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EXAMINING THE EFFECTIVENESS OF SINGLE-SEX SCHOOLS: EVIDENCE FROM PISA DATA IN IRELAND

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Article Info

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Abstract

Based on data from the Programme for International Student Assessment (PISA), this study examines the relationship between attending single-sex schools and academic performance, using Irish data. The study aims to investigate whether there is a difference in reading, mathematics, and science performance between those attending single-sex or mixed-sex schools after controlling for socioeconomic and school-level factors. The sample consists of 15-year-olds, and the study found no statistically significant difference in academic outcomes between those attending single-sex or mixed-sex schools. However, gender differentials in mathematics and reading are more substantial for students educated in single-sex schools than for those in coeducational schools. The study concludes that more empirical evidence is necessary to better understand the relationship between single-sex and mixed-sex schooling. The research adds important evidence to the policy space by providing new insights on the impacts of single-sex and mixed-sex schooling on student outcomes, particularly within the Irish context.

INTRODUCTION

The topic of single-sex versus mixed-sex schooling continues to be a source of debate within education policy in many countries. If single-sex schools bring about better academic outcomes for students, such a policy would be a low-cost way in which to raise general educational attainment relative to other measures such as changes to class size or infrastructural investments.[1] As well as this, such a finding could help address two important issues within education—the underperformance of boys in secondary education and the lack of females in STEM careers—if significant differences are found in mathematics or science-related outcomes across the different school types.

Previous empirical evidence is somewhat ambiguous, with some studies finding a positive impact of single-sex schooling on education achievement (Jackson, 2002; Lee et al., 2014; Park et al., 2013) but others finding average null effects (Jackson, 2012; Pahlke et al., 2014). To our knowledge, no studies have found that single-sex schools hinder students or that mixed-sex schools have positive academic outcomes. Research in the area has tended to

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be concentrated on a small number of countries due to the fact that in most countries, single-sex schools are selective and the numbers attending them are small (Doris et al., 2013; Halpern et al., 2011). Furthermore, many studies do not control for selection effects and student characteristics (Pahlke et al., 2014) and the heterogeneous effects of such policies are rare in existing studies (McCarey, 2017). This suggests that more empirical evidence in the area is required to better understand this relationship.

Meanwhile, relatively few countries have readily available data. This is the case in Ireland, where a high proportion of secondary school children (~1/3) attend a single-sex school and these schools are largely state-funded and non-selective with respective to previous academic performance, differing mainly in composition compared to mixed-sex schools. For this reason, the Irish educational system provides an interesting setting for exploring the outcomes of single-sex schooling. In this context, this paper contributes to the existing literature and uses data from the 2018 Irish wave of the OECD's Programme for International Student Assessment (PISA) on reading, mathematics and science to focus on the association between attending a single-sex school and academic performance. This data allows us to control for a wide range of potential confounding socioeconomic and school-level factors in examining this relationship. The richness of this data allows us to not only focus on how single-sex schooling may influence the 'conditional mean' of performance but also explore further heterogeneities, such as whether any association between this type of schooling and student outcomes varies across the performance distribution. For the latter we utilise unconditional quantile regression (UQR) methods. To our knowledge we are the first study to utilise such an empirical approach using the PISA data and, after Jackson (2021) and Sohn (2016), the third study to use such a method in the context of single-sex schooling, with the latter having focused on reading performance only.

In terms of key findings, we find significant raw gaps in reading, science and mathematics scores between females in single-sex and mixed-sex schools and in mathematics scores for males across the same school types. After controlling for a rich set of individual, parental and school-level factors we find that, on average, this difference is not significant for any of the academic outcomes for either males or females across the school types. However, we do find that the gender differentials in mathematics and reading are larger for students educated in single-sex schools compared to coeducational schools. In examining possible heterogeneities, while we find evidence of some heterogeneity across the performance distribution, these are statistically insignificant for both males and females. Our study adds important evidence to this policy space and is structured as follows: the next section presents a review of the relevant literature; the third section presents our data and methods; the fourth section gives the main empirical results; and the fifth section concludes.

LITERATURE

There are several possible explanations as to why single-sex and mixed-sex schooling may foster different academic outcomes for boys and girls. For example, lower academic engagement may occur due to the presence of the opposite sex in class, or an increase in gender stereotyping may occur across school types due to the salience of gender identities in mixedsex school settings (Jackson, 2012). Another mechanism is linked with potential differences in self-confidence and motivation cultivated by the different school types. It may also be the case that single-sex schools are more likely to have teachers who share the gender of the students, with both students and teachers performing better as a result of this teacher– student gender match.

Moving from the mechanisms to the effects on academic outcomes, useful summaries are provided in studies such as Mael et al. (2005), McCarey (2017), Pahlke et al. (2014) and Smyth (2010) with the results ambiguous when examining both cognitive and non-cognitive outcomes. More recently, several empirical studies have focused specifically on the relationship between academic performance and single-sex schooling. In South Korea, students living in Seoul are randomly assigned to schools within specific districts upon entering secondary education. This has led to a range of studies that have examined the outcomes of single-sex schooling in a causal manner. For example, Choi et al. (2014) used a fixed-effect estimation for each district to obtain a district-specific coefficient before estimating the school production function. Using scores on a high-stakes examination at the end of secondary education (College Scholastic Ability Test (CSAT)), they found a positive and significant relationship between attending a single-sex school and scores in this outcome measure. Dustmann et al. (2018) exploited the same policy feature and also added a second source of information: the conversion of some existing single-sex schools to mixed school type over time. To measure student's academic achievement, they used scores on the Korean language tests within the CSAT with the sample made up of 12th graders acorss the period 1996–2009. They again found robust evidence that pupils in single-sex schools outperform their counterparts in coeducational schools in the English and mathematics elements of this examination. Finally, in the Korean setting,[2] Park et al. (2018) examined the impact of single-sex schools on students' STEM outcomes. Within this, they first examined the effect of single-sex schooling on high school seniors' national college entrance scores for mathematics for seven different cohorts; secondly, they studied the effect of single-sex schools on student's choice of advanced mathematics—this test is required for those who apply for STEM majors, therefore students' choice of the test is an important outcome to be examined with respect to STEM careers. They find a positive relationship between attending a single-sex school and both mathematics performance and choosing advanced mathematics subjects in school for boys but do not find the same for girls.

Jackson (2012) studied the effects of single-sex schooling on student outcomes, exploiting the fact that students in Trinidad and Tobago are assigned to secondary schools by the Ministry of Education based on their performance in a secondary school entrance examination and a list of school choices, so that attendance at single-sex schools is partially beyond the student's control. Using an instrumental variable approach based on variations in student preferences and test score data on entry to secondary school and 5 years after entry, he found that those in single-sex schooling had better examination performance and a higher likelihood of progressing to higher education. However, he concluded that these positive effects were not due to school type but the benefits associated with being admitted to a preferred school.

Jackson (2021) further studied single-sex schooling within Trinidad and Tobago, taking advantage of a policy change in 2010 whereby the Ministry of Education converted 20 low-performing mixed-sex schools into single-sex types. This allowed a comparison of students who attended the same school under both coeducational and single-sex regimes and so it was possible to isolate the effect of adopting a single-sex policy from all other school-level differences that might exist between coeducational and single-sex schools. The entrance records of students were then linked to national examination data, arrest records and birth registry data and showed that single-sex education improved both boys' and girls' outcomes: 3 years after being assigned to a single-sex secondary school, both boys and girls have higher test scores; 5 years later, they had higher chances of completing secondary school and in the long run, boys were less likely to have been arrested and girls were less likely to be teen mothers.

In Europe, Eisenkopf et al. (2015) studied the effects of random assignment to coeducational and single-sex classes on the academic performance of female high school students in Switzerland.[3] In their case, the strategy consists of exploiting a natural experiment in the German-speaking part of Switzerland. A school there is run and financed by the local canton and applies standard curricula and teacher recruitment policies but, for pedagogical reasons, the school board randomly assigns incoming female students to coeducational and single-sex classes. They found a positive effect of single-sex education on proficiency in mathematics but not native language skills. They found that the effect tended to be stronger if girls in a single-sex class were taught by a male teacher.

In the Irish context, Hannan et al. (1996) used a multi-level empirical approach and found that once student background and school process variables were controlled for, there were no statistically significant differences in academic performance between those in single-sex and coeducational secondary schools. This was true for performance in students' upper secondary high-stakes terminal examinations, as well as performance in lower secondary education. From a non-cognitive viewpoint, they also found that being in a coeducational school (rather than a single-sex school) was associated with lower levels of self-reported body image for boys, but not for girls. In comparing this study to the analysis presented here, it is noteworthy that the academic performance used as outcome measure was high-stakes examinations. Similar to our analysis, they also examined this relationship across ability differences but not with quantile regression methods. Instead, they split their sample into low, middle and high-ability students and found no statistically significant differences in academic performance between those in single-sex and coeducational secondary schools. The one exception was some evidence of coeducational schooling boosting performance for low-ability boys in lower secondary level. More recently, Doris et al. (2013) used data on children in primary school to examine the relationship between single-sex education at primary level and mathematics achievement at the top of the distribution. They show that boys in single-sex schools are more likely to be in the top quartile of achievement compared to boys in coeducational schools, but found no such effect for girls. Our paper is most closely aligned with this, using an econometric approach to focus on the association between single-sex schooling and a broader set of students' academic outcomes.

CONTEXT, DATA AND METHODS

Study setting

It is useful to understand the institutional context in which our analysis takes place and given the age profile of our data, we focus on secondary education in Ireland. Secondary education in Ireland is largely state-funded, with only 7% (51) of the 722 secondary schools in Ireland in 2018 designated as private fee-paying schools (Department of Education, 2021). Furthermore, 33% of secondary schools are single-sex (Department of Education, 2021), with all school types following the same state-prescribed curriculum and taking the same state public examinations. From a policy perspective, secondary level schools that are deemed to be underprivileged may access supplementary resources such as extra learning support for teachers and a home-to-community liaison programme through the Delivery of Equality of Opportunity in Schools (DEIS) system (Department of Education and Science, 2005). It is also notable that schools deemed eligible for the DEIS scheme may receive funding to enable a lower student-to-staff ratio.[4] Single-sex schools in Ireland are almost entirely Catholic denominated, and while there is currently no explicit government policy in Ireland around the expansion or reduction in the number of single-sex secondary schools, it is noteworthy that there have been policy steps taken to increase the number of multi- and non-denominational schools (Department of Education and Skills, 2018).

With regard to school admissions, in Ireland students usually attend their local school but can apply to attend any school in the country. Schools must accept all students who apply to them, unless they receive more applications than there are places. In that case, schools will give priority on the basis of their own admissions policy but, with the exception of fee-charging secondary schools, cannot charge fees or ask for contributions as a condition for admission. Moreover, schools cannot prioritise one student over another on the basis of family status, religion, race or disability. Research by Byrne and Smyth (2011) showed that single-sex schools in Ireland had similar levels of oversubscription to other school types in Ireland, and that the most important criteria for student admissions in oversubscribed schools were having a family member already in the school and living locally. They also suggest that students in single-sex schools are more likely to be in a school which has been actively chosen by their parents, and that those from higher professional backgrounds are significantly more likely to be attending a school outside their local area than those from other class backgrounds. This implies some degree of social gradient in the social mix of single-sex schools versus other school types.

Data

The data used is from the 2018 Irish wave of PISA that examines what students know in reading, mathematics and science, and what they can do with what they know (OECD, 2019).[5] The assessment provides comparable information with regard to these outcomes for 15/16-year-old students by testing how well they apply their knowledge in everyday life situations. The dataset also includes extensive information about individual characteristics and school contexts. The Irish data has an achieved sample of 5577 respondents from 157 different schools, with both school-level (100%) and student-level (87%) response rates above OECD requirements (McKeown et al., 2019).[6] Using only those with relevant socioeconomic and school-level information from this group leaves us with an estimation sample of 4944 individuals.

With regard to our outcome variable, as in other similar tests (e.g., PIRLS, TIMSS, PIAAC), student performance in the PISA test is presented in plausible values which are generated using a combination of Item Response Theory (IRT) and latent regression modeling. Then, using the model, in PISA 2018, a sample of 10 values is extracted (in previous editions this number varied), which are 10 'plausible', probable values for that student. These grades already appear in the standardised databases, with a mean of 500 and a standard deviation of 100 for all OECD students. The way to compare the results of students who have answered different tests is through IRT, which allows the estimation of a student's knowledge function and the subsequent sample generation of plausible values. As well as these test results, the dataset also includes a rich set of information sourced directly from questionnaires filled out by the students and school principals, respectively. For our study, among the most relevant variables at the individual level are the student's gender, school year, whether the student is native to Ireland and a proxy for socioeconomic background. Similar to Jerrim and Moss (2019) and Sortkær (2019), we proxy the latter by utilising the economic, social and cultural status (ESCS) variable within PISA. The ESCS variable is an index variable constructed from students' responses to questions surrounding their parents' education level, occupation and amount of home possessions, including educational possessions at home.[7]

The PISA data also includes information on a range of school-level variables that may be associated with academic performance. It is important to control for such factors given that they may explain some of the relationship between gender composition and educational test score observed in a raw manner. For example, we have data such as the student-to-staff ratio and the number of students enrolled in each school within the sample. Previous literature (e.g., Denny & Oppedisano, 2013; Humlum & Smith, 2015; Jepsen, 2015; Leithwood & Jantzi, 2009) has examined the role these factors may play in student outcomes. Furthermore, to capture variations in school resources, we are able to include dummy variables that indicate whether learning in the school is hindered to some extent (or a lot) in its capacity to provide instruction by the educational resources available to it or by a lack of teaching staff. As a proxy for the level of parental engagement within a school, we include a variable that indicates the proportion of student parents who actively participate in the school management. We also have information on whether the school is located in an urban or a rural location, and whether the school uses previous academic performance in considering admissions. To control for potential non-gender-related peer effects and also proxy for potential resource differences at school level associated with policy interventions, such as the aforementioned DEIS scheme, we also include a dummy variable indicating whether the school is classed as 'disadvantaged'. In constructing this we adopt a similar methodology to OECD (2020) and assume a school is disadvantaged if the average ESCS index among the students sampled within a school is in the bottom quartile of the distribution of the index in the entire sample. Previous research examining educational expenditure (Jackson et al., 2016), school–parent relations (Hampden-Thompson & Galindo, 2017), school availability (Agasisti, 2011) and school socioeconomic composition (Sciffer et al., 2022) help motivate the selection of these variables. Finally, based on the enrolment numbers by gender within each school, we are able to create a dummy variable to indicate single-sex or coeducational, and by extension know whether the individual student attended either of these types of school. A detailed description of the variables used in this study is presented in Table 1.

To examine differences in these characteristics across school type, Table 2 presents summary statistics across gender and school type. This shows a total estimation sample of 4944, with 39% attending single-sex schools, with a slightly higher proportion of females doing so. We see that there are substantial differences in the characteristics of single-sex and coeducational schools, with the former tending to be more urban-based, have lower problems of staff shortages, higher student-to-staff ratios and higher levels of parental engagement, and also less likely to be disadvantaged. Table 2 also illustrates some wide variations in our socioeconomic indices between the groups, with girls in single-sex schools having the highest average socioeconomic index.

Similarly, Table 3 presents the raw mean scores in the different PISA competences for each of the four groups. These suggest that single-sex schools perform better than coeducational schools across all three metrics. However, for boys these differences are only statistically significant in comparing mathematics scores, but are significant for all tests in comparing girls in single-sex schools to girls in coeducational schools.

To initially explore heterogeneity in the reading, science and mathematics test scores, we also present kernel density functions of one of the plausible values of each subject (mathematics, reading and science) by gender and school type. Figures 1–3 illustrate the distribution in performance for mathematics, reading and science, respectively, with those attending single-sex schools more heavily concentrated towards the upper end of the performance distribution relative to those in coeducational schools, particularly for girls.

Methods

In order to model the relationship between PISA performance and single-sex schooling, we must acknowledge the complex structure within PISA, which requires specific calculations to obtain reliable standard errors. Jerrim et al. (2017) outlines some of the problems derived from said structure and how to overcome them. As suggested by them, we employ the REPEST command within STATA, developed by Avvisati and Keslair (2014), to analyse the data. REPEST carries out estimations using the balanced repeated replicate weights method proposed by the OECD (2009), and is suitable for use with plausible values, such that the average value of the estimations is obtained and the imputation error is incorporated into the variance of the estimated parameter. This allows us to run models such as standard linear regressions that are technically robust and meet the criteria of the usual OECD studies. When considering the relationship between performance and single-sex schooling, selection bias is a key issue. Thus, our models control for a range of observable socioeconomic and school-level factors likely to be correlated with performance in PISA, and attending a single-sex school, such as those outlined in Table 1. Given this, to examine our relationship of interest we estimate three separate standard linear regressions, such that:

TABLE 1 Variable descriptions

Variable	Type	Description
Outcome variables		
PISA Reading performance	Continuous	Ten plausible values for literacy
PISA Mathematics performance	Continuous	Ten plausible values for mathematics
PISA Science performance	Continuous	Ten plausible values for science
Student and socioeconomic variables		
Female	Indicator	= 1 if student is female; 0 else
Single-sex	Indicator	= 1 if student attends single-sex school; 0 else
School year	Categorical	School year/Grade year that the student occupies
Economics, Social and Cultural Status index (ESCS)	Continuous	ESCS is a composite score based on three indicators: highest parental occupation, parental education and home possessions, including educational resources in the home. A higher value indicates a higher level of economic, social and cultural status
Native	Indicator	= 1 if student was born in the country and at least one parent also born in the country; 0 else

School where PISA represents the PISA scores for mathematics, reading and science of student i, respectively, β_1 represents the parameter to be estimated between single-sex schooling and PISA performance on average. However, we also include the interaction term β_3 between single-sex and gender to estimate how this relationship may vary for males and females, while controlling for our set of socioeconomic and school-level variables. $\mathbf{X}_i$ is a vector of

	Female		**Male**	
Variable	**Single-sex Mean (SD) or %**	**Mixed-sex Mean (SD) or %**	**Single-sex Mean (SD) or %**	**Mixed-sex Mean (SD) or %**
School year	9.42 (0.62)	9.46 (0.68)	9.35 (0.64)	9.38 (0.68)
ESCS	0.25 (0.87)	0.08 (0.87)	0.15 (0.84)	0.08 (0.84)
Native	78.06%	83.77%	83.63%	83.48%
Student-to-staff ratio	14.11 (1.63)	12.43 (1.89)	13.15 (1.77)	12.41 (1.95)
School size	661.88 (243.54)	637.07 (270.23)	611.14 (191.85)	628.35 (260.73)
Staff shortage	39.92%	54.46%	23.13%	54.46%
Quality of teaching material	24.31%	26.59%	38.71%	24.21%
Selective admissions	13.93%	17.58%	25.05%	19.47%
Rural location	26.28%	64.18%	20.65%	62.47%
Parental engagement	9.54%	7.84%	8.18%	7.81%
Disadvantaged	12.85%	29.73%	13.54%	30.31%
Observations	1014 (21%)	1407 (28%)	892 (18%)	1631 (33%)

Source: Author's calculations – PISA data (2018).

TA B L E 3 PISA performance across gender and school type

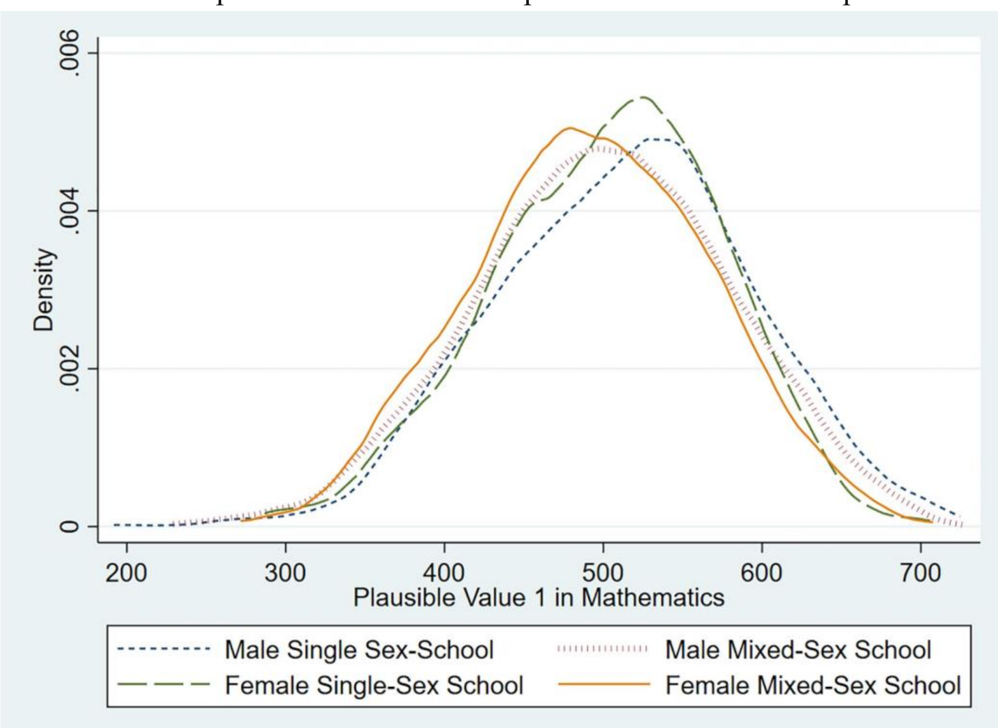
	Female		**Male**		**Difference (*t*-test)**	
Variable	**Single-sex**	**Mixed-sex**	**Single-sex**	**Mixed-sex**	**Female**	**Males**
PISA Reading test score	541.27	525.03	513.25	506.44	16.24***	6.81
PISA Mathematics test score	506.10	492.06	512.27	500.47	14.03***	11.80**
PISA Science test score	506.12	493.35	500.72	496.50	12.77**	4.22
Observations	1014	1407	892	1631		

TA B L E 2 Sample descriptive statistics

Source: Author's calculations using REPEST by STATA for PISA data (2018). *** denotes significant at 1%, ** denotes significant at 5%.

student- and school-level characteristics such as socioeconomic background information and school resources, with ε_i representing the error term.

In an extension to our analysis, we also estimate the UQR model proposed by Firpo et al. (2009)[8] with this technique previously applied in the education performance area by Cullinan et al. (2021) and Lounkaew (2013). While numerous studies in the education space have previously utilised conditional quantile estimates in conducting distributional analysis, this is potentially problematic as the interpretation of the coefficients in the conditional approach relates to the quantiles of the distributions defined by the conditional distribution, and so results may be difficult to interpret. Porter (2015) provides a valuable education-related example around the potential problems using the conditional analysis. He describes estimating a conditional quantile regression at the median, with mathematics proficiency as the hypothetical dependent variable and with dummy variables for gender. In such a model, the coefficient for the mathematics developmental should be interpreted as the effect at the median of the distribution for males and at the median of the distribution for females, as opposed to the average effect at the median of the test score distribution. So, if females score higher than males such that these medians differ substantially, the conditional quantile regression coefficients are effects of the programme at these different medians for the different groups (i.e., low-achieving boys and high-achieving girls). Adding more independent variables to the specification makes interpretation even more complex.



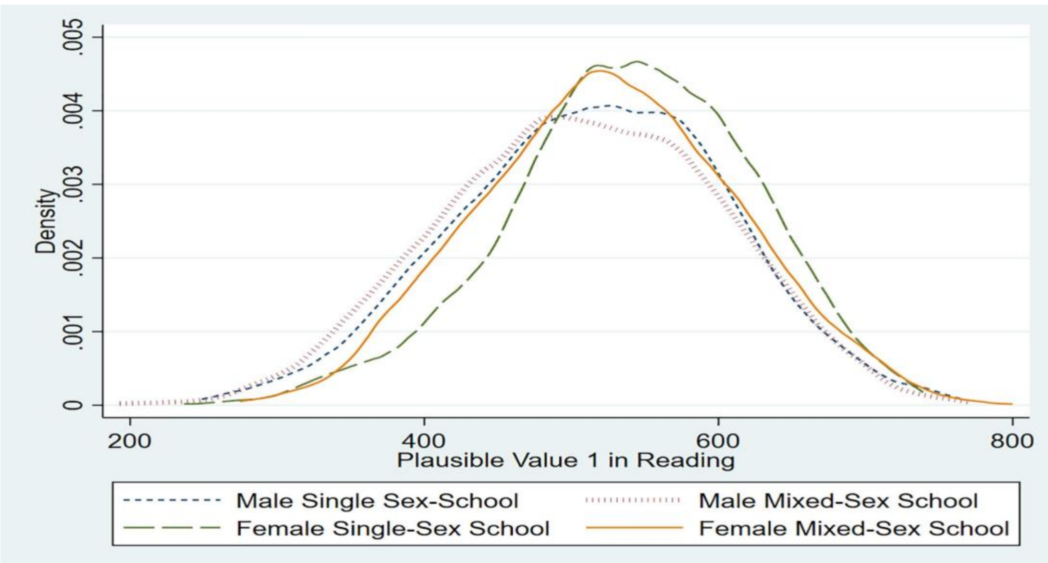
F I G U R E 1 Distribution of mathematics scores (plausible value 1) by gender and school type. [Colour figure can be viewed at wileyonlinelibrary.com]

Within the context of examining single-sex schooling, such an analysis is warranted to explore whether any association between single-sex schooling and academic outcomes differs for girls or boys of different academic abilities. We therefore present UQR estimates within this paper to help tell us if there are potential differences in the relationship for low- and high-performing students.

EMPIRICAL RESULTS

Table 4 first presents a series of linear regression models with our different PISA outcome variables, estimated using ordinary least squares (OLS) without any interaction effects. We find that many of our observed characteristics are significantly associated with a higher score in mathematics, reading or science. For example, higher levels of economics, social and cultural status, higher levels of parental engagement with school government activities and attending a non-disadvantaged school are associated with higher scores across each of the three tests. We also see that females perform significantly lower than males in mathematics but higher in reading; those born in Ireland or with a parent born in Ireland perform significantly better in reading compared to those not, while no statistically significant relationship is observed for our single-sex dummy.

However, to better examine this relationship, we estimate these models with our singlesex dummy interacted with gender and generate the predicted scores for each of the three PISA tests across gender and single-sex/coeducational groups. These are presented in Table 5 and allow us to estimate if there are significant differences in mathematics, reading



F I G U R E 2 Distribution of reading scores (plausible value 1) by gender and school type. [Colour figure can be viewed at wileyonlinelibrary.com]

or science, both within gender and between gender, by whether a student attends a singlesex school or not. In other words, we test whether the difference in the predicted scores for those going to a single-sex school compared to a coeducational school is significantly different from zero for boys and girls separately. Furthermore, we are able to do the same for the predicted scores across gender but within schooling type.

The results show that for boys, the significant raw advantage in mathematics performance from attending a single-sex school relative to boys in a coeducational school (observed in Table 2) goes away once we condition for socioeconomic and school-level characteristics. Similarly, the raw advantage for girls attending a single-sex school goes away once we condition for observable characteristics.[9] While these estimates show no evidence of an academic advantage from attending a single-sex school for boys or girls, the predicted scores (conditional on our observed variables) presented in Table 5 suggest a bigger gender gap across single-sex schools. In a result that is similar to that found for primary school children in Ireland (Doris et al., 2013), the gap between males and females in single-sex schools (14.02 points) is larger than that seen for males and females in coeducational settings (9.38 points). The same is also true with regard to reading, but in the opposite direction and to a greater extent: the gap between single-sex schools for girls and boys is 20.28 points, whereas the gap is 17.80 points in coeducational schools. We find no significant results in terms of science performance.

Although these results suggest no difference in performance for mathematics, reading or science for those attending single-sex schools on average, it is important to examine heterogeneity further. Based on the estimates of unconditional quantile regressions for the 20th, 40th, 60th and 80th percentiles of PISA mathematics performance, Table 6 presents

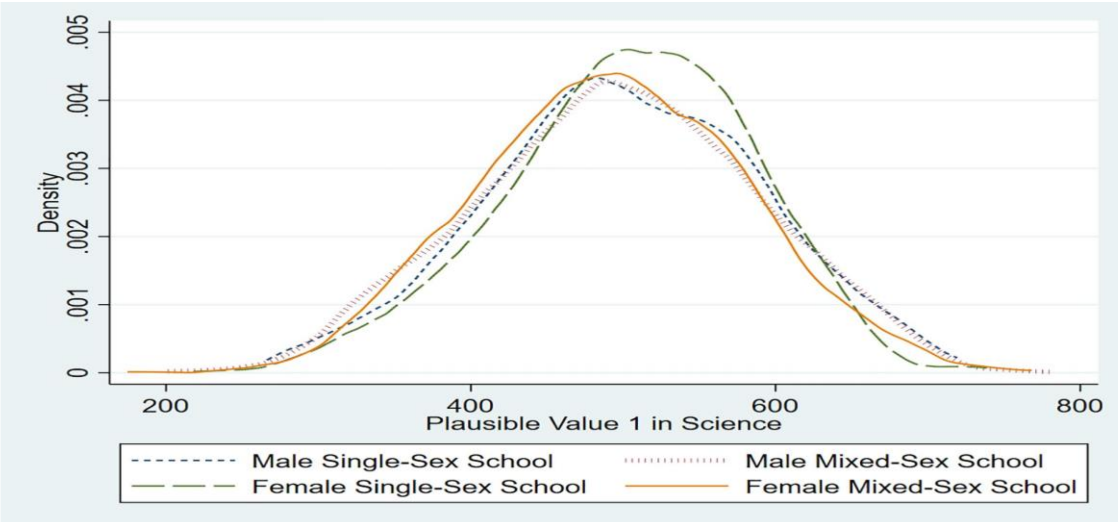


FIGURE 3 Distribution of science scores (plausible value 1) by gender and school type. [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 4 OLS estimates of PISA test performance for mathematics, reading and science

	Mathematics	Reading	Science
Female	−11.08 (3.08)***	18.71 (3.09)***	−3.36 (3.38)
Single-sex school	5.81 (4.67)	2.53 (5.11)	1.82 (5.97)
School year	8.09 (1.90)***	6.31 (1.85)***	6.85 (2.00)***
ESCS	25.08 (1.79)***	27.25 (2.01)***	28.49 (2.07)***
Native	1.37 (3.21)	10.53 (3.53)***	−3.70 (3.63)
Student-to-staff ratio	1.43 (1.00)	1.58 (0.98)	0.40 (1.05)
School size	0.17 (0.01)*	0.01 (0.01)	0.01 (0.01)
Staff shortage	2.14 (3.51)	6.16 (4.06)	4.45 (3.91)
Quality of teaching material	−3.88 (4.04)	−5.38 (4.28)	−5.64 (4.54)
Selective admissions	1.49 (5.47)	0.08 (5.98)	0.46 (6.08)
Rural location	3.85 (4.53)	−1.40 (5.01)	1.42 (5.64)
Parental engagement	0.34 (0.12)***	0.37 (0.12)***	0.32 (0.12)***
Disadvantaged	−23.88 (4.51)***	−28.57 (4.84)***	−24.00 (4.96)***
Constant	395.57 (23.66)***	415.36 (22.45)***	421.06 (25.91)***
Observations	4944	4944	4944
Adj-R^2	0.15	0.15	0.13

Notes: The estimates are based on an OLS model estimated using the REPEST command. Standard errors in parentheses. *** denotes statistically significant at 1%, * denotes statistically significant at 10%.
Source: Analysis of PISA data (2018).

TABLE 5 Predicted scores and estimated difference in mathematics, reading and science PISA tests for single-sex and coeducational schools across gender

	Mathematics (including individual, socioeconomic and schoollevel controls)	Reading (including individual, socioeconomic and schoollevel controls)	Science (including individual, socioeconomic and schoollevel controls)
Male single-sex (1)	505.11	499.95	494.73
Male mixed-sex (2)	496.89	498.71	493.53
Female single-sex (3)	491.09	520.23	492.32
Female mixed-sex (4)	487.50	516.51	489.78
Difference between school types for males (1–2)	8.22 (5.62)	1.24 (6.71)	1.04 (7.6)
Difference between school types for females (3–4)	3.58 (5.53)	3.72 (5.59)	2.54 (6.35)
Difference between gender for single-sex schools (1–3)	14.02*** (5.02)	−20.28*** (5.89)	2.41 (6.25)
Difference between gender for mixed-sex schools (2–4)	9.38** (3.72)	−17.80*** (3.47)	3.91 (3.82)

Notes: The predicted scores are based on an OLS model estimated using the REPEST command including an interaction term between gender and attending a single-sex school. The differences between the various groups are tested to examine if they are significantly different from zero. Standard errors are in parentheses. *** denotes significant at 1%, ** denotes significant at 5%.

TABLE 6 Estimated difference in mathematics PISA tests for single-sex and mixed-sex schools across gender and performance distribution

	OLS	20th	40th	60th	80th
Male single-sex − Male mixed-sex	8.22 (5.62)	8.92 (7.41)	9.19 (6.06)	8.71 (7.08)	6.85 (7.93)
Female single-sex − Female mixed-sex	3.58 (5.53)	7.22 (7.66)	6.31 (7.09)	4.15 (7.89)	1.48 (7.78)
Observations	4944	4944	4944	4944	4944
Adj-R^2	0.15	0.10	0.11	0.09	0.07

Notes: The table presents estimated coefficients from unconditional quantile regressions of PISA performance in mathematics with results for the 20th, 40th, 60th and 80th percentiles using the REPEST command. Standard errors are in parentheses.
Source: Analysis of PISA data (2018).

the difference in mathematics performance between those attending single-sex and coeducational schools for both males and females, respectively, across the performance distribution. Each of these four models uses the same specification as the OLS results presented in Table 5, with the single-sex dummy variable interacted with gender, with the differences estimated by the earlier OLS model repeated in the first column of Table 6 to facilitate comparison. Table 7 presents similar distributional estimates but with reading performance as the dependent variable rather than mathematics performance.

The results in both Tables 6 and 7 illustrate that there is a degree of heterogeneity in the relationship between attending a single-sex school and mathematics/reading performance. For example, Table 6 shows that for both males and females, the positive association between being in a single-sex school is higher at the lower end of the distribution relative to the upper end. However, as with the differences observed based on the OLS estimates, none of these differences are statistically significant. With respect to reading performance, Table 7 shows that attending a single-sex school has a stronger positive effect for females around the median percentile of performance compared to those at the tails. Interestingly, for males, the 'premium' associated with attending a single-sex school is reversed for those at the higher end of the performance; those attending a coeducational school have a higher score. Again, however, none of these results present as statistically significant. Therefore while our distributional analysis indicates some level of heterogeneity in our relationship of interest, we find again no evidence of any statistical difference in mathematics or reading performance between those attending single-sex or coeducational schools once we condition for other factors.

CONCLUSION

The topic of single-sex schooling continues to be a source of policy discussion in many countries. The previous empirical literature has tended to be concentrated on a small number of countries due to the fact that in most countries, single-sex schools are selective and the numbers attending them are small. This study adds to this literature by using the latest PISA data for Ireland to examine the relationship between single-sex schooling and performance in mathematics, reading and science for boys and girls. We find no association between attending single-sex schools and performance in mathematics, reading or science scores for either males or females. A further contribution of our study is to go beyond an analysis of the 'conditional mean' and examine the association between attending a single-sex school across the performance distribution using a UQR approach. These estimates support the results seen in the OLS estimates. Overall, these results have a number of implications. Firstly, the results presented here are more ambiguous surrounding the merits of singlesex schooling relative to previous findings in Korea and Malta, but more in line with previous results from Trinidad, and so suggest that the impact of such schooling on education outcomes may be context-specific. Therefore, this implies that more analysis in different countries should be undertaken to accurately inform policy. Secondly, our results suggest that after controlling for other individual characteristics, gender gaps in mathematics performance are larger across single-sex schools. This implies that these types of schools could have a subsequent negative influence on gaps in STEM-related outcomes. While beyond the scope of this paper, such evidence related specifically to STEM careers was found in the aforementioned studies relating to single-sex schooling in Korea. Finally, in looking beyond the issue of single-sex schooling, the positive association between PISA performance and other factors in our model provides food for thought. For example, across reading, mathematics and science, our proxy for parental engagement with school activities has a positive relationship with student performance, suggesting that a better level of parent–school relationships may be positively associated with academic outcomes.

In considering the results of this analysis, some limitations should be borne in mind. Firstly, the outcome measure we utilise is designed to capture 15-year-olds' ability to use their reading, mathematics and science knowledge and skills to meet real-life challenges rather than educational attainment or qualifications. While previous research has noted that there are strong relationships between performance on PISA domains and performance on the equivalent state examination subjects in Ireland (Eivers, 2010), using educational attainment as an outcome measure may be useful in future. Secondly, there may be other unobserved individual-level characteristics that may impact PISA performance, such as teacher gender or non-cognitive student-level attributes, which could lead to omitted variable bias if they are also correlated with the selection of single-sex schools versus mixed-sex schools. Therefore, we present our results as associations, rather than causal effects. Despite this limitation, and given the relative richness of observable characteristics we are able to utilise, the paper makes an important contribution to the existing literature on single-sex schooling and the analysis presented should prove useful to the policy debate. We recommend that future studies in this area explore more casual identification strategies such as instrumental variables estimation in their analysis which, given our context and data, was unfortunately not possible in this paper.

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REFERENCES

Agasisti, T. (2011). The effect of competition on schools' performance: Preliminary evidence from Italy through OECD–PISA data. *European Journal of Education*, *46*(4), 549–565.

Agyire-Tettey, F. C., Ackah, G., & Asuman, D. (2018). An unconditional quantile regression based decomposition of spatial welfare inequalities in Ghana. *The Journal of Development Studies*, *54*(3), 537–556.

Avvisati, F. (2020). The measure of socio-economic status in PISA: A review and some suggested improvements. *Large-Scale Assessments in Education*, *8*, 8.

Avvisati, F., & Keslair, F. (2014). *REPEST: Stata module to run estimations with weighted replicate samples and plausible values*. Boston College, Department of Economics Statistical Software Components S457918 (revised 6 January 2020).

Black, S. E., Devereux, P. J., & Salvanes, K. G. (2013). Under pressure? the effect of peers on outcomes of young adults. *Journal of Labor Economics*, *31*(1), 119–153.

Borgonovi, F., & Pokropek, A. (2021). The evolution of socio-economic disparities in literacy skills from age 15 to age 27 in 20 countries. *British Educational Research Journal*, *47*, 1560–1586.

Byrne, D., & Smyth, E. (2011). *Behind the scenes? A study of parental involvement in post-primary education*. ESRI Research Series No. BKMNEXT178.

Choi, J., Hyungsik, R. M., & Geert, R. (2014). Estimation of an education production function under random assignment with selection. *American Economic Review*, *104*(5), 206–211.

Choi, J., Park, H., & Behrman, J. R. (2015). Separating boys and girls and increasing weight? Assessing the impacts of single-sex schools through random assignment in Seoul. *Social Science and Medicine*, *134*, 1–11.

Cullinan, J., Denny, K., & Flannery, D. (2021). A distributional analysis of upper secondary school performance. *Empirical Economics*, *60*, 1085–1113.

Denny, K., & Oppedisano, V. (2013). The surprising effect of larger class sizes. *Labour Economics*, *23*, 57–65.

Department of Education. (2021). *Data on individual schools: Post primary schools list*. https://www.education.ie/en/ publications/statistics/data-on-individual-schools/

Department of Education and Science. (2005). *Delivering equality of opportunity in schools (DEIS): An action plan for educational inclusion*. DES.

Department of Education and Skills. (2018, May 28). *Minister Bruton commences plan to increase provision of multi- and non-denominational schools* [Press release]. https://www.gov.ie/en/press-release/e0de59-minister-bruton-commences-plan-to-increase-provision-of-multi-and-no/?referrer=http://www.education.ie/en/ Press-Events/Press-Releases/2018-press-releases/PR18-05-28.html

Doris, A., O'Neill, D., & Sweetman, O. (2013). Gender, single-sex schooling and maths achievement. *Economics of Education Review*, *35*, 104–119.

Dustmann, C., Kub, H., & Kwakc, D. W. (2018). Why are single-sex schools successful? *Labour Economics*, *54*, 79–99.

Eisenkopf, G., Hessami, Z., Fischbacher, U., & Ursprung, H. W. (2015). Academic performance and single-sex schooling: Evidence from a natural experiment in Switzerland. *Journal of Economic Behavior and Organization*, *115*, 123–143.

Eivers, E. (2010). PISA: Issues in implementation and interpretation. *The Irish Journal of Education*, *38*, 94–118.

Firpo, S., Fortin, N. M., & Lemieux, T. (2009). Unconditional quantile regressions. *Econometrica*, *77*, 953–973.

Halpern, D., Eliot, L., Bigler, R. S., Fabes, R. A., Hanish, L. D., Hyde, J., Liben, L. S., & Martin, C. L. (2011). Education. The pseudoscience of single-sex schooling. *Science*, *333*(6050), 1706–1707.

Hampden-Thompson, G., & Galindo, C. (2017). School–family relationships, school satisfaction and the academic achievement of young people. *Educational Review*, *69*(2), 248–265.

Hannan, D. F., Smyth, E., McCullagh, J., O'Leary, R., & McMahon, D. (1996). *Coeducation and gender equality*. Oak Tree Press/ESRI.

Humlum, M. K., & Smith, N. (2015). Long-term effects of school size on students' outcomes. *Economics of Education Review*, *45*, 28–43.

Jackson, C. (2002). Can single-sex classes in co-educational schools enhance the learning experiences of girls and/or boys? An exploration of pupils' perceptions. *British Educational Research Journal*, *28*, 37–48.

Jackson, C. K. (2012). Single-sex schools, student achievement, and course selection: Evidence from rule-based student assignments in Trinidad and Tobago. *Journal of Public Economics*, *96*(1), 173–187.

Jackson, C. K. (2021). Can introducing single-sex education into low-performing schools improve academics, arrests, and teen motherhood? *Journal of Human Resources*, *56*(1), 1–39.

Jackson, C. K., Johnson, R. C., & Persico, C. (2016). The effects of school spending on educational and economic outcomes: Evidence from school finance reforms. *Quarterly Journal of Economics*, *131*(1), 157–218.

Jepsen, C. (2015). Class size: Does it matter for student achievement? *IZA World of Labor*, *2015*, 190. https://doi.org/10.15185/izawol.190

Jerrim, J. (2021). PISA 2018 in England, Northern Ireland, Scotland and Wales: Is the data really representative of all four corners of the UK? *Review of Education*, *9*, e3295.

Jerrim, J., Lopez-Agudo, L. A., Marcenaro-Gutierrez, O. D., & Shure, N. (2017). What happens when econometrics and psychometrics collide? An example using the PISA data. *Economics of Education Review*, *61*(Suppl. C), 51–58.

Jerrim, J., & Moss, G. (2019). The link between fiction and teenagers' reading skills: International evidence from the OECD PISA study. *British Educational Research Journal*, *45*, 181–200.

Lavy, V., & Schlosser, A. (2011). Mechanisms and impacts of gender peer effects at school. *American Economic Journal: Applied Economics*, *3*(2), 1–33.

Lee, S., Niederle, M., & Kang, N. (2014). Do single-sex schools make girls more competitive? *Economics Letters*, *124*(3), 474–477.

Leithwood, K., & Jantzi, D. (2009). A review of empirical evidence about school size effects: A policy perspective. *Review of Educational Research*, *79*, 464–490.

Lounkaew, K. (2013). Explaining urban–rural differences in educational achievement in Thailand: Evidence from PISA literacy data. *Economics of Education Review*, *37*, 213–225.

Mael, F. A., Alonso, A., Gibson, D., Rogers, K., & Smith, M. (2005). *Single-sex versus coeducational schooling: A systematic review (DOC #2005-01)*. US Department of Education Office of Planning, Evaluation and Policy Development.

McCarey, C. (2017). *The impact of single-sex schools on educational and personal outcomes*. https://stanfordeconjournal.com/2017/06/28/mccarey/

McKeown, C., Denner, S., McAteer, S., & Shiel, G. (2019). *Learning for the future: The performance of 15-year-olds in Ireland on reading literacy, science and mathematics in PISA 2018 (issue 1, 3rd December 2019)*. Educational Research Centre.

OECD (Ed.) (2009). Replicate weights. In *PISA data analysis manual: SPSS* (2nd ed.). OECD Publishing.

OECD. (2019). *PISA 2018 results (vol. I): What students know and can do*. OECD Publishing.

OECD. (2020). *PISA 2018 technical report*. OECD Publishing.

Pahlke, E., Hyde, J. S., & Allison, C. M. (2014). The effects of single-sex compared with coeducational schooling on students' performance and attitudes: A meta-analysis. *Psychological Bulletin*, *140*(4), 1042–1072.

Park, H., Behrman, J., & Choi, J. (2013). Causal effects of single-sex schools on college entrance exams and college attendance: Random assignment in Seoul high schools. *Demography*, *50*(2), 447–469.

Park, H., Behrman, J. R., & Choi, J. (2018). Do single-sex schools enhance students' STEM (science, technology, engineering, and mathematics) outcomes? *Economics of Education Review*, *62*, 35–47.

Porter, S. R. (2015). Quantile regression: Analyzing changes in distributions instead of means. In M. Paulsen (Ed.), *Higher education: Handbook of theory and research* (Vol. 30). Springer.

Schneeweis, N., & Zweimüller, M. (2012). Girls, girls, girls: Gender composition and female school choice. *Economics of Education Review*, *31*(4), 482–500.

Sciffer, M. G., Perry, L. B., & McConney, A. (2022). Does school socioeconomic composition matter more in some countries than others, and if so, why? *Comparative Education*, *58*(1), 37–51.

Smyth, E. (2010). Single-sex education: What does research tell us? *Revue française de pédagogie*, *171*, avril–juin.

Smyth, E. (2015). *Wellbeing and school experiences among 9- and 13-year-olds: Insights from the Growing Up in Ireland study*. ESRI and NCCA.

Sohn, H. (2016). Mean and distributional impact of single-sex high schools on students’ cognitive achievement, major choice, and test-taking behavior: Evidence from a random assignment policy in Seoul, Korea. *Economics of Education Review*, *52*, 155–175.

Sortkær, B. (2019). Feedback for everybody? Exploring the relationship between students' perceptions of feedback and students' socioeconomic status. *British Educational Research Journal*, *45*, 717–735.

Sullivan, A. (2009). Academic self-concept, gender and single-sex schooling. *British Educational Research Journal*, *35*, 259–288.