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# Do Single-Sex Classes Affect Achievement?

## A Study in a Coeducational University\*

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### Abstract

We examine the effect of single-sex classes on the pass rates, grades, and course choices of students in a coeducational university. We randomly assign students to all-female, all-male, and coed classes and, therefore, get around the selection issues present in other studies on single-sex education. We find that one hour a week of single-sex education benefits females: females are 7.5% more likely to pass their first year courses and score 10% higher in their required second year classes than their peers attending coeducational classes. We find no effect of single-sex education on the subsequent probability that a female will take technical classes and there is no effect of single-sex education for males. Furthermore we are able to examine potential mechanisms and indirect effects of single-sex education. We find that the effects of single-sex education do not appear to be driven by a tracking mechanism and that there are indirect effects on class attendance and completion of optional assignments for females. However, the indirect effects cannot explain much of the effect of single-sex education for females.

**JEL Classification:** C9, C91, C92, J16, J16, J24

**Keywords:** gender, single-sex groups, cognitive ability

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## I. Introduction

Women are under-represented in the highest levels of mathematics, the physical sciences, and engineering (NAS 2006), despite the fact that more women now attend university than men.<sup>2</sup> Furthermore, there is a gender gap in standardized mathematics tests scores,<sup>3</sup> especially at the top of the distribution.<sup>4</sup> Single-sex education is sometimes viewed as a mechanism to decrease these gaps. This is because advocates of single-sex education claim that educating females in single-sex classes will increase their test scores, especially in mathematics and science, and that females taught in single-sex classes will then be more likely to take technical courses than their counterparts educated in mixed gender classes.

Policy makers, in seeking to decrease gender gaps in test scores and increase female representation in high-tech sectors of the workforce, have begun to listen to advocates of single-sex education and to allow expansion of publicly funded single-sex schools. According to the National Association for Single Sex Public Education (NASSPE), in 2002 there were only about a dozen US public schools offering single-sex classes; as of 2010 there were 540, of which 91 were all-girl or all-boy schools. In 2006, the US federal government eased regulatory restrictions on single-sex education that had been enforced under title IX, and now allows districts to create single-sex schools and have single-sex classes in publicly funded schools as long as enrollment is voluntary. In the UK, where single-sex education has been on the decline,<sup>5</sup> top education leaders have been calling for more government support for single-sex education (Lydall, 2012).

The expansion of single-sex education and calls for its support have occurred in spite of scientific evidence showing few, if any, benefits of single-sex education: a 2005 US Department of Education systematic review found 'minimal' evidence supporting single-sex education; Smithers and Robinson (2006) along with Tompson and Ungerleider (2004) argue that observed benefits of single-sex education are due to student selection into schools and Jackson (2012) shows that only females who have a strong preference to attend single-sex schools show any benefit from single-sex education; Halpmen et. al. (2011) go further stating "there is no well-designed research showing that single-sex education improves students' academic performance" and argue that "there is evidence that sex segregation increases gender stereotyping and legitimizes institutional sexism."

While there is a lack of evidence showing benefits from single-sex education, there is a small literature showing that the proportion of females in a classroom has an effect on educational and economic outcomes. Lavy and Schlosser (2011) show that, as the proportion of females in a classroom increases, the cognitive outcomes of both males and females improve. Schneeweis and Zweimüller (2012) show that, when a female studies in a class with a higher proportion of females, she is more likely to choose

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<sup>2</sup> In the US in the 1960s there were 1.55 males for every female undergraduate but by 2003 there were 1.30 females for every male undergraduate (Goldin et. al. 2006)

<sup>3</sup> A gender gap in standardized mathematics tests does exist but it varies by country (Else-Quest et. al. 2010, Guiso et. al 2008) and some argue it may not be large enough to be of any practical importance (Hyde et. al. 2008). Fryer and Levitt (2010), however, document a substantial gender gap in mathematics in the US; after six-years of education there is a 0.2 of a standard deviation gender gap in test scores. That gap is roughly half as large as the black-white test score gap.

<sup>4</sup> What is agreed on is that, at the top of the distribution, there is a large and significant gap in mathematics test scores. For example, there is a 2:1 to 1 male-female ratio among students scoring 800 on the math SAT (Ellison and Swanson, 2010).

<sup>5</sup> Despite the decline of single-sex education in the UK, over 60% of the top 50 secondary schools, based on GCSE results, were single-sex in 2011 according to the BBC league tables.

to study in a technical school later on. Anelli and Peri (2013) find that a women in a high school class with a larger share of female peers will have a higher wage; this primarily because the higher proportion of same-sex peers increases the likelihood a woman will choose majors associated with high earning jobs such as economics, business, medicine, or engineering. Individuals' attributes – such as willingness to behave competitively or to take risks – also affect outcomes; for example, math test scores are shown to be influenced by competitive behavior (Niederle and Vesterlund, 2010). Moreover, a growing recent literature explores how competitive and risk-taking attributes vary in response to cultural factors. Gneezy et al. (2009) show that females in matrilineal societies are more likely to compete than males in that society, and compete as much as men in a patriarchal society. Booth and Nolen (2012a, 2012b) show that all-female environments make females more competitive and less risk averse.

When considering this literature alongside the research on single-sex education, the following questions arise: Is completely gender-segregated education taking things too far, perhaps increasing gender stereotyping and legitimizing institutional sexism? Might single-sex classes within a coeducational environment be a useful alternative way forward? Would single-sex classes in the technical subjects benefit women without adversely affecting men? We address the last two of these questions in the present paper. Specifically, we examine the effect of single-sex classes on test scores and course choices using a field experiment conducted at a high-ranked coeducational economics program in the UK. We randomly assigned first-year economics students into all-female, all-male, or coeducational classes. The students attend a coeducational university and, if assigned to a single-sex class, are only in that environment for one hour a week.<sup>6</sup> The randomization allows for straightforward identification of the effect of single-sex education on pass rates and course grades. This is an advantage over other recent work trying to identify the effects of single-sex education because our students attend the same school, get the same instruction, and did not choose to attend the school because there was a high probability they would be assigned to single-sex classes. Furthermore, we are able to follow students over time and can examine what courses they chose to take in the second year of study<sup>7</sup> and whether or not their grades in second year courses are affected by the first year class allocation. Thus the experiment is able to examine two of the key claims made by single-sex advocates: does being in an all-female class cause females to do better? And does exposure to all-female classes cause females to take more technical courses? We are also able to look at whether there is a longer term effect of single-sex education by seeing how class allocation affects the grades of students more than a year after they stopped being taught in single-sex classes.

Our sample is different than those used in previous studies; most of the research to date has focused on students from primary and secondary schools. Therefore this paper is of particular importance because many universities are facing decisions on how to minimize gender inequalities that exist in higher education and studies on single-sex university education are rare.<sup>8</sup> Indeed the results are

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<sup>6</sup> First-year students receive twelve hours of instruction per week. Eight hours are lectures by economics faculty members and four hours are additional classes taught by graduate teaching assistants. This field experiment deals with one of the classes taught by graduate teaching assistants.

<sup>7</sup> In the first year nearly all economics students take the same set of courses. There is the possibility for a student to substitute one option depending on the student's background or degree scheme.

<sup>8</sup> Harvard Business School, for example, has been implementing policies aimed at decreasing gender disparities that develop after women begin their studies (refer to "Harvard Business School Case Study: Gender Equity" in the *New York Times* on September 7, 2013).

important for understanding what affects the accumulation of human capital at the university level. Furthermore, our students spend less time in their single-sex classes – one hour per week – and are older and arguably less likely to be influenced by their environment than students who are in primary or secondary school. Therefore, one might see the choice of this sample as biasing us towards finding no effect of single-sex education. Despite these factors, though, we find a considerable impact of single-sex schooling: females in all-female classes are over 7% more likely to pass their introductory economics course, score 8% higher on the course grade, and score 10% higher in their required courses a year after being assigned to a single-sex class than their counterparts assigned to coed classes. Moreover, this increase in female attainment occurs with no additional expenditure.

We designed our study to see if single-sex education could have an effect within an overall coeducational environment, and to examine what potential mechanisms might be driving the effects. There is no shortage of possible mechanisms that could be driving the effects we document: peer effects; changes in teacher behavior; or social dynamics outside the classroom for instance. Given that researchers have documented a gender gap in math tests scores at the higher end of the distribution, though, we are keen to examine if our results can be explained by one particular mechanism: tracking. Tracking by ability, as discussed in Dulfo et al. (2011) when looking at primary school children, allows teachers to be more effective because it reduces the variance in ability present in the classroom. If the variance in ability differs by gender, then segregating classes by gender could cause females in single-sex classes to do better. More precisely, if the variance of the distribution of ability for females is smaller than the variance of the distribution for males, then segregating by gender means that females in single-sex classes are all closer to the median.<sup>9</sup> The teacher can then teach to the median student rather than spending time teaching to different parts of the distribution.

Besides specifically checking whether there is evidence that tracking could be driving our results we also look at attendance, coursework, and aspects of classroom structure. We find that the results are independent of teacher characteristics and that students in single-sex classes did not view their teachers as performing better than when the same teachers taught coed classes. This suggests that the results are not likely to be driven by changes in teaching style. We do find that girls in single-sex classes are more likely to attend classes and do all optional assignments for the course, though. These results are consistent with reports from female students that they felt more comfortable in all-female classes. A reduction in stereotype threat, as discussed in Steele et al. (2002), would be consistent with causing females to attend more classes, do better on exams, and potentially do more optional assignments.<sup>10</sup> However, we have no formal test for whether stereotype threat is driving the results. Our examination of tracking and looking at standard classroom effects does show the indirect effects that can lead females to score better on exams and overall, though. Therefore, when considering policies aimed at increasing the performance of females in higher education, one could potentially use

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<sup>9</sup> As shown by Ellison and Swanson (2010), at the top of the distribution, there is a large and significant gap in mathematics test scores. For example, there is a 2.1 to 1 male-female ratio among students scoring 800 on the math. Therefore, if men are more likely to be in the top tail of the distribution, single-sex classes could reduce the variance in ability for females.

<sup>10</sup> Under the idea of stereotype threat, females could be seen as facing added anxiety when taking tests because they have been conditioned to believe they are worse at economics. Therefore, a female enrolled in an all-female class should be more willing to participate in discussion and feel less pressure when taking exams. Consequently, she should do better in courses and show up to more classes given the absence of the negative stereotype caused by having males present.

single-sex education or try to design a mechanism that has the same indirect effects.<sup>11</sup> However, our results suggest there is a direct effect of single-sex education on exams scores above and beyond the indirect effect of increasing attendance and completion of optional coursework assignments.

The next section lays out the conjectures that our field experiment was designed to test. The third section discusses the experimental design, context, and subjects involved. The fourth section presents the results and the fifth section concludes.

## II. Conjectures

This section lays out one set of conjectures and a discussion of possible mechanisms and indirect effects. The first subsection deals with the conjectures regarding the effects of single-sex education on pass rates, course selection, and second year course grades. The second subsection lays out a conjecture on tracking that we will test later in the paper. It also discusses other potential mechanisms that motivate the indirect effects.

### 2.1 Pass Rate, Course Selection, and Exam Marks

Systematic reviews of the literature on single-sex education have shown that observed benefits of single-sex environments are primarily due to selection into schools.<sup>12</sup> However, the economics of education literature has shown that there is an effect of having more females in a class on cognitive outcomes and student choices regarding which type of classes to take. Therefore, to examine the effect of having a fully single-sex class, we designed a field experiment, a randomized control trial, to test the following conjectures.

*Conjecture One:* Females in single-sex classes are more likely to pass their introductory economics course than females in coeducational classes.

Supporters of single-sex education argue that females may face pressure to conform to gender stereotypes in order to fit in socially. For instance, a female may be exposed to the stereotype that females are worse at economics than males. If this is the case, then, a female who does well in an economics course, may be ostracized or teased by her peers. Psychologists have shown that the framing of tasks and cultural stereotypes does affect the performance of individuals (see Steele et al. 2002 and the references there in). Therefore, by educating females and males separately, females will not face pressure to conform to negative stereotypes and instead will perform better on tests and thus be more likely to pass the courses in which they are enrolled. We focus on pass rates and not on the final mark because of the weaker incentives first-year students face.<sup>13</sup>

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<sup>11</sup> For instance, at Harvard Business School, females were given classes on how to raise their hands and participate in class discussions which could conceivably increase class participation and attendance by females.

<sup>12</sup> See US Department of Education (2005), Smithers and Robinson (2006), and Tompson and Ungerleider (2004). Doris et al. (2012), when looking at single-sex schooling in Ireland, show that there is no effect of single-sex education. Jackson (2012) shows that most students do not benefit from single-sex education and that females at single-sex schools take fewer science courses.

<sup>13</sup> UK degrees are awarded an overall classification – a first class degree, an upper-second class degree (2.1), a lower-second class degree (2.2), or a third class degree – and the marks received in the first year of study usually do not affect the degree classification. In our setting, students only have the incentive to get a mark of 40 or higher. This will be discussed further in the results section.

*Conjecture Two:* Females who studied in single-sex classes during their first-year are more likely to take the technical courses required for a BSc during their second year of study than females who studied in coeducational classes during their first year.

If females enrolled in single-sex classes do better and feel more comfortable studying economics, then they may be more likely to take more technical, mathematically intensive courses in their second year of study. This is an argument often made by single-sex advocates. While not looking at fully gender-segregated classes, Schneeweis and Zweimüller (2012) examine the college choices of students in Austria based on the type of high school they attended. Using variation in the proportion of females in adjacent cohorts within schools, they find that females studying with a higher proportion of females are more likely to enter a technical college when they continue their education. Therefore, educating females in single-sex class may cause them to choose to enroll in technical course in their second year. We focus on choices in the second year because nearly all students take the exact same set of courses in their first year.<sup>14</sup> However, in the second year, they can choose to take more mathematical courses from a set of available options.

*Conjecture Three:* Females who were in single-sex classes during their first year earn higher grades in their required second year courses than females who were in coeducational classes.

Females who were randomly assigned to single-sex classes during their first-year may gain long term benefits from only briefly being educated separately from males. Cohen et al. (2009) show that even subtle interventions to lessen the psychological threat of being negatively stereotyped can have long lasting benefits. Cohen et al. (2006) found that African-Americans who completed a series of writing assignments designed to provide self-affirmation immediately earned higher GPAs and that two years later (in the follow-up survey Cohen et al., 2009) they found that those students earned higher marks as well. European-American students did not benefit from the intervention immediately or in the two year follow-up. If females in single-sex classes do better because of the decrease in psychological threat then they may earn higher marks in the second year because they continue to benefit from the first-year intervention.

### 2.1 Tracking and Potential Mechanisms

There are many potential mechanisms that could cause single-sex education to have an effect: class disruptions may be lower in all-female classes; graduate teaching assistants (GTAs) may adjust their teaching style; students may feel more comfortable in asking questions. Before discussing all potential mechanisms, though, we want to examine one formally with the following hypothesis.

*Conjecture Four:* The distribution of ability in single-sex classes does not differ from the distribution of ability in coeducational classes.

The literature on gender gaps in test scores shows that males are more likely to be in the top part of the distribution than females. Therefore, when females are segregated from males, the distribution of ability in all-female classes may be smaller than in coeducational classes; there may be a form of

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<sup>14</sup> All students in economics have to take the same three year-long courses in the first year. The fourth course will depend on the degree scheme the student enrolled in when coming to the university. Conditional on the degree scheme, students have no options in the first year unless they seek special permission to be exempt from requirements.

tracking taking place. Recent work by Duflo et al. (2011) shows that tracking by ability can benefit both high and low-performing students at primary schools in Kenya. In examining the effects of tracking, Duflo et al. (2011) lay out a model that is useful to consider the mechanisms by which tracking could benefit even university students, though, university students are more likely to be at the higher end of the IQ distribution which may leave less room for further tracking by ability. In our situation, GTAs are incentivized to have students do well (e.g. get good marks) or they may be removed from their teaching position.<sup>15</sup> If the GTA is teaching at a level too far away from a student's ability, the student will not benefit. Thus, if there is a large distribution of ability, the GTA has to teach to each part of the distribution to allow students to learn and minimize complaints. If the distribution of ability is small, the GTA can teach to the median level and all students will benefit. Given this framework, if single-sex classes have a lower distribution in ability than coeducational classes, females could benefit due to being in a class with a decreased variance in ability and not because of a psychological factor such as a reduction in stereotype threat. Before any instruction took place we had students take an IQ test and will use that as a measure of ability to examine if there is evidence supporting conjecture four.

Tracking is only one potential mechanism for why single-sex education might affect the exam scores of females. For example changes in peer effects, either in the classroom or through endogenously formed study groups, due to the treatment, could explain the effect. Teachers may also change their behavior due to the presence of single-sex classes by either teaching differently or favoring the all-female classes over other class types. Rather than design an experiment to test all possible mechanisms along with trying to get a cleanly identified effect of single-sex education, we propose first to test some things directly, and second to look at outcomes on indirect effects that are known to have a positive effect on exam scores. For example, to look at the role of teachers, we can use GTA fixed effects and see if GTAs were scored higher by their students when they taught single-sex classes. This should allow us to examine directly if teacher differences are behind any observed changes in exam scores. When considering indirect effects we propose to look at such things as attendance at classes and examine if there is an indirect effect of single-sex classes through attendance. For example, if being assigned to an all-female class causes attendance at classes to increase, then the effect of single-sex education could be due to the increase in attendance. In that case, any intervention that has the same impact on attendance for females and leaves male attendance unchanged could produce the same effect as single-sex classes. However if we can include attendance in the regression with the treatment effect, we can examine if there is a direct effect of single-sex education above and beyond any indirect effect through the increase in attendance. The presence of a direct effect would suggest that the impact of single-sex education might not be able to be mimicked by other policies known to affect inputs in the education production function.

### **III. Experimental Design**

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<sup>15</sup> Classes are taught by Graduate Teaching Assistant (GTAs) from the economics department, who are PhD students hired in a competitive hiring process from the pool of PhD applicants. If first-year students file a legitimate complaint about their Graduate Teaching Assistant (GTA), or if the professor taking the lectures sees problems when reviewing marks from the first term test, a GTA can be relieved of their teaching duties.



Our experiment was designed to test the conjectures listed above. Given the issues of selection raised when the conclusions of other studies were examined,<sup>16</sup> we used random assignment to class type in order to identify the effect of the educational environment. Below we discuss the randomization, the experimental set-up and look at the descriptive statistics.

### 3.1 *Subjects and Educational Environment*

The students in our experiment arrived at the University of Essex in October 2010 and they all took a year-long introductory economics course, either EC111 or EC100. EC111 is primarily for economics students and EC100 is primarily for student in the business school. The introductory economics course was one of the four required year-long courses that students had to take in their first year. Both introductory courses run over 20 weeks and have the same structure: each week a professor from the economics department gives a two hour lecture and a graduate teaching assistant (GTA) gives a one hour class. The lecture takes place in a large auditorium designed to hold over 1000 students. The one hour class is taught by a GTA in small classroom that can hold no more than 30 students.<sup>17</sup>

During their first year of study students receive 240 hours of instruction, 60 hours per course. The focus of our experiment will be the one hour of class time per week taught by GTAs in the introductory economics course. That amounts to 20 hours of instruction, or 8.3% of the total instruction received by a student in the first year.

### 3.2 *Experimental Design*

Students were randomly assigned to a single-gender or coeducational class. Class assignments were made randomly by the timetabling office before students arrived on campus. Once assigned to a class, students were not allowed to change their class and attendance at the assigned class was enforced.<sup>18</sup> The procedures regarding class-assignment and attendance are the same used each year. There was no change in the way students were assigned to classes in any of the other year-long courses and courses were scheduled by timetabling so that there was no conflict between class times and any lecturers. Furthermore, the assignment to classes in other courses was independent of the introductory economics class assignment. At no stage were the students told the purpose of the class assignment nor did we have any enquiries. All students enrolled in the course are supposed to attend

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<sup>16</sup> Recent work has aimed to get at the effect of single-sex education but has been forced to rely on comparing students attending different types of schools or looking at the effect within a school where *ex ante* the student knew she was very likely to attend single-sex classes. For instance Park et. al. (2012a, 2012b) try to use a natural experiment regarding the allocation of students into high schools in Korea to get at the effects of single-sex education but the single-sex and coed schools differ in how they are funded and teacher allocation making it hard to attribute the effect solely to the gender make-up of the schools. Eisenkopf et al. (2011) look at students who chose to attend a school that prepares them to be teachers. Since teaching is a primary female occupation roughly 85% of their sample is female. The minimal male presence means when students are assigned to classes some classes end up being all-female but the students knew this *ex ante* and their school choice is related to the probability of being in an all-female environment. The *ex ante* selection is likely to bias the results because, as shown by Jackson (2012), the few females that benefit from single-sex education are those with a preference to attend single-sex schools.

<sup>17</sup> For this experiment, GTAs were told not to discuss with students any of the details – or objectives – of the experiments. In classes the instructors discuss with students problem-sets that relate directly to the material taught in that week's *Introduction to Economics* lectures. The Professor of the course tells the GTAs what material should be covered in each class. The problem sets are the same across all classes in EC100 and in EC111 (though they differ between EC100 and EC111).

<sup>18</sup> The university is required to take attendance so that it can provide evidence that international students who are in the UK on student visas are actually attending classes. Indeed the visa requirements for most international students includes the provision that they must attend lectures and classes.

the classes and do the compulsory exercises. Lectures and classes began immediately after student arrival at campus.

There were 20 classes in EC100 and 17 classes in EC111. Of the 20 classes in EC100, 4 were all-female, 7 were all-male, and 9 were coed. Of the 17 classes in EC111, 3 were all-female, 4 were all-male, and 10 were coed. That means – at the class level – we have 7 all-female classes, 11 all-male classes, and 19 coed classes.<sup>19</sup> As in other years our sample was, roughly, 35% female and 65% male. We chose to create this number of all-male and all-female classes because it kept the gender distribution roughly what it would have been without the experiment taking place; i.e. in the 19 coed classes each class was, on average, 30% female and 70% male.

During the first class meeting, GTAs had students take an IQ test, fill out a demographic questionnaire, and participate in a risk and competition experiment. The IQ test was a modified 20-minute version of Raven's Matrices appropriate for university-aged students.

The grade for introductory economics is based on assignments, tests, and an exam. At the end of the first term, students have a take-home assignment that they have to do on their own. They will also take a one-hour test in a lecture hall while being supervised. At the end of the second term, students will again do a take-home assignment and take a one-hour test. The assignments and tests are marked by the class teacher who can see the name of the student.<sup>20</sup> Generally no curve is forced on the assignment or test marks; the course professor gives a detailed outline of what marks should be awarded based on potential answers. However, the professor responsible for the course does look at marks to make sure there is no discrepancy across GTAs. During the summer term (the third and final term for the academic year), students take a 2 hour exam. As is the standard procedure in the UK, that exam is double-blind marked by two members of the economics department and neither marker knows the name or gender of the student. Furthermore, an external examiner – a professor from another UK University – reviews the exams to ensure they are of a particular standard and that the marks are appropriate. No curve is forced on final exam marks.

A student's overall grade in the course is based on a max-rule. The scores from assignments and tests are averaged. If the average is *above* the exam mark, the student's final mark will be 50% of the coursework (assignments and tests) mark plus 50% of the exam mark. If the coursework average is *below* the exam score, then the student's final mark will be the exam mark. Students know this rule from the beginning – it is explained to them during the first lecture – and all courses in the economics department are graded in the same manner.<sup>21</sup> Given that coursework may not count towards the final score a number of students choose not to do it. However, all students *must* take the exam.

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<sup>19</sup> Given that treatment was at the class level we cluster standard errors at the class level and look at class level regressions in the results section.

<sup>20</sup> As shown in Lavy (2008) when teachers are aware of the gender of the student prejudices can occur in marking that could lead to gender differences in test scores that are not there when objective measures are used.

<sup>21</sup> Note that the max-rule is applied by the economics department automatically, and students do not themselves make any choice about its application *ex post*. However they might choose to do no coursework; indeed at least 15% of our sample did not do all the coursework.

Degrees in the UK are classified into one of four categories: a first class degree, which is the best degree classification; an upper second (i.e. 2.1) which is the second best classification; a lower second degree (i.e. 2.2.) which is the third best; or a third which is the lowest classification. At Essex University (and at many other British universities), the degree classification is based on the scores students get in their second and third years only. All a student has to do is 'pass' all courses in the first year, i.e. get a score of 40 or higher in all four courses, in order to continue into the second year of study. Thus, when looking at the effect of single-sex education in the first year we will focus on the margin that will matter the most for students, whether they 'passed' their course.

In the second year of study students in the economics department have to take 5 full-year courses (one of the courses can be composed of two half-year courses). Two courses are required, microeconomics, EC201, and macroeconomics, EC202, and the rest can be chosen from a list of courses, though, there is less flexibility for some students because of degree type. All economics students are offered two mathematically intensive courses: EC251, Mathematical Methods in Economics; and EC252, Introduction to Econometric Methods. Students who take both of these courses and pass can graduate with a BSc rather than a BA. Students in the business school who were required to take EC100 in their first year also have to take 5 full-year courses in their second year. All of them must take BE111, management accounting. If a student in the business school wants to graduate with a BSc the student can choose from a set of more technical courses depending on the type of degree. Therefore, when looking at the effect of single-gender classes on the choice of a student to take technical courses, we will focus on whether the student chose to take the requirements for the BSc. When looking at grades in the second year, we will look at EC201 and BE111, because they are both required and taught in the autumn term (the first term of the academic year).<sup>22</sup>

### 3.3 Descriptive Statistics

To examine the effect of single-gender classes on pass rates we will look at the sample of all students who took introductory economics. To look at the effect of single-gender classes on the probability of taking the technical courses required for a BSc in the second year or second year marks we will focus on students enrolled in the economics department or the business school.<sup>23</sup> Since class type was randomly assigned we expect that the observables should not differ by class type. Table 1 shows the summary statistics by class type.

[Insert Table 1 Here]

The first seven variables in table one are outcome variables that could have been affected by assigning students to single-gender classes. The summary statistics show that, for a female, being assigned to an all-female class is associated with a higher probability of passing the first year course, with a higher overall score, a higher exam score, and with a higher average coursework mark. In the second year,

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<sup>22</sup> Even though the courses are taught in the autumn term, the exam for the courses is given during the summer term (the third and final term of the academic year). As with the first year courses, the exams are mandatory, double-blind marked, and reviewed by an external.

<sup>23</sup> Students enrolled in joint degree schemes such as government with economics or sociology with economics have to take the introductory economics course. However those degrees are not overseen by the economics department or the business school and, consequently, the students do have the same required courses in their second year. Therefore, we do not focus on these students when looking at second year course choices or grades.

females who had been assigned to all-female classes in their first year, scored higher on their required course despite no longer being in all-female classes for over 12 months but the difference was not significant. None of these effects are present for males. However, there is no effect on the probability of males or females enrolling in the BSc program due to being assigned to a same-gender class.

These summary statistics provide initial evidence for conjectures one and three; assignment to all-female classes is associated with females being more likely to pass their introductory course and that the effects of being assigned to an all-female class lasts for at least a year (the point estimate for the second year effect is large). However, based on the summary statistics, there is no evidence for conjecture two; that girls assigned to all-female classes are more likely to enroll in a BSc program. Furthermore, we have a positive effect of single-gender classes on at least one indirect variable, attendance, for females only. We will examine these initial effects more closely in the regression analysis below.

The last 13 variables presented in Table 1 allow us to examine how well the randomization worked. For the majority of the variables, there is no difference between the treatment (single-gender) and control (coed) groups. There are slightly more black students and slightly less white students in all-boy classes than coed classes. Females in all-female classes are marginally more likely to be native English speakers and have more female siblings. As with all randomizations, some differences are likely to occur. Indeed, using the 10% significance level we would expect, with random assignment, roughly three observable differences. This is what we have: the difference in English speaking for females; the number of sisters for females; and the racial make up for all-boys.<sup>24</sup> To see if these differences matter, we will control for all observables in the in the regression analysis and examine if including them changes our estimated effects.

The two major differences between coed and single-sex classes that can be seen in the descriptive statistics are that females in the all-female group are younger than their classmates in coed classes, and that class sizes in the all-female classes are larger than the coed classes. The age difference is because the few older, non-traditional students were randomly assigned to the coed classes.<sup>25</sup> To examine if the age distribution had a difference we will control for age in the regression analysis and see if it affects the estimate of our variable of interest. The class size difference occurred because of the assignment to classes, though, and could have an effect on the learning of students in classes.

For introductory economics, the number of classes is typically based on predicted enrollment and classes were capped at 20 students in EC111 and 22 in EC100. To minimize the number of classes needed, as many classes as possible are filled to the maximum number of students and then, if needed, more are created. In the year of our experiment, two more coed classes in EC111 and EC100 were created and each had fewer than the maximum number of students. When those additional classes are excluded from the sample, the enrollment between coed and single-sex classes at the beginning

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<sup>24</sup> By construction if the percent black goes up the percent white is very likely to go down so those two variables will be correlated and pick up whether the racial make-up varies by class type.

<sup>25</sup> There are two things pushing the average age up for the coed group: (i) there is one 44 year old female and three 26 year old females that were assigned to coed classes; and (ii) the starting age, on average, is higher in the business school where we have a larger proportion of coed classes in comparison to all-female classes for the introductory class for business students, EC100.

of the year is the same. However, over the year, some students drop out or switch to different degree schemes (e.g. switch from being an economics student to a government student). A higher proportion of female students assigned to the coed courses switched courses or dropped out.<sup>26</sup> This means that, by the end of the year, there were fewer students on average in coed classes than in the all-female classes. Based on the education literature (Angrist and Lavy, 1999; Hoxby, 2000; and Krueger and Whitmore 2001), we know that smaller class sizes benefit students. Therefore, if anything, this difference in class size that occurs by the end of the year will drive us to not find an effect of single-sex classes. Furthermore, we can also examine this empirically by controlling for class size differences and seeing the effect it has on our estimate of interest.

#### IV. RESULTS

In this section we present the results. We examine if there is any evidence to support the conjectures on the main effects – pass rates, second year marks, and technical course choices – or the tracking conjecture and indirect effects discussed in the second section.

##### 4.1 *Pass Rate, Exam Marks, and Coursework in the First Year*

Table 2 shows the regression results that allow us to examine whether there is evidence supporting conjecture one.

[Insert Table 2 here]

Columns [1]-[5] in table two show that there is strong evidence for conjecture one: that females assigned to all-female classes are more likely to pass the introductory economics course than females assigned to coed classes. Column [1] shows that girls in all-female classes are 6.7 percentage points more likely to pass their introductory course than females assigned to coed classes. The pass rate for the introductory course is 89% so the increase of 6.7 percentage points represents a 7.5% increase in the pass rate for females. That is a large effect given that no additional resources were needed. When we control for age and class size the estimated effect doesn't change, as seen in column [2]. This suggests that the randomization worked because inclusion of these variables does not affect the estimate.<sup>27</sup> Furthermore, controlling for all observables from table one does not change the point estimate, as seen in column [3].<sup>28</sup> Again this suggests that it is unlikely that the results are being driven by unexplained heterogeneity; indeed the point estimate for all-female is the same in columns [2] and [3] and only the standard error of the coefficient decreases when more controls are added, as would be expected with a well-designed and implemented RCT.

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<sup>26</sup> We actually find that being in an all-female classes is associated with a much lower likelihood of dropping out or switching to a different degree scheme. However, we cannot follow the students that are no longer in one of the introductory economics courses and the number of students involved are small.

<sup>27</sup> The class sizes in EC100 are, by design, larger than those in EC111. Thus we have to interact class size with the EC111 dummy variable since, because of the design, class size and the EC111 dummy will be correlated.

<sup>28</sup> We control for the variables listed in Table One: a student's raw IQ score; whether a student is a native English speaker (=1); white (=1); black (=1); the eldest sibling (=1); born in the UK (=1); born in the EU (=1); the number siblings a student has; the number of sisters a student has; if the student's father had a university degree (=1); and if the student's mother had a university degree (=1) .

Since this experiment takes place at the class level, we also run class-level regressions as shown in column [4]. Column [4] shows that the pass rate of all-female classes were 6.3 percentage points higher than coed and all-male classes. The consistency of the estimated effect of being in an all-female class across all four specifications shows that the randomization likely worked well and that the estimate is getting at the causal effect of being assigned to an all-female class. However, as one more check, we also want to control for the class teacher's ability so we use GTA fixed effects in column [5].<sup>29</sup> We are able to do this because, by design, GTAs taught both types of classes: coed and single-gender classes. The results in column [5] show that students in the all-female classes were, on average, 7.6 percentage points more likely to pass than female students in coed classes taught by the same GTA. One may speculate that the GTA could have changed her teaching style based on the gender composition of the class or that the result could be due to a Hawthorne effect; we will explore this later in the mechanism section of the paper but it appears that the GTA was perceived as teaching each type of class – the coed and same-gender classes – equally as well. We do learn from column [5], though, that even controlling for differences in GTAs we find that the single-sex effect is still present, and estimated to be the same, for females.

Our dependent variable of interest is whether or not a student passed the introductory economics course. We chose this because the marks a student receives in the first year do not affect the type of degree a student earns upon graduating. In the first year of study at Essex, a student need only get a 40% or higher in all courses in order to continue in her studies. However, if we look at the impact of being assigned to an all-female class on the average grade received by a student, we see that there is a positive effect. In column [6], we see that females in all-female classes score 4.5 points higher overall than their female counterparts in coed classes. But if we look at the 15<sup>th</sup> quantile, we see the estimated effect is more than double and much more significant.<sup>30</sup> This shows that being assigned to an all-female class is having a large effect for those students most at risk of not passing. In fact, at the 15<sup>th</sup> quantile, being assigned to an all-female class increases the score of a female by over 22%.

The aggregate course mark depends on the exam and coursework scores of the student. Each student has to take the exam but students can choose to do none or only some of the coursework. Column [8] shows that females in all-female classes score 4.7 points higher than females in coed classes. However, as in the case with the aggregate mark, the main effect is at the lower end of the distribution; the 15<sup>th</sup> quantile regression in column [9] shows that the effect is nearly double and much more significant. As shown in column [10] the effect of all-female classes on the coursework mark also appears to be positive. However, since some students chose not to do all four of the coursework assignments this coefficient might be biased upwards; students in all-female classes might have done the coursework because they knew they would do better.

Table two provides a compelling picture of the effect of single-gender classes on first year outcomes: only females appear to benefit from single-gender classes; females in all-female classes are much more likely to pass their first year course than females in coed classes; the estimated effect of being in an all-female class is robust to inclusion of many observable factors and even GTA fixed effects; the

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<sup>29</sup> GTAs only taught in only one introductory course, either EC111 or EC100, so we cannot estimate the EC111 coefficient in this specification.

<sup>30</sup> We chose the 15% quantile because, on average over the years, 15% of students get a mark below 40 in the introductory economics course.

effect of being in an all-female class is much stronger at the lower end of the distribution; and the effects are present even in the double-blind marked exams that are reviewed by externals. Thus there strong evidence that females can benefit from being in an all-female class. However, we want to examine how long these benefits last and check if the females who were in all-female classes might even do worse when they switch into coed classes in their second year.

#### 4.2 Course Selection and Exam Marks in the Second Year

Table 3 shows regression results that allow us to examine whether there is evidence supporting conjectures two or three.

[Insert Table 3 here]

Columns [1]-[4] of Table 3 allow us to examine if there is any evidence in support of conjecture two: that females who studied in single-sex classes during their first-year are more likely to take any of the technical courses required for a BSc during their second year of study than females who studied in coeducational classes. In the economics department and business school, students have to take a certain block of courses in their first year. In their second year, students take different courses based on their degree scheme. Students pick a provisional degree scheme upon entering the University but can change it at any time as long as they have the required courses for the scheme. One major choice a student faces in the second year is whether to take technical courses required to earn a BSc instead of a BA degree.<sup>31</sup> We therefore examine if being assigned to an all-female class causes a female to be more likely to take the BSc required courses.<sup>32</sup> As can be seen in column [1], there is no evidence supporting the second conjecture. When all controls are added in columns [2] and [3], or when the class level effect is examined in column [4], there is still no significant effect; indeed the estimated effect is zero.

There are a few reasons we may not find an effect. In our case, students choose a provisional degree program when entering the university. While they are free to switch between degree schemes as long as they have the requisite courses, if students view changing as sufficiently painful, or have a preference for the status-quo, then this could explain the lack of observed effect. If switching pain is correlated with gender or other observables then it is unclear what effect being assigned to a single-sex class may have. Furthermore, the treatment might cause a student to take a more mathematical course, such as econometrics or financial economics, which is optional but not enough to qualify a student for a BSc degree. In Schneeweis and Zweimüller (2012) these confounding effect do not exist. Therefore we find no evidence that, after entering university, a female assigned to an all-female class is any more likely to take the courses required for a BSc degree in economics or business.

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<sup>31</sup> An economics student would have to take two EC251, Mathematical Methods in Economics and EC252, Introduction to Econometric Methods, to earn a BSc and a Business student would have to take additional accounting courses.

<sup>32</sup> It is common for students to switch between BSc and BA degrees. On average, in the economics department 15% switch from BA to BSc in any given year. Students do switch from BSc to BA but that is harder to estimate for second year students because their degree scheme would not be shown as switched until the third year. In our data 25% of students switched in one direction or another during their time at Essex.

Next we examine how long the effect of being in an all-female class lasts. To do this, we look at whether there is any evidence to support conjecture three, that females who were in single-sex classes during their first year earn higher marks in the second year than females who were in coeducational classes. In the second year, students in both the business school and economics department have to take core courses.<sup>33</sup> We examine the effect of first year class assignment on second year grades in these required core courses. During the second year classes all students would be taking coed classes and be assigned to coed lectures. Column [5] shows that females who studied in all-female classes do, on average, 5 points better in their required second year course than females who had studied in coed classes. That represents a 10% increase in the average second year grade. When controls for classes and age are added, as in column [6], the result becomes more significant but the point estimate stays the same. When all initial observables listed in table one are control for, as in column [7], the results do not go away and the point estimate stays the same. Given that the random assignment was at the class level we also run class level regressions in column [8] and – again – get a large significant coefficient that is close to the initial estimate in column [5]. This consistency of the point estimate shows that it is unlikely that unexplained heterogeneity is driving our result. Indeed, columns [5] through [8] provide strong evidence in support of conjecture two. This shows that, being assigned to an all-female class for as little as one hour a week can have a long lasting (at least a year) positive effect on the scores received by females. Given that the marks in the second year do play a role in determining the degree classification for students, these longer run results could mean that females are more likely to end up with higher degree classifications which, in the UK, is likely to lead to better, higher paying jobs. Furthermore, if the being in an all-female class had led to negative effects for females – such as socialization issues or a lack of confidence when being integrated with males – that should show up in the second year marks. Instead we find that, upon being returned to a coed setting, the girls from single-sex classes are doing much better than their peers who had studied in coed classes.

#### 4.3 *Tracking and Potential Mechanisms*

We have found a large, significant effect of educating females in all-female classes for one hour a week while they are attending a coeducational university. This suggests that some amount of single-sex education, at least for females, could be beneficial. However, the literature, as summarized by Halpmen et. al. (2011) shows that there could be negative effects from fully segregating students by gender. Therefore, we want to examine what may be driving our estimated effects and to consider if another type of educational policy could replicate these effects.

By changing the gender composition of classes, student peer-groups could be affected. One potential effect is that the average ability of a student's classmates could be changed due to the creation of single-sex classes. Since other studies have shown that females are less likely to be high performers in mathematically-based subjects, it could be the case that females in all-female classes may have lower ability classmates than females in coed classes. Duflo et. al. (2011) show that tracking primary school students by ability can cause students to benefit. The mechanism that they outline is that, as the variance in ability in a class decreases, a teacher can teach more effectively. Thus, if separating

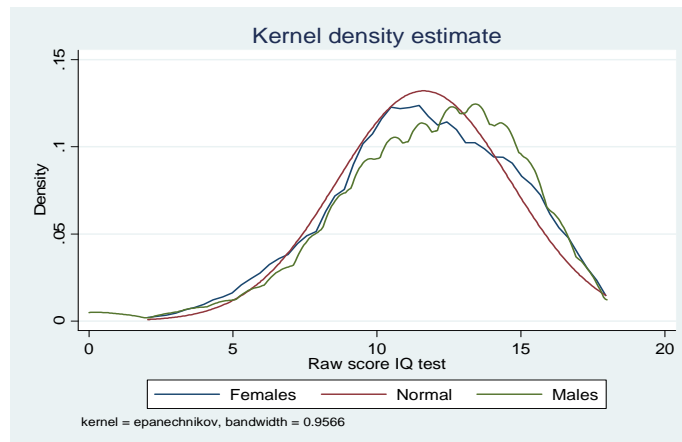
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<sup>33</sup> In economics students have to take EC201, intermediate macroeconomics, and in the business school students have to take BE111, management accounting. Both courses are taught in the autumn term but the exams take place in the summer term.



classes by gender causes the variance in ability in classes to decrease, students may be benefiting owing to a tracking effect and not to single-sex instruction. To test if a tracking effect is driving the result, we see if our evidence supports conjecture four, that the distribution of ability in single-sex classes does not differ from the distribution of ability in coeducational classes.

To do this, we look at the distribution of ability. Before taking the course, we had students complete an IQ test. If we look at the distribution of ability in figure one – as measured by the raw score on the IQ test – we see that there is little difference between the ability of females and males. Both follow a normal distribution and we cannot reject the null-hypothesis that the two distributions (male and female ability) are the same using the Kolmogrov-Smirnov test (p-value = 0.29).



Furthermore, we calculated the standard deviation of ability by class. The standard deviation in the raw IQ score for coed classes was 3.00 points, for all-female classes it was 3.21, and for all-male classes 2.86. Using a t-test for differences in means, one cannot reject the hypothesis that the standard deviation for coed and all-female classes is the same (p-value = 0.38). Therefore, there is no evidence that single-sex education is causing the deviation in ability to change at the class level. Therefore we cannot reject conjecture four. Our conclusion is that we have no evidence that the effects we found from single-sex education can be attributed to the same mechanism that causes tracking to benefit students.

Tracking is only one of many potential mechanisms that could be causing the observed single-sex class effect for females, though. For example changes in peer-effects due to the treatment, either in the classroom or outside (through study groups for instance), or changes in the way teachers respond to the class composition could explain our results. Rather than test a multitude of potential mechanisms we will examine some indirect effects of single-sex education on aspects known to effect course marks – class attendance and completion of optional work assignments – and explore whether any correlates of teacher performance can explain the observed results.

[Insert Table 4 here]

As shown in table two, even when we control for GTA fixed effects, females in all-female classes are more likely to pass the first year course. However, it could be the case that GTAs adjust their behavior when teaching an all-female course. Column [1] of Table 4 shows that there is no evidence for this

potential effect, though. Students in introductory economics score their GTAs on a scale from 1 to 5; where a score of 5 means a student strongly agrees that “Overall the classes were taught well” and a score of 1 means a student strongly disagrees with the statement. As shown in column [1] GTAs did not get scored any higher when teaching all-female classes. When doing this at the class level, as in column [2], there is also no evidence that students viewed their GTAs as doing a better job when they taught single-sex classes. Indeed we can even use GTA fixed effects and examine if females in the all-female class scored the GTA higher than the students in the coed class taught by the same GTA. Column [3] shows that there is no evidence that this is the case. However, one may question if the GTA score is correlated with quality of instruction the student actually achieved.<sup>34</sup> Column [4] shows that, when students scored GTAs higher the students were more likely to pass the course. This suggests that students do score GTAs higher if they received higher quality instruction, in the sense that the type of instruction received was correlated with higher probability of passing. Furthermore, including the score of the GTA in column [4], does not change the estimated effect of all-female classes on the pass rates of females. This suggests that the effect of instruction quality is orthogonal to the single-sex class effect: there is no evidence that teachers are driving the observed effect of all-female classes on pass rates.

Students in the first year are given the opportunity to do optional coursework assignments. Grades on the optional assignments can help the student if the student does better on the assignments than the exam; if the student’s exam grade is lower than the average of the student’s coursework then the overall grade for the course is an average of the exam grade and the coursework. Therefore doing the optional coursework assignments not only helps a student learn the material, it also gives the student insurance against a bad exam grade. Column [5] shows that females assigned to an all-female class are 9.3 percentage points more likely to do all the coursework. Besides coursework, though, attendance in the classes taught by GTAs is assumed to be correlated with better grades in courses. As we see in column [6] being in an all-female increases attendance by nearly 6 percentage points. Could the single-sex effect for females be explained by the choice to do more optional coursework and the increase in attendance?

Column [7] shows that doing all the coursework is associated with a 43 percentage point increase in the probability of passing introductory economics. This point estimate is clearly biased upwards<sup>35</sup> but, if we take it seriously, that means that the indirect effect of all-female classes through the coursework channel is a 3.9 percentage point increase in the pass rate.<sup>36</sup> That is slightly over half of the estimated effect of single-sex education shown in column [1] of table two and suggests that all-female classes are doing more than just affecting coursework completion. Column [8] shows the effect of attendance on the pass rate; attending all classes means a student is 28 percentage points more likely to pass the course than a student who does not attend any classes. Again, this point estimate is clearly biased upwards<sup>37</sup> but, if we take it seriously, it means that the indirect effect of all-female classes through

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<sup>34</sup> Carrell and West (2010) show that the rating of instructors in University is not a very good measure of the instructional quality that the student may have received.

<sup>35</sup> Students who put in the time to do the optional assignments are likely the studious, hard-working students who would have passed the course even if coursework did not factor into the overall grade for the course.

<sup>36</sup> This is calculated by taking the change in the probability of doing all course work (0.093) and multiplying it by the effect of doing all coursework on the pass rate (0.429). Doing that gives the indirect effect of 0.039 (=0.093\*0.429).

<sup>37</sup> Students who attend classes are likely to be more studious and hard-working and thus are more likely to pass the course.

attendance equates to only a 1.7 percentage point increase in the pass rate; less than a quarter of the overall effect of all-female classes. This suggests that single-sex education is having a large, direct effect on the pass rate of females. However, to check if attendance is indeed biased upwards we will instrument for attendance using the time of the class interacted with the day of the week.<sup>38</sup> Students are much more likely to attend a class if it is held later in the day. Furthermore, classes earlier in the week – Monday, Tuesday, or Wednesday – have higher attendance than those held on Thursdays or Fridays. Therefore, we predict attendance at a class based on day of the week dummy variables interacted with time.<sup>39</sup> Column [9] shows that IV linear probability model (IV LPM) results for the effect of attendance on the pass rate. There is no estimated effect of attendance on passing the one's first year course and the estimated effect of being in an all-female class, while not significant, is roughly the same as the estimate in the main specification shown in column [1] of table two. Therefore the calculated indirect effects of attendance (and coursework) are likely to be overestimates of any effect on pass rates.

There is evidence that being assigned to a single-sex class caused females to adopt behaviors that were beneficial for academic performance: such as attending class more regularly or doing all optional coursework. While these changes in behavior do not explain the entire effect of all-female classes on pass rates in the first year, perhaps the adoption of better habits explains the second year effects. Columns [10] – [12] allow us to look at whether habits developed in the first year have any effect on second year outcomes. Column [10] shows that students who did all the optional coursework in the first year get roughly 8 points more for their final grade in the second year. The indirect effect of single-sex education through this channel would then be 0.75 ( $=0.093*8.153$ ) points; less than 15% of the estimated effect of all-female classes shown in column [5] in table three. Column [11] shows that attending all classes in the first year is correlated with an increase of nearly 15 points in the second year course grade, implying an indirect effect of only 0.88 ( $=0.059*14.868$ ) points; just over 15% of the estimated effect of all-female classes. Finally column [12] shows the IV LPM results suggesting that indeed attending more classes in one's first year causes a student to do better in the second year of study. Interestingly, though, for the second year effects, the point estimate on being in an all-female class is nearly identical to the overall effect estimated in column [5] of table three even when coursework choices and attendance in the first year are included; in columns [11] and [12] the estimated effects are significant. This means that the estimated effect of single-sex education for females in the second year are independent of the behavioral changes that occurred in the first year. This could imply that behaviors in the first year of university are not indicative how one will behave in the second year. It could also imply that the entire effect of all-female classes is direct and policies that affect class attendance or the incentives to complete optional coursework could not mimic the outcomes of single-sex education for females.

From looking at the distribution of IQ scores and examining indirect effects we are able to narrow down some aspects of the mechanisms driving the effect of all-female classes. There is no evidence that single-sex education is working in the same way as tracking by ability; the distribution of ability in all-female, all-male, and coed classes are statistically similar. Furthermore, there is no evidence

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<sup>38</sup> See appendix table for the first stage regressions for the IV results in columns 9 and 12 in table four.

<sup>39</sup> Classes are taught on Tuesdays, Wednesdays, Thursdays, and Fridays and at 09:00, 10:00, 11:00, 12:00, 14:00, 15:00, 16:00, and 17:00 each day. First stage regression results are shown in the appendix.

that changes in teacher behavior are driving the effects; the results hold even with GTA fixed effects and when measures of GTA teaching quality are included in the regressions. There is evidence that all-female classes are causing students to attend more classes and take advantage of the opportunity to do coursework. However, changes in attendance and coursework completion cannot explain more than half of the estimate all-female effect. There is strong evidence that the effect of all-female classes last for at least one year after the treatment is removed. There are potentially many mechanisms that could have these effects yet we have ruled out a large set of standard policies that are typically used in education. For instance, a reduction in stereotype threat (as discussed in Spencer et al. (1999), Steele (1997), or Steele et al. (2002)) or psychological threat (as discussed in Cohen et al (2006)) would be consistent with the observed results and policies designed to work in those settings could have the same effect as single-sex education for females. However, the results also suggest that policies aimed at increasing attendance or encouraging students to do optional work are not likely to have the same effect as all-female classes.

## V. Conclusions

Advocates of single-sex education have been pushing to expand single-sex education in the hopes of addressing existing gender gaps in test scores and choices to study technical degrees. However, there has been mixed evidence on the effect of single-sex education and a lack of “well-designed research showing that single-sex education improves students’ academic performance” – at least according to Halpmen et al. (2011).

To examine the effects of single-sex education, we randomly assign students to all-female, all-male, and coed classes. The instruction students receive does not vary with class type and students do not choose to attend the course or university because they would like to be educated in a single-sex environment. Therefore, the issues of selection highlighted by critiques of previous studies are not present.

We examine if single-sex education in a coeducational environment has an effect on female test scores, pass rates, and choice of what courses to study. We find that females assigned to all-female classes are 7.5% more likely to pass their introductory economics course and score 10% higher in their required second year course; a year after the experiment finished. However, we find no effect on the likelihood that a female will chose to study a technical subject. These results all occurred with no additional expenditure on the part of the university. Typically programs that increase female pass rates or improve student performance are much more costly: study on the Achievement Awards demonstration in Israel by Angrist and Lavy (2009) found that females were more likely to earn a Bagrut<sup>40</sup> if offered \$1500 for completion but that men were not any more likely to earn the qualification; schools in NYC paid students up to \$500 to do well on standardized tests and show up for classes.<sup>41</sup> While comparing the costs and benefits of programs based on different outcome

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<sup>40</sup> A Bagrut is the official Israeli matriculation certificate attesting to the graduation of a student from high school. Bagrut is a prerequisite for higher education in Israel.

<sup>41</sup> See [http://www.nytimes.com/2007/06/19/nyregion/19schools.html?\\_r=0](http://www.nytimes.com/2007/06/19/nyregion/19schools.html?_r=0)

variables is not easy, a program that causes a female to be 7.5% more likely to pass a course and to score 10% better overall in classes at no additional cost is rather extraordinary.

The positive benefits of single-sex education in our study are only present for females. While single-sex education does have an effect on the behavior of females – they are more likely to attend classes and do optional coursework – those changes cannot account for the effect of being assigned to an all-female class. Therefore, the driving factors behind single-sex education we observe for females at university are driven by direct effects of the policy. This means that females in primary and secondary schools may also benefit from a small amount of single-sex education while remaining part of a coeducational institution.

Our study focuses on only a few aspects of single-sex education – its effects on pass rates, grades, and course selection. While these outcomes can influence wages and job prospects for students, other factors that we are not examining, such as socialization, could also play a role in labor market outcomes. Therefore, while we find large positive effects of single-sex classes for females, we need to emphasize that more research is needed. We show that one hour of single-sex education can benefit females in a coeducation institution and that there is no negative effect on grades or pass rates for males; however would two hours of single-sex education still be beneficial? Three hours? The research summarized by Halpern et al. (2011) suggests that having all instruction done in a single-sex environment has no positive effect or could be harmful. Furthermore, we have shown that single-sex education benefits females in a subject area where women are in the minority. However, will there be benefits for women studying in subject areas where females are in the majority? Will the benefits of single-sex education be even greater when women are even more of a minority? Will men benefit from single-sex education if they are in the minority? Therefore, more research is necessary to establish if there is an optimal amount of single-sex education that is beneficial for students and in what other contexts females or males might benefit.

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