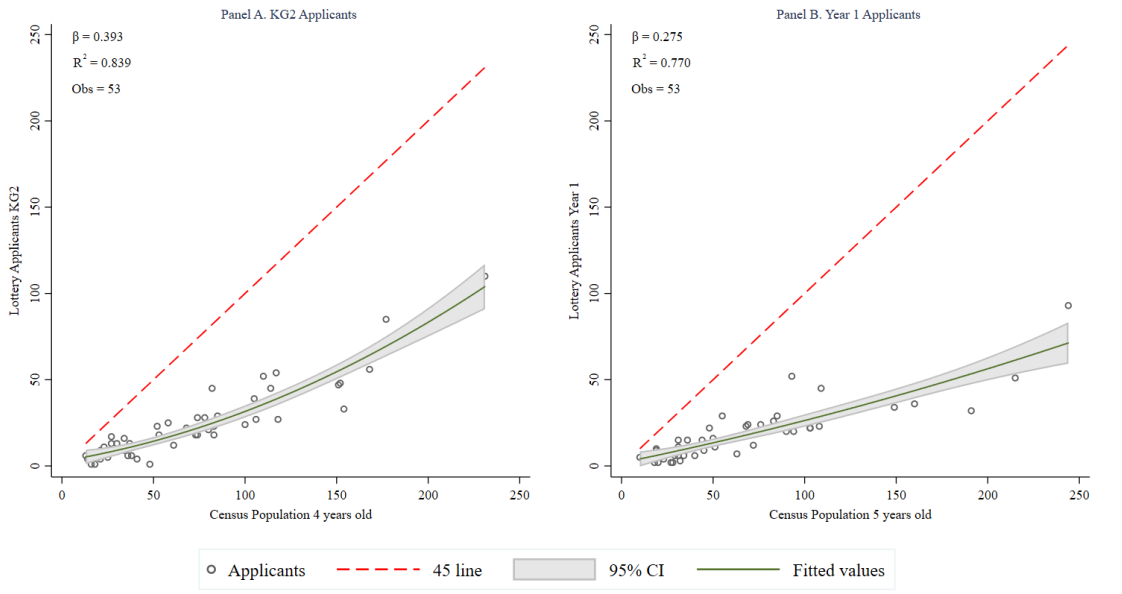
Notes: This map displays the location of primary schools in the island of Malta. Each marker represents a school. Catholic schools are indicated in red dots, state schools are indicated in light-blue triangles, while independent schools are indicated in blue crosses. The number of schools is 21, 51 and 14 for the Catholic, State and Independent sector, respectively. The map also shows the division of the island into 54 localities.

Figure 2. School Quality



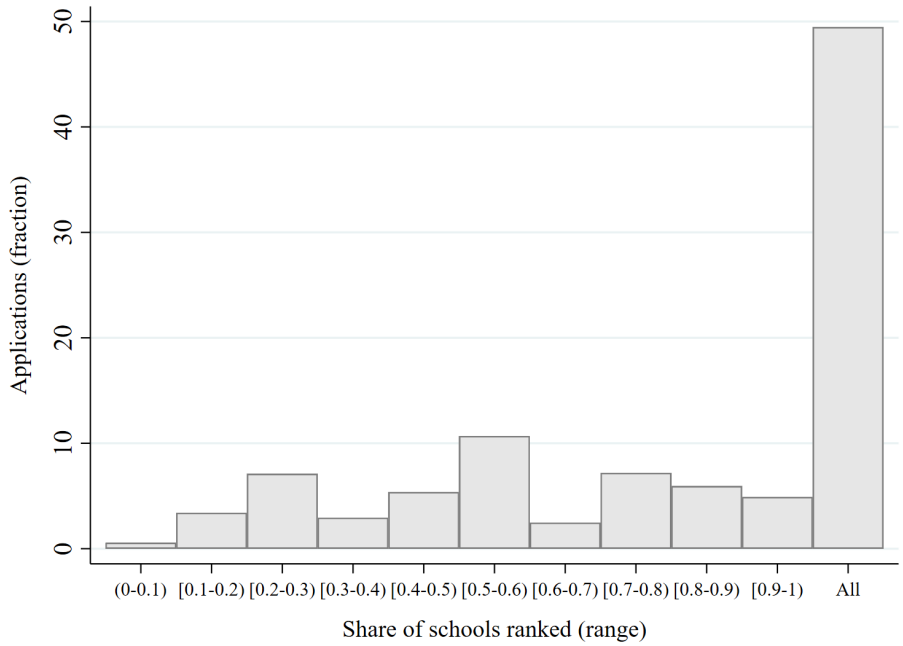
Notes: Each bar represents a school. The y-axis shows estimates results from a OLS regression of students composite score at end-of-primary exam on the full set of year and school fixed effect dummies. The composite score is the average of the scores in English, Maltese and mathematics and was standardized to have mean zero and unit variance by year. Sample includes all End of Primary Benchmark test-takers from state and catholic schools during 2014-2015.

Figure 3. Lottery Applicants Representativeness



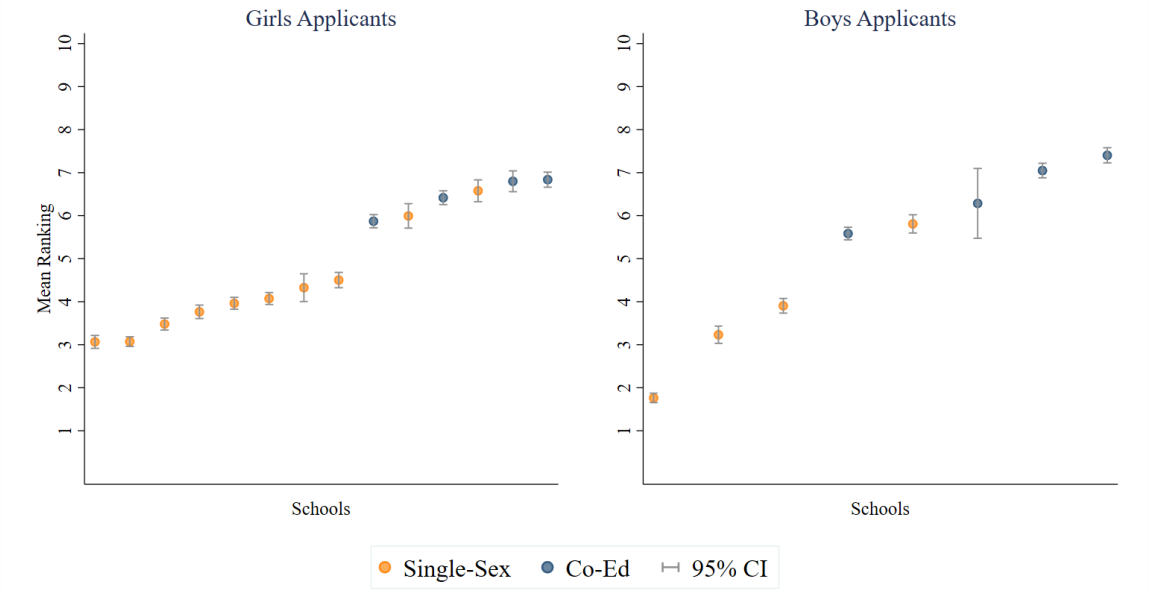
Notes: Panel A (Panel B) shows the applicant population for KG2 (Year 1) lottery in each census locality for 2010. Coefficient reported comes from a regression on the number of applicants per locality on the census population for a given age.

Figure 4. Applicants Distribution According to the Share of School Ranked



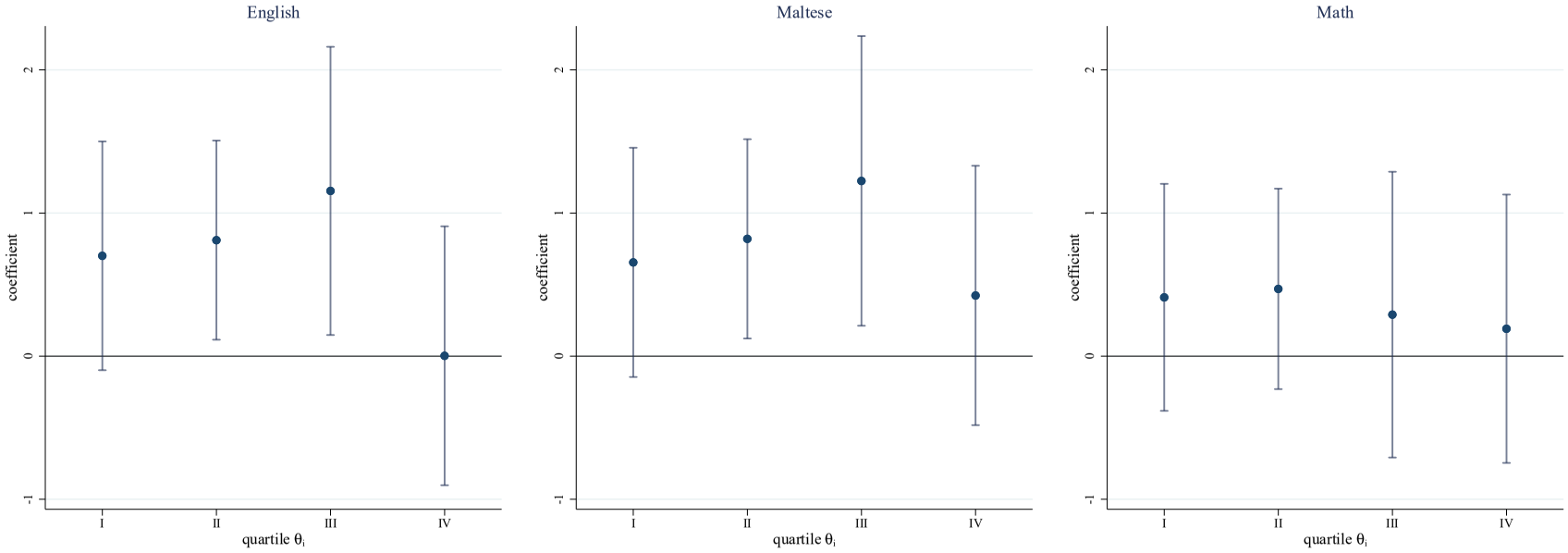
Notes: Each bar represents the fraction of applicants whose share of school ranked falls within the specified range.

Figure 5. Catholic Schools Ranking



Notes: Each dot represents a school. The y-axes shows the average rank order per school based on the submitted rank-order lists (ROLs). Vertical bars represent 95% confidence intervals. As girls and boys have different number of choices at every lottery (year-grade of application), the ranking was transformed in order to have the same 1 to 10 absolute scale.

Figure 6. Heterogeneity in Treatment Effect by Weight on Single-sex Attribute



Notes: This figure shows heterogeneous treatment effects by parent's single-sex preference intensity for English, Maltese and Math test scores. Each figure shows the estimated coefficient (and the 95 % confidence intervals) on $SingleSex_i$ interacted with dummies for the quartile of single-sex weight ($\hat{\theta}_i$) on test scores from the 2SLS model described in equation (2). Regression controls for baseline demographic characteristics, quartiles of the single-sex attribute weight, year of exam fixed effect and lottery fixed effect.

Table 1. Applicants and Single-sex School offers per Lottery

Cohort	Lottery Year	Total Applicants	Randomized Applicants	Percent offered a seat
	(1)	(2)	(3)	(4)
Panel A: Lottery KG2				
Cohort 2005	2009	1091	901	16.3
Cohort 2006	2010	1182	1023	17.1
Panel B: Lottery Year 1				
Cohort 2005	2010	979	834	34.9
Cohort 2006	2011	952	716	58.7
Panel C: Lottery Year 4				
Cohort 2005	2013	292	264	67.0

Notes: Column 1 shows the calendar year the lottery was held. Column 2 shows the number of applicants for catholic schools slots. Column 3 shows the number of randomized applicants (i.e those in the marginal priority group). Column 4 shows the share of randomized applicants who got a single-sex offer.

Table 2. Descriptive Statistics and Balance Regression

	Applicants not Offered Single-Sex Slot (1)	Applicants Offered Single-Sex Slot (2)	Balance Regression (3)
Born Quarter 1	0.241	0.267	0.029
			(0.018)
Born Quarter 2	0.257	0.240	-0.011
			(0.019)
Born Quarter 3	0.242	0.237	-0.002
			(0.018)
Born Quarter 4	0.257	0.253	-0.015
			(0.018)
Biblical Name	0.101	0.097	-0.011
			(0.013)
Popular Surname	0.247	0.254	-0.003
			(0.018)
Mother Age	33.7	34.4	-0.125
			(0.226)
Father Age	36.0	37.1	0.067
			(0.248)
Distance to Local School	1.25	1.27	-0.062
			(0.117)
High Quality Local School	0.283	0.301	0.006
			(0.019)
Southern Harbour	0.148	0.140	-0.012
			(0.015)
Northern Harbour	0.321	0.307	-0.001
			(0.019)
South Eastern	0.159	0.170	0.006
			(0.016)
Western	0.194	0.195	-0.011
			(0.017)
Northern	0.175	0.186	0.019
			(0.015)
Social Assistance	4119	4113	-6.030
			(31.081)
Observations	1773	1064	
F-test			47.750
p-value			0.775

Notes: Columns 1 and 2 report mean values for applicants according to their admission lottery status. Column 3 reports the coefficient (and standard deviation) from a regression of the variable indicated in each row on a dummy variable equal to one if the applicant received a single-sex offer and zero otherwise. For detailed description of the variables, see Appendix A. Each regression includes lottery fixed effects. Sample comprises randomized applicants in non-degenerate lotteries. The F-statistics jointly test balance for all baseline covariates. An asterisk indicates statistically significant differences at the 5% level.

Table 3. Coeducational and Single-sex Catholic School Characteristics

	Catholic Schools		Difference
	Coeducational	Single Sex	(2)-(1)
	(1)	(2)	(3)
Panel A: School staff			
Female (%)	94.7	91.6	-3.127
Age (years)	40.4	41.1	0.706
Bachelor (%)	50.7	60.2	9.479
Teaching Experience (years)	10.6	10.9	0.258
Tenure (years)	8.4	6.0	-2.381
Distance to School (miles)	2.4	2.4	0.046
Wage (log)	9.6	9.5	-0.076
Observations	171	585	
F-stat			10.351
p-value			(0.170)
Panel B: Teachers			
Female (%)	96.7	96.5	-0.187
Age (years)	36.8	37.2	0.446
Bachelor (%)	83.6	85.0	1.393
Teaching Experience (years)	10.5	10.1	-0.405
Tenure (years)	8.2	8.3	0.107
Distance to School (miles)	2.6	2.3	-0.256
Wage (log)	9.8	9.8	-0.008
Observations	61	202	
F-stat			2.529
p-value			(0.925)
Panel C: School Characteristics			
School Size (m2)	4673.3	4032.3	-641.0
Distance to Valletta (miles)	1.92	2.53	0.616
Subject instruction time (hs per week)			
English	5.75	5.84	0.086
Maltese	4.97	4.75	-0.224
Math	5.53	5.62	0.093
PE	1.06	1.26	0.192
Religion	2.42	2.56	0.142
Other	1.60	1.15	-0.456
Total instruction time (hs per year)[a]	883.04	936.25	53.208
Class Size	25.7	25.4	-0.394
Observations	4	17	

Notes: Columns 1 and 2 report mean values for staff at each school type, as specified in the column headings. Column 3 reports the difference in means across groups of the variable indicated in each row. The *F*-statistics, reported at the bottom of the panels, jointly test balance for all baseline covariates. Asterisk indicates statistically significant differences between groups at the 5% level. Unless otherwise indicated, all variables comes from administrative school data for 2010. [a] Variables from PIRLS 2016.

Table 4. Single-Sex School Effect on Test Scores

	All Lotteries			Lotteries with Preferences		
	First Stage (1)	Reduced Form (2)	2SLS (3)	First Stage (4)	Reduced Form (5)	2SLS (6)
English	0.777***	0.238***	0.320***	0.596***	0.441**	0.638***
	(0.053)	(0.066)	(0.086)	(0.109)	(0.167)	(0.190)
Observations	2590	2590	2590	1275	1275	1275
Maltese	0.777***	0.254***	0.346***	0.598***	0.534**	0.742***
	(0.053)	(0.075)	(0.098)	(0.109)	(0.240)	(0.277)
Observations	2587	2587	2587	1273	1273	1273
Math	0.785***	0.141	0.194	0.602***	0.391*	0.554**
	(0.050)	(0.111)	(0.141)	(0.115)	(0.209)	(0.239)
Observations	2555	2555	2555	1257	1257	1257

Notes: This table reports 2SLS estimates of the single-sex school effect on end-of-primary test scores. First stage in columns 1 and 4 reports coefficient for the single-sex offer instrument. All models include year, risk set controls and demographics (quarter of birth, biblical name and region fixed effects). Columns 1-3 sample use all the lotteries and risk set controls are defined by the application pattern. Columns 4-6 sample use lotteries with ROL and risk set controls are defined by the interaction between the propensity score and the application pattern. Robust standard errors, clustered at school level, are reported in parenthesis. Significance levels are indicated by * $< .1$, ** $< .05$, *** $< .01$.

Table 5. Robustness Check: Single-Sex School Effect on Test Scores

	All Lotteries			Lotteries with Preferences		
	First Stage (1)	Reduced Form (2)	2SLS (3)	First Stage (4)	Reduced Form (5)	2SLS (6)
English	0.771***	0.361***	0.488***	0.541***	0.270**	0.443**
	(0.070)	(0.094)	(0.139)	(0.140)	(0.118)	(0.176)
Observations	1665	1665	1665	896	896	896
Maltese	0.771***	0.366***	0.504***	0.542***	0.407*	0.612**
	(0.070)	(0.108)	(0.147)	(0.140)	(0.243)	(0.304)
Observations	1662	1662	1662	894	894	894
Math	0.780***	0.149	0.205	0.551***	0.283	0.385
	(0.064)	(0.135)	(0.179)	(0.139)	(0.227)	(0.278)
Observations	1641	1641	1641	883	883	883

Notes: This table reports 2SLS estimates of the single-sex school effect on end-of-primary test scores. First stage in columns 1 and 4 reports coefficient for the single-sex offer instrument for the first lottery a student participates. All models include year, risk set controls and demographics (quarter of birth, biblical name and region fixed effects). Columns 1-3 sample use all the lotteries and risk set controls are defined by the application pattern. Columns 4-6 sample use lotteries with ROL and risk set controls are defined by the interaction between the propensity score and the application pattern. Robust standard errors, clustered at school level, are reported in parenthesis. Significance levels are indicated by * $< .1$, ** $< .05$, *** $< .01$.

Table 6. Single-Sex School Effect on Girls and Boys Test Scores

	All Lotteries			Lotteries with Preferences		
	All	Girls	Boys	All	Girls	Boys
	(1)	(2)	(3)	(4)	(5)	(6)
English	0.320***	0.390**	0.288***	0.638***	0.405*	0.901**
	(0.086)	(0.168)	(0.084)	(0.190)	(0.237)	(0.448)
Observations	2590	1119	1471	1275	623	652
Maltese	0.346***	0.406***	0.351***	0.742***	0.528*	1.070*
	(0.098)	(0.120)	(0.115)	(0.277)	(0.277)	(0.633)
Observations	2587	1119	1468	1273	623	650
Math	0.194	0.314**	0.149	0.554**	0.712	0.449*
	(0.141)	(0.155)	(0.168)	(0.239)	(0.517)	(0.268)
Observations	2555	1112	1443	1257	619	638

Notes: This table reports 2SLS estimates of the single-sex school effect on end-of-primary test scores, separately for girls (columns 2 and 5) and boys (columns 3 and 6). All models include year, risk set controls and demographics (quarter of birth, biblical name and region fixed effects). Columns 1-3 sample use all the lotteries and risk set controls are defined by the application pattern. Columns 4-6 sample use lotteries with ROL and risk set controls are defined by the interaction between the propensity score and the application pattern. Robust standard errors, clustered at school level, are reported in parenthesis. Significance levels are indicated by * $< .1$, ** $< .05$, *** $< .01$.

Table 7. Single-Sex School Effect on Option Subjects

	All Lotteries		
	All	Girls	Boys
	(1)	(2)	(3)
At least one science subject	-0.112*	-0.089	-0.116*
	(0.063)	(0.202)	(0.066)
Two science subjects	-0.027	0.211*	-0.064
	(0.050)	(0.110)	(0.054)
At least one *female* subject	-0.124**	-0.191	-0.074
	(0.068)	(0.194)	(0.077)
At least one vocational subject	-0.176***	-0.325**	-0.118*
	(0.055)	(0.162)	(0.061)
Observations	1303	1303	1303

Notes: Table reports 2SLS estimates of the effect of single-sex primary school on the outcome variables shown in each row. Regressions for female and vocational subjects add a control for the number of prevalently female and vocational subjects offered, respectively. Risk set controls are defined by the application pattern. Sample includes student cohorts born in 2005 and 2006 at (18 out of 19) catholic secondary schools that participated in the primary admission lotteries. Robust standard errors are reported in parenthesis. Significance levels are indicated by * $< .1$, ** $< .05$, *** $< .01$.

Table 8. Effect of Single-sex School on Teachers Inputs

	Girls-only Schools (1)	Boys-only Schools (2)
Panel A: Teacher Satisfaction & Quality of the Teacher-Student Relationship		
Teacher satisfaction	-0.271	-0.326
	(0.232)	(0.211)
Students are respectful of the teachers	0.664**	0.254
	(0.284)	(0.264)
Panel B: Classroom Environment & School Discipline		
Student misbehavior	-0.640**	0.123
	(0.269)	(0.346)
School rules are clear and enforced	0.583**	0.372
	(0.284)	(0.227)
Panel C: Instructional Practices		
Individualized instruction & feedback	0.300	-0.657*
	(0.498)	(0.387)
Aligned pedagogical practices	-0.051	-0.382
	(0.290)	(0.274)
Guided instruction	0.801**	0.935**
	(0.349)	(0.390)
Ability grouping	-0.790	-0.803
	(0.571)	(0.578)
Panel D: Self- and Student Assessment		
Curriculum expertise	-0.912**	0.137
	(0.371)	(0.269)
Students' performance	0.086	0.026
	(0.590)	(0.590)

Notes: Table reports OLS estimates of the effect of single-sex school on the outcome variable shown in each row. Regressions include a dummy variable equal to one if the school belongs to the Catholic sector and 0 if it belongs to the State sector. Sample includes 165 teachers of Year 5 students enrolled in catholic and state schools in 2016 that participated in the PIRLS survey. Robust standard errors, clustered at school level, are reported in parenthesis. Significance levels are indicated by * < .1, ** < .05, *** < .01. See Appendix A for details on the definition of the outcome in each row.

Table 9. Effect of Single-sex School on Students Inputs

	Girls-only Schools (1)	Boys-only Schools (2)
Panel A: Student Satisfaction & School Bullying		
Student satisfaction	0.602	0.026
	(0.374)	(0.206)
Absenteeism	-0.269*	-0.021
	(0.143)	(0.074)
Bullying index	0.056	-0.388*
	(0.299)	(0.234)
Panel B: Teacher-Student Relationship		
Teachers at my school are fair to me	0.208	-0.204*
	(0.254)	(0.121)
Panel C: Instructional Practices		
Aligned pedagogical practices	0.306	-0.279
	(0.345)	(0.170)
Panel D: Self-assessment and confidence		
I usually do well in reading	0.341	0.097
	(0.385)	(0.180)
Reading is easy for me	-0.216	-0.034
	(0.359)	(0.191)
Reading is harder for me than any other subject	0.064	-0.072
	(0.303)	(0.187)
Reading is harder for me than for many of my classmates	0.094	-0.251
	(0.279)	(0.224)
I am just not good at reading	0.241	-0.362*
	(0.288)	(0.195)

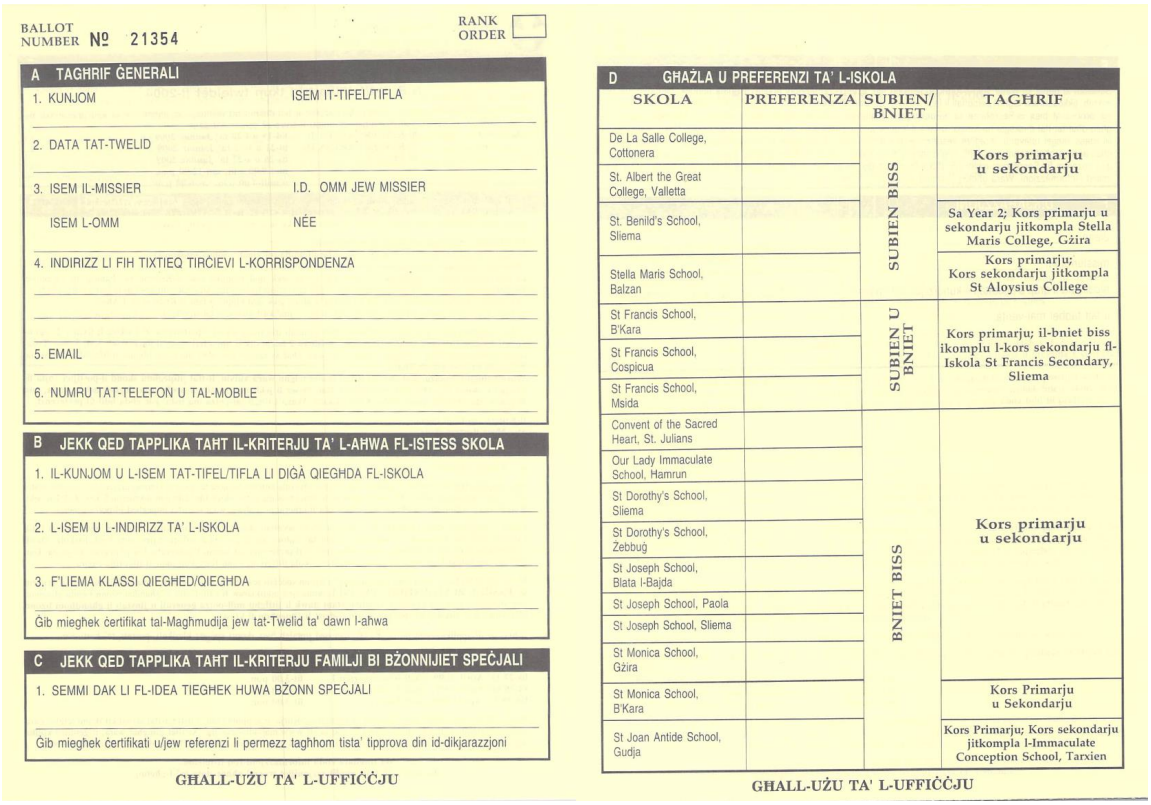
Notes: Table reports 2SLS estimates of the effect of single-sex school on the outcome variable shown in each row. Regressions include an indicator for girls-only schools, an indicator for boys-only schools and the interaction between a catholic sector indicator and an indicator for female student. As such, coefficients in column 1 (2) are interpreted as the effect of single-sex education for girls (boys) relative to girls (boys) students at coeducational catholic schools. Sample includes 840 randomized applicants born in 2006 that participated in KG2 and Year 1 lotteries and were matched with the PIRLS survey. Robust standard errors are reported in parenthesis. Significance levels are indicated by * < .1, ** < .05, *** < .01. See Appendix A for details on the definition of the outcome in each row.

A. Variable Definition and Sources

A.1. Catholic Schools Lottery Data

The lottery analysis file is constructed using applications, school assignment and enrollment provided by the Secretariat for Catholic Education in Malta for school years 2008-2011. The catholic school application form is divided into four parts (A-D) as shown in the figure below. Section A ask parents to submit information about the applicants' full name, date of birth and gender. It also requires the name of the father and the mother and to provide the ID of any of them, their address and contact information. In Section B, parent need to declare if the applicant has siblings already enrolled in any of the catholic schools and report the school and year attended. Section C asks parent of any special educational need the applicant may have. In Section D parents submit their rank order list (ROL) by ranking schools in order of their preference.

Figure A1. Application Form



BALLOT NUMBER № 21354

RANK ORDER

A TAGĦRIF ĠENERALI

1. KUNJOM — ISEM IT-TIFEL/TIFLA
2. DATA TAT-TWELID
3. ISEM IL-MISSIER — I.D. OMM JEW MISSIER
   ISEM L-OMM — NÉE
4. INDIRIZZ LI FIH TIXTIEQ TIRĊIEVI L-KORRISPONDENZA
5. EMAIL
6. NUMRU TAT-TELEFON U TAL-MOBILE

B JEKK QED TAPPLIKA TAĦT IL-KRITERJU TA' L-AĦWA FL-ISTESS SKOLA

1. IL-KUNJOM U L-ISEM TAT-TIFEL/TIFLA LI DIĠÀ QIEGĦDA FL-ISKOLA
2. L-ISEM U L-INDIRIZZ TA' L-ISKOLA
3. F'LIEMA KLASSI QIEGĦED/QIEGĦDA

Ġib mieghek ċertifikat tal-Maghmudija jew tat-Twelid ta' dawn l-aħwa

C JEKK QED TAPPLIKA TAĦT IL-KRITERJU FAMILJI BI BŻONNIJIET SPEĊJALI

1. SEMMI DAK LI FL-IDEA TIEGĦEK HUWA BŻONN SPEĊJALI

Ġib mieghek ċertifikati u/jew referenzi li permezz taghhom tista' tipprova din id-dikjarazzjoni

GĦALL-UŻU TA' L-UFFIĊĊJU

D GĦAŻLA U PREFERENZI TA' L-ISKOLA

SKOLA	PREFERENZA	SUBIEN/ BNIET	TAGĦRIF
De La Salle College, Cottonera		SUBIEN BISS	Kors primarju u sekondarju
St. Albert the Great College, Valletta			
St. Benild's School, Sliema			Sa Year 2; Kors primarju u sekondarju jitkompla Stella Maris College, Gżira
Stella Maris School, Balzan			Kors primarju; Kors sekondarju jitkompla St Aloysius College
St Francis School, B'Kara		SUBIEN U BNIET	Kors primarju; il-bniet biss ikomplu l-kors sekondarju fl-Iskola St Francis Secondary, Sliema
St Francis School, Cospicua			
St Francis School, Msida			
Convent of the Sacred Heart, St. Julians		BNIET BISS	Kors primarju u sekondarju
Our Lady Immaculate School, Hamrun			
St Dorothy's School, Sliema			
St Dorothy's School, Zebbuġ			
St Joseph School, Blata l-Bajda			
St Joseph School, Paola			
St Joseph School, Sliema			
St Monica School, Gżira			
St Monica School, B'Kara			Kors Primarju u Sekondarju
St Joan Antide School, Gudja			Kors Primarju; Kors sekondarju jitkompla l-Immaculate Conception School, Tarxien

GĦALL-UŻU TA' L-UFFIĊĊJU

Notes: Application form used to admit student at catholic schools during scholastic year 2010-2011. Source: Secretariat for Catholic Education.

Demographic information of applicants are used to compute the variables in the balance table:

Biblical Name is a dummy variable equal to one if the student first name is a proper name from the Bible. Traditional biblical names were identified using reports from the Population and Tourism Statistics Unit at the National Statistic Office that compile, each year, a ranking of popular names for babies registered at the Public Registry. Typical biblical names are Elena, Eliza, Catherine, Maria and Anna for girls. For boys the list includes Luke, Matthew, Jacob, Zachary, John and Isaac.

Popular Surname is an dummy variable equal to one if the applicant's surname is one of the 10 most common surnames as identified in the 2011 Population Census: Borg, Camilleri, Vella, Farrugia, Zammit, Galea, Micallef, Grech, Attard and Spiteri.

Mother (Father) Age can be recovered from the reported mother (or father) id number. The last two digits of a person ID in Malta correspond to the person year of birth.

Distant to Local School is the distance (in miles) between the applicant home address to the local state-run school.

High Quality Local School variable is an indicator equal to one if the state-run school in the locality the applicant resides is above the national average and zero if it is below. To infer school quality I use a fixed effect model based on the students performance at the Benchmark during 2014 and 2015.

Social Assistance is computed as the average of the social assistance expenditure per beneficiary (in euros) in the locality in which the applicant resides.

A.2. Applicant outcomes

End of Primary Benchmark Test scores for English, Maltese and Math exam are available for years 2014-2017 and was provided by the Educational Assessment Unit (EAU), Department of Curriculum Management. Each observation in the Benchmark data file corresponds to a student's test results in a particular year. Exam scores are standardized to have mean zero and unit standard deviation within a a subject-year.

Option Subjects Administrative data on student's choice of elective subjects was collected in catholic secondary schools. Optional subjects comprise a set of academic and vocational subjects and students have two choose two at the end of their second year of secondary education (Year 8). The sample comprises Year 8 students in catholic schools for the scholastic years 2016-2019.

A.3. Teacher Survey

I use the Progress in International Reading Literacy 2016 (PIRLS 2016) data to obtain measures of the teachers school satisfaction, teaching practices and other inputs. PIRLS is run by the International Association for the Evaluation of Educational Achievement (IEA) and, in Malta, covers all teachers of Year 5 students.
Teacher satisfaction is an index derived from five survey questions which ask teachers to classify how often they feel in a particular way about being a teacher. The statements are "I am content with my profession as a teacher", "I find my work full of meaning and purpose", "I am enthusiastic about my job", "My work inspires me", "I am proud of the work I do". The answer categories are 1 for Very often, 2 for Often, 3 for Sometimes, and 4 for Never or almost never. Each variable scale was reverted. I sum teacher responses to each of the statements and standardized the index to be have zero mean and unit variance.
The measure of the quality of the teacher-student relationship is constructed based on teacher agreement to the statement "The students are respectful of the teachers". The answer categories are 1 for Agree a lot, 2 for Agree a little, 3 for Disagree a little, and 4 for Disagree a lot. The variable scale was reverted and standardized to have zero mean and standard deviation of one.
Student misbehaviour represents an index of the extent to which teachers reported that disruptive students limit how they teach the class and their disagreement with the statement "The students behave in an orderly manner". Each variable is standardized before creating the average.
The measure for school rules combines agreement with the statements "This school has clear rules about student conduct" and "This school's rules are enforced in a fair and consistent manner". The answer categories are 1 for Agree a lot, 2 for Agree a little, 3 for Disagree a little, and 4 for Disagree a lot. The numerical values assigned to each answer category is reversed. The index is constructed by summing teachers responses to each of the above two questions, standardized to have zero mean and standard deviation of one.
The measure of *individualized instruction and feedback* is derived using answer to the following three statements: "I use individualized instruction for reading", "Provide materials that are appropriate for the reading levels of individual students", and "Give individualized feedback to each student". The answer categories for the first item are 1 for Always or almost always, 2 for Often, 3 for Sometimes, and 4 for Never. The answer categories for the last two items are 1 for Every or almost every lesson, 2 for About half the lessons, 3 for Some lessons, and 4 for Never. The numerical values assigned to each answer category is reversed. Teachers responses to the above

three questions are summed and then standardized to have zero mean and standard deviation of one.

To measure the teacher alignment of pedagogical practices, I combine answers to the statements: "Provide reading materials that match the students' interests", "Link new content to students' prior knowledge", "Use multiple perspectives (among students and texts) to enrich understanding", and "Teachers' ability to inspire students". The answer categories for the first three items are 1 for Every or almost every lesson, 2 for About half the lessons, 3 for Some lessons, and 4 for Never. For the last items the answer categories are 1 for Very high, 2 for High, 3 for Medium, 4 for Low and 5 for Very low. The numerical values assigned to each answer category is reversed. Each variable is standardized before creating the average.

Guided instruction is a measure derived from a survey question asking teachers how often they organize students "to work independently on an assigned plan or goal". The answer categories are 1 for Always or almost always, 2 for Often, 3 for Sometimes, and 4 for Never. The variable is standardized to have zero mean and standard deviation of one.

Ability grouping variable is derived from a survey question asking teachers how often they "create same-ability groups". The answer categories are 1 for Always or almost always, 2 for Often, 3 for Sometimes, and 4 for Never. Answer categories were reversed before standardizing to have zero mean and standard deviation of one.

Teachers' measure of curriculum expertise is based on teacher characterization of their school for the following statements: "Teachers' understanding of the school's curricular goals" and "Teachers' degree of success in implementing the school's curriculum". The teachers assessment of students performance is constructed using the statements: "Students' desire to do well in school" and "Students' ability to reach school's academic goals". The answer categories for both measures are 1 for Very high, 2 for High, 3 for Medium, 4 for Low and 5 for Very low. The numerical values assigned to each answer category is reversed. The responses to the above questions are summed and then standardized to have zero mean and standard deviation of one.

A.4. Student Survey

The *Student satisfaction* variable is an index derived from three survey questions which ask students how much they agree with the following statements: "I like being in school", "I feel like I belong at this school", and "I am proud to go to this school". The answer categories are 1 for Agree a lot, 2 for Agree a little, 3 for Disagree a little, and 4 for Disagree a lot. The variable scale was reverted and student responses to each of the statements are summed and standardized to have a mean of zero and

unit variance.

Absenteeism is a dummy variable equal to one if the student reports being absent from school at least once a month.

The *bullying index* combines responses to the reported frequency a student experience the following things from other students in their school: "Made fun of me or called me names"; "Left me out of their games or activities"; "Spread lies about me"; "Stole something from me"; "Hit or hurt me (e.g., shoving, hitting, kicking)"; "Made me do things I didn't want to do"; "Shared embarrassing information about me"; "Threatened me". The answers range from 1 for At least Once a week, 2 for Once or twice a month, 3 for A few times a year, and 4 for Never. The numerical values assigned to each answer category is reversed. The index is constructed by summing students responses to each of the above eight questions, standardized to have zero mean and standard deviation of one.

The measure of the quality of the teacher-student relationship is constructed based on the student agreement to the statement "Teachers at my school are fair to me". The answer categories are 1 for Agree a lot, 2 for Agree a little, 3 for Disagree a little, and 4 for Disagree a lot. The variable scale was reverted and standardized to have zero mean and standard deviation of one.

Teachers alignment of pedagogical practices is derived using students answers to the statements: "My teacher gives me interesting things to read", "My teacher is easy to understand", and "My teacher does a variety of things to help us learn". The answer categories are 1 for Agree a lot, 2 for Agree a little, 3 for Disagree a little, and 4 for Disagree a lot. The numerical values assigned to each answer category is reversed. Students responses to the above three questions are summed and then standardized to have zero mean and standard deviation of one.

Three items in the questionnaire supply information about student self-assessment related to reading: "I usually do well in reading", "Reading is easy for me", and "Reading is harder for me than any other subject". Another two do it in relation to the student self-confidence (in reading): "Reading is harder for me than for many of my classmates" and "I am just not good at reading". The answers range from 1 for Agree a lot, 2 for Agree a little, 3 for Disagree a little, and 4 for Disagree a lot. Each variable scale was reverted and standardized to have zero mean and standard deviation of one.

B. Matching Rate

The overall match rate between randomized students and the Benchmark is 82 percent. Several reasons explain not achieving a perfect match: (i) students may have moved outside Malta, (ii) there are 3 catholic schools that do not participate in the End of Primary Benchmark and, (iii) the application data per lottery vary in term of key variables for matching.[43] Except for the few cases in which I have the student ID number, the key matching variables used were: (a) surname, name and date of birth; (b) surname, name and mother name; (c) surname, name and father name. Table B1 below show the match rate per lottery grade and year.

Table B1. Matching Rate between Lottery Applicants and Exam Takers

Lottery Year	Total Applicants	Randomized Applicants	Match Rate	Balance Regression	
				All Lotteries	Benchmark Participating Schools
	(1)	(2)	(3)	(4)	(5)
Panel A: Lottery KG2					
2009	1091	901	0.765		
2010	1182	1023	0.774		
Panel B: Lottery Year 1					
2010	979	834	0.788		
2011	952	716	0.777		
Panel C: Lottery Year 4					
2013	292	264	0.981		
2009-2013				-0.106	-0.002
				(0.016)	(0.015)

Notes: Column 1 shows the number of candidates to get admission into catholic schools. Column 2 shows the number of randomized applicants (i.e those in the marginal priority group). Column 3 shows the match rates from randomized applicants to scores data at the end of primary school (Benchmark). Column 4 reports the coefficient (and standard deviation) from a regression of the match indicator variable on a dummy variable equal to one if the applicant received an offer (Z_{ij}), using all the lotteries. Column 5 reports the coefficient of the same specification as in column 4 but excluding those applicants who received an offer from a non-benchmark participating school. Regressions include controls for application year, grade and SEN-lottery.

[43]For lotteries held before 2011 it was not possible to get digital file formats and data was recovered from archived documentation. By that time, the preservation of records was not a priority after the school admission process was completed and having incomplete data for some lotteries is more the result of bad luck when the data collection for this paper started in 2016 than to a selective matching.

I assess the quality of the matching procedure by testing if the match rate differ by lottery status. The match differential for lottery winners and losers is about -10.6 percent (column 4), so the probability of being matched is lower if the applicant is a lottery winner, which is consistent with (ii). When applicants who received an offer from any of the three non-participating schools are excluded, the estimated coefficient falls to 0.002 (SE = 0.015), indicating that admission lottery winners are not more likely to be matched than losers.

Note that being a Benchmark participating school is a fact that is unlikely to be related to whether a student is a lottery winner or loser. Moreover, these students would not be part of the regression sample when evaluating the effect of single-sex education on test scores.

C. Additional Balance Tables

Table C1. Child Population and Lottery Applicants

	Child Population (1)	Applicants not Offered Single-Sex Slot (2)	Applicants Offered Single-Sex Slot (3)
Born Quarter 1	0.248	0.241	0.267
Born Quarter 2	0.245	0.257	0.240
Born Quarter 3	0.249	0.242	0.237
Born Quarter 4	0.257	0.257	0.253
Popular Surname	0.243	0.247	0.254
Southern Harbour	0.195	0.148	0.140
Northern Harbour	0.296	0.321	0.307
South Eastern	0.182	0.159	0.170
Western	0.149	0.194	0.195
Northern	0.178	0.175	0.186
Observations	7109	1773	1064

Notes: This table shows summary statistics for children born 2005-2006 (column 1) and for the applicant sample according to their admission lottery status (columns 2 and 3). Data in column 1 comes from the the National Obstetric Information System and the National Statistic Office. Applicants sample (columns 2 and 3) is restricted to randomized applicants in non-degenerate lotteries. For detailed description of the variables, see Appendix A.

Table C2. Descriptive Statistics and Balance Regression

	Lottery Winners			Catholic Offer		
	Coed Offer (1)	Single-Sex Offer (2)	Balance Reg. (3)	Lottery Losers (4)	Lottery Winners (5)	Balance Reg. (6)
Born Quarter 1	0.234	0.267	0.032	0.244	0.261	0.019
			(0.040)			(0.019)
Born Quarter 2	0.195	0.240	0.041	0.259	0.239	-0.015
			(0.038)			(0.019)
Born Quarter 3	0.273	0.237	-0.019	0.241	0.239	-0.001
			(0.042)			(0.018)
Born Quarter 4	0.296	0.253	-0.054	0.253	0.259	-0.002
			(0.044)			(0.019)
Biblical Name	0.132	0.097	-0.031	0.100	0.099	-0.012
			(0.031)			(0.013)
Popular Surname	0.296	0.254	-0.046	0.243	0.259	0.009
			(0.043)			(0.019)
Mother Age	34.6	34.4	0.348	33.6	34.5	-0.192
			(0.461)			(0.238)
Father Age	37.6	37.1	-0.123	35.9	37.1	0.173
			(0.481)			(0.260)
Distance Local School	1.78	1.27	-0.379	1.22	1.31	-0.019
			(0.338)			(0.117)
Quality Local School	0.434	0.437	0.012	0.431	0.436	-0.003
			(0.049)			(0.022)
Southern Harbour	0.179	0.140	-0.045	0.147	0.144	-0.007
			(0.036)			(0.016)
Northern Harbour	0.242	0.307	0.061	0.325	0.303	-0.009
			(0.041)			(0.020)
South Eastern	0.257	0.170	-0.090*	0.152	0.178	0.029
			(0.041)			(0.016)
Western	0.218	0.195	-0.016	0.193	0.197	-0.012
			(0.038)			(0.017)
Northern	0.101	0.186	0.090*	0.181	0.176	0.000
			(0.031)			(0.016)
Social Assistance	4086	4113	44.210	4123	4109	-17.808
			(67.637)			(32.368)
Observations	149	1064		1624	1213	
F-test			35.123			55.301
p-value			0.510			0.463

Notes: Columns 1-2 (4-5) report mean values for applicants according to admission lottery status. Column 3 (6) reports the coefficient (and standard deviation) from a regression of the variable indicated in each row on a dummy variable equal to one if the applicant received a single-sex (catholic) offer. Regression includes lottery fixed effects. Sample is restricted to randomized applicants in non-degenerate lotteries. The F-statistics jointly test balance for all baseline covariates. Asterisk indicates statistically significant differences at the 5% level.

Table C3. Characteristics of Non-randomized Applicants and Single-sex Schools Lottery Winner

	Non-randomized Applicants (1)	Lottery Winners (2)	Balance Regression (3)
Born Quarter 1	0.229	0.261	0.028
			(0.022)
Born Quarter 2	0.255	0.239	-0.013
			(0.023)
Born Quarter 3	0.251	0.239	-0.013
			(0.022)
Born Quarter 4	0.264	0.259	-0.002
			(0.023)
Biblical Name	0.083	0.099	0.011
			(0.015)
Popular Surname	0.255	0.259	-0.004
			(0.023)
Mother Age	34.8	34.5	-0.867*
			(0.294)
Father Age	37.3	37.1	-0.710*
			(0.310)
Distance Local School	1.27	1.31	0.032
			(0.148)
High Quality Local School	0.264	0.304	0.039
			(0.023)
Southern Harbour	0.160	0.144	-0.020
			(0.019)
Northern Harbour	0.308	0.303	0.005
			(0.024)
South Eastern	0.155	0.178	0.023
			(0.019)
Western	0.197	0.197	-0.008
			(0.021)
Northern	0.177	0.176	0.000
			(0.019)
Social Assistance	4150	4109	-47.952
			(38.343)
Observations	541	1213	
F-test			13.707
p-value			0.471

Notes: Columns 1 and 2 report mean values for non-randomized students and single-sex slot winners, respectively. Column 3 reports the coefficient (and standard deviation) from a regression of the variable indicated in each row on a dummy variable equal to one if the students won admission to a single-sex school via random lottery numbers and zero if the student won admission by priority status (non-randomized). Each regression includes lottery fixed effects. Columns 1-3 sample is restricted to applicants that born in 2005 and 2006, in lotteries where there is variation in the running variable and with complete baseline characteristics. For detailed description of the variables, see Appendix A. The F-statistics jointly test balance for all baseline covariates. Asterisk indicates statistically significant differences at the 5% level.

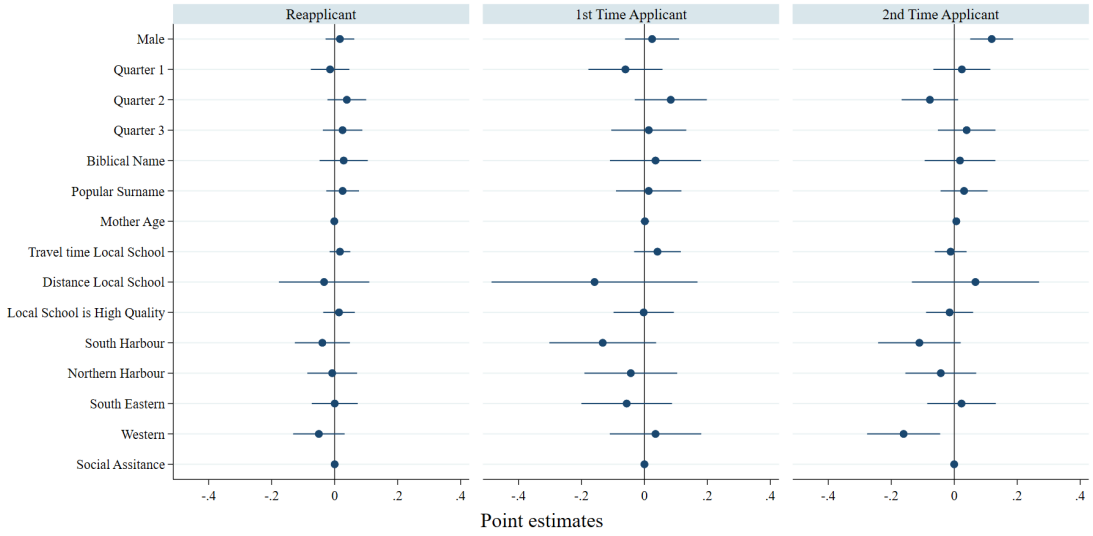
Table C4. Coeducational, Girls-only and Boys-only Catholic School Characteristics

	Catholic Schools			Diff (2)-(1)	Diff (3)-(1)
	Coed	Girls Only	Boys Only		
	(1)	(2)	(3)	(4)	(5)
Panel A: School staff					
Female (%)	94.7	93.3	88.8	-1.404	-5.898
Age (years)	40.4	42.3	39.4	1.856	-1.042
Bachelor (%)	50.7	64.5	53.8	13.805*	3.073
Teaching Experience (years)	10.6	10.8	11.0	0.144	0.429
Tenure (years)	8.4	5.2	7.3	-3.222	-1.124
Distance to School (miles)	2.4	2.4	2.5	-0.030	0.167
Wage (log)	9.6	9.5	9.5	-0.065	-0.093
Observations	171	361	224		
F-stat				18.536	6.621
p-value				(0.010)	(0.469)
Panel B: Teachers					
Female (%)	96.7	98.5	93.1	1.740	-3.666
Age (years)	36.8	37.9	36.1	1.100	-0.708
Bachelor (%)	83.6	85.9	83.3	2.331	-0.273
Teaching Experience (years)	10.5	10.2	10.1	-0.364	-0.482
Tenure (years)	8.2	8.3	8.3	0.134	0.057
Distance to School (miles)	2.6	2.2	2.5	-0.345	-0.099
Wage (log)	9.8	9.8	9.8	0.001	-0.024
Observations	61	130	72		
F-stat				1.611	6.363
p-value				(0.978)	(0.498)
Panel C: School Characteristics					
School Size (m2)	4673.3	2997.0	6448.0	-1676.3	1774.6
Distance to Valletta (miles)	1.92	2.25	2.93	0.334	1.018
Subject instruction time (hrs x week)					
English	5.75	5.92	5.63	0.175	-0.120
Maltese	4.97	4.65	4.97	-0.317	-0.005
Math	5.53	5.85	5.09	0.321	-0.440
PE	1.06	1.30	1.16	0.233	0.097
Religion	2.42	2.74	2.13	0.327	-0.292
Other	1.60	0.98	1.53	-0.622*	-0.069
Total instruction time (hrs x year)[a]	883.0	907.8	974.1	24.813	91.069
Class Size	25.7	25.3	25.4	-0.458	-0.325
Observations	4	10	7		

Notes: Columns 1-3 report mean values for staff at each school type, as specified in the column headings. Columns 4-5 reports the difference in means across groups of the variable indicated in each row. The *F*-statistics, reported at the bottom of the panels, jointly test balance for all baseline covariates. Asterisk indicates statistically significant differences between groups at the 5% level. Unless otherwise indicated, all variables comes from administrative school data for 2010. [a] Variables from PIRLS 2016.

D. Lottery Reapplication

Figure D1. Determinants of Reapplication



Notes: Each subgraph represents the results of a separate regression of applicants' baseline characteristics on reapplication. The first outcome is defined as a dummy variable equal to one if the applicant has ever reapply and zero otherwise. The second outcome is defined as a dummy variable equal to one if the applicant has reapply once and zero if the applicant never reapplied. The last outcome is defined as a dummy variable equal to one if the applicant has reapply twice.

E. Catholic Secondary Schools

E.1. Transition from Primary to Secondary

While there is a combination of single-sex and coeducational schools at primary level, all secondary schools are single-sex within the Catholic sector. The transition from primary to secondary schools occurs in a way that every student is guaranteed a place. For those primary schools that offer secondary education (in a different building and sometime in a different location), students usually stay within the same school. Students from primary schools that do not offer secondary education have to be allocated into (single-sex) secondary schools. A high school admission lottery creates this allocation, which guarantee that students cannot select into different catholic high schools.[44] Thus, secondary schools comprises students coming from both single-sex and coed primary schools.

E.2. Subject Options

Although schools can differ in the set of optional subjects offered, these differences are unlikely a concern for a number of reasons. First, all schools offer the same science courses (physics, chemistry and biology). In boys-only schools, physics is usually mandatory and the other two science courses are available in the option subject set. For girls-only schools, there is usually not such a requirement of physics being mandatory. A typical female student has to choose 3 optional subjects, but the science subjects are displayed in a way that they have to choose at least one of them, with the rest remaining available if they want to take more than one science course. So, for every student in the sample I net out one science subject (physics for boys and the first observed for girls), and use the rest of their choices. Second, in all cases it is possible to observe a wide number of topics that span very similar fields. Finally, conditional on gender, the available subjects are quite similar irrespective of the type of primary school education.

Table E1 shows that the number of vocational and prevalently female subjects differ slightly according to the type of primary attended. The regression for the number of science was excluded as there is no variability among schools. Science courses comprise biology, chemistry and physics and all secondary schools offer them. Vocational courses include Information Technology, Engineering Technology,

[44] As there are usually more slots than candidates from the catholic primary, students coming from other school sectors participate.

Hospitality, Agribusiness, Health and Social Care, Media Literacy Education and Textiles and Fashion.[45] Prevalently female subjects include Home Economics, Health and Social Care, Hospitality, Textile and Fashion and Art/Drama.

Table E1. Optional Subject Set and Primary School Attended

	Prevalently Female Subjects		Vocational Subjects	
	Girls (1)	Boys (2)	Girls (3)	Boys (4)
Single-Sex Primary	-0.260***	0.098	-0.013	-0.157**
	(0.053)	(0.065)	(0.042)	(0.071)
Mean coed	3.22	2.42	1.36	1.81
Observations	2024	1565	2024	1594

Notes: Table reports OLS estimates of the effect of single-sex primary schooling on the number of prevalently female (columns 1 and 2) and vocational (columns 3 and 4) subjects offered in catholic secondary schools. The third row reports the average number of subjects offered to students coming from a coeducation primary school. Sample includes all graduate students from catholic primary schools. Robust standard errors are reported in parenthesis. Significance levels are indicated by * < .1, ** < .05, *** < .01.

Girls that attended coeducational schools end up in catholic secondary schools that offer, on average, 3.2 prevalently female subjects, as reported in the second row of column 1. Girls coming from single-sex primary schools face a slightly less number of female dominated subjects (-0.260). For boys, the effect goes in the other direction, though it is not statistically significant. In relation to the number of vocational subjects reported in columns 3 and 4, while there is evidence of a balanced number of subjects offered to girls, boys coming from single-sex primary schools face less number of vocational subjects to opt for (-0.157) compared to boys coming from coeducational schools. Given these small differences, the main specification include the number of subjects offered as controls.

[45] Hairdressing and Beauty and Retail should be included in this list but none of the schools offer these subjects.

Table E2. Subject Options and Primary School Attended

	At least one science subject (1)	Two science subjects (2)	At least one female subject (3)	At least one vocational subject (4)
Girls-only Primary	0.022	0.138**	-0.191	-0.360***
	(0.139)	(0.070)	(0.148)	(0.136)
Boys-only Primary	-0.092	-0.073	-0.028	-0.156**
	(0.060)	(0.052)	(0.061)	(0.063)
Observations	1022	1022	1022	1022

Notes: Table reports OLS estimates of the effect of single-sex primary schooling on the outcome variable shown in the column header. Columns 3 and 4 add a control for the number of prevalently female and vocational subjects offered, respectively. Regressions include lottery fixed effects and application pattern. Sample includes all students at catholic secondary schools that participated in the primary admission lotteries. Robust standard errors, clustered at individual level, are reported in parenthesis. Significance levels are indicated by * $<$ .1, ** $<$ .05, *** $<$ .01.

F. Mechanisms

Table F1. Effect of Single-sex School on Teachers Inputs
(excluding teachers from non-participating schools)

	Girls-only Schools (1)	Boys-only Schools (2)
Panel A: Teacher Satisfaction & Quality of the Teacher-Student Relationship		
Teacher satisfaction	-0.121	-0.388
	(0.213)	(0.241)
Students are respectful of the teachers	0.604*	0.100
	(0.307)	(0.278)
Panel B: Classroom Environment & School Discipline		
Student misbehavior	-0.661**	0.441
	(0.306)	(0.411)
School rules are clear and enforced	0.666**	0.194
	(0.278)	(0.188)
Panel C: Instructional Practices		
Individualized instruction & feedback	0.338	-0.652
	(0.568)	(0.463)
Aligned pedagogical practices	-0.069	-0.260
	(0.308)	(0.279)
Guided instruction	0.704*	1.083**
	(0.353)	(0.452)
Ability grouping	-0.852	-0.647
	(0.582)	(0.598)
Panel D: Self- and Student Assessment		
Curriculum expertise	-0.849*	0.163
	(0.433)	(0.334)
Students' performance	0.124	0.124
	(0.614)	(0.653)

Notes: Table reports OLS estimates of the effect of single-sex school on the outcome variable shown in each row. Regressions include a dummy variable equal to one if the school belongs to the Catholic sector and 0 if it belongs to the State sector. Sample includes 154 teachers of Year 5 students enrolled in catholic and state schools in 2016 that participated in the PIRLS survey and exclude those working at schools that do not participate in the Benchmark examination. Robust standard errors, clustered at school level, are reported in parenthesis. Significance levels are indicated by * < .1, ** < .05, *** < .01.

Table F2. School Principals' Survey

	Girls-only Schools (1)	Boys-only Schools (2)
Panel A: Quality of the Teacher-Student Relationship		
Intimidation or verbal abuse of teachers or staff	-1.928	-2.004
	(0.595)	(0.631)
Panel B: Classroom Environment		
Absenteeism/Late arrival at school	-0.433	-0.123
	(0.589)	(0.624)
Classroom disturbance	-1.158*	-0.914
	(0.587)	(0.622)
Intimidation or verbal abuse among students	0.144	0.516
	(0.600)	(0.636)
Physical fights among students	-0.998*	0.203
	(0.574)	(0.609)
Panel C: Teacher and Student Assessment		
Curriculum expertise	0.041	0.029
	(0.594)	(0.630)
Students' performance	0.455	0.680
	(0.582)	(0.617)

Notes: Table reports OLS estimates of the effect of single-sex school on the outcome variable shown in each row. Regressions include a dummy variable equal to one if the school belongs to the Catholic sector and 0 if it belongs to the State sector. Sample includes 72 school principals of catholic and state primary schools in 2016 that participated in the PIRLS survey. Robust standard errors, clustered at school level, are reported in parenthesis. Significance levels are indicated by * $< .1$, ** $< .05$, *** $< .01$.

Table F3. Effect of Single-sex School on Students Inputs

	Girls-only Schools (1)	Boys-only Schools (2)
Panel A: Student Satisfaction & School Bullying		
Student satisfaction	0.096	0.127***
	(0.151)	(0.047)
Absenteeism	-0.101***	-0.055
	(0.036)	(0.056)
Bullying index	-0.028	-0.187
	(0.171)	(0.210)
Panel B: Teacher-Student Relationship		
Teachers at my school are fair to me	-0.092	-0.120
	(0.130)	(0.125)
Panel C: Instructional Practices		
Aligned pedagogical practices	-0.145	-0.142
	(0.108)	(0.149)
Panel D: Self-assessment and confidence		
I usually do well in reading	-0.004	0.065
	(0.057)	(0.073)
Reading is easy for me	-0.133***	-0.038
	(0.036)	(0.131)
Reading is harder for me than any other subject	-0.015	-0.222
	(0.068)	(0.136)
Reading is harder for me than for many of my classmates	-0.109	-0.229*
	(0.067)	(0.137)
I am just not good at reading	0.155**	-0.269*
	(0.070)	(0.138)

Notes: Table reports OLS estimates of the effect of single-sex school on the outcome variable shown in each row. Regressions include an indicator for girls-only schools, an indicator for boys-only schools and the interaction between a catholic sector indicator and an indicator for female student. As such, coefficients in column 1 (2) are interpreted as the effect of single-sex education for girls (boys) relative to girls (boys) students at coeducational catholic schools. Sample includes 3015 Year 5 students enrolled in catholic and state schools in 2016 that participated in the PIRLS survey. Robust standard errors, clustered at school level, are reported in parenthesis. Significance levels are indicated by * $< .1$, ** $< .05$, *** $< .01$.