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Gender, and attitudes towards mathematics and student achievement

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Gender, and attitudes towards mathematics and student achievement

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Abstract

That girls continue to be underrepresented in science, technology, engineering, and mathematics (STEM), is of concern both for the future of work and for the reduction of labour market inequalities. This study employs distributional analysis to investigate the relationship between attitudes towards mathematics and achievement for grade 9 girls and boys and the gender gap in mathematics using the TIMSS 2019 South Africa dataset. Results show that girls outperform boys at the mean, but once individual and background characteristics are controlled for, the gender gap in mathematics achievement actually favours boys. This suggests that mean characteristics differ between grade 9 boys and girls and that the gender gap favouring girls reflects, for example, the fact that there is a far larger share of boys in the overage category, resulting in a mismatch in average contrasts. Also, the gender gap across the distribution differs by school quintiles with girls from no fee schools (quintiles 1 to 3) doing better than boys across the achievement distribution, while boys from fee paying schools (quintiles 4 and 5) outperform girls at the top of the performance distribution. While we find a significantly positive relationship between being confident in mathematics and performance, only a small share of boys and girls, especially those from disadvantaged schools, are confident in mathematics with girls reporting having disproportionately lower self confidence in comparison to boys. The policy implications are two-fold, that is, urgent attention needs to be directed towards curtailing the repeat rates among relatively underperforming older boys, and policy campaigns aimed at reducing the gender gap adverse to girls must be aggressively continued. This means that there is still need for role models and programmes that normalize excelling in mathematics for both boys and girls.

Keywords: Gender, Mathematics achievement, Attitudes

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1 Introduction

1.1 Background

South Africa is one of a few countries in Sub-Saharan[2] Africa where women are disproportionately more likely to participate in tertiary education (Arias et al., 2019). Female students in South Africa outnumber male students in university enrolments both in public and private universities (Khuluvhe et al., 2021; Asmal et al., 2020; Reddy et al., 2016). In this sense, South Africa follows the trend of many developed countries where the gender gap in college enrolment has closed (Bossavie & Kanninen, 2018; Blau & Kahn, 2017; Buchmann & DiPrete, 2006; Goldin et al., 2006).

In 2019, females made up about 60% (640,333) of public university enrolment while men made up 40% (434,514) (DHET, 2019). Also, regardless of the field of study, female students have a higher graduation rate compared to males (Spaull & Makaluza, 2019). In 2019, the female graduation rate[3] was about 22% compared to a 21% male graduation rate (Khuluvhe et al., 2021). And, out of the 221,942 higher education graduates in 2019, 63% (138, 816) were female (DHET, 2019).

The puzzle[4], however, is that although the segregation of field of study by gender is declining, globally, women continue to be underrepresented in science, technology, engineering, and mathematics (STEM[5]) fields (Sahoo & Klasen, 2021; Ceci et al., 2014; Else-Quest et al., 2010). Most recently, Khuluvhe et al. (2021) report that female students in South Africa were the majority in all fields of study at the university except in science, engineering, and technology (SET) where they made up 48% of all students enrolled. They also note that while the gender gap in SET is narrowing at the university, in the technical and vocational education and training (TVET) colleges, there is a continued gender bias with only 17% of all the female students acquiring an engineering qualification compared to 40% of males (Khuluvhe et al., 2021).

Qualifications in STEM subjects are linked to better labour market outcomes, such as higher wages and greater employment rates for graduates (Gerber & Schaefer, 2004). There is evidence showing that the underrepresentation of women in STEM fields is an important determinant of the pay gap between college-educated men and women (Francesconi & Parey, 2018; Waite, 2017). So, with the list of occupations in high demand (OIHD) in South Africa containing mostly STEM related fields (Khuluvhe et al., 2021), the implication is that compensation (wages) for these skills will also be

[2] Other countries are Botswana, Cabo Verde, Mauritius, Senegal, and Seychelles (Arias et al., 2019)

[3] The graduation rate is defined as the number of students who graduated in 2019 regardless of the year of study divided by the total number of students enrolled in 2019 (Khuluve et al., 2021)

[4] While the question of why boys have lower enrolment and completion rates is an important question and has gained a lot of attention in recent times (Legewie &Di Prete. 2012), we do not address this question in here as it is beyond the scope of this study.

[5] In this paper, we use the acronym STEM synonymously with SET (science, engineering, and technology) because in South Africa, the Classification of Educational Subject Matter (CESM) classifies fields of study into three categories: business, commerce, and management studies; science, engineering, and technology (SET) which is the STEM equivalent and humanities.

higher. A positive step to close the persistent gender wage gap and the already wide employment gap between men and women[6] thus involves increasing the representation of women in STEM fields.

One reason given for the gender gap in STEM fields is gender differences in attitudes towards mathematics (Fennema & Peterson, 1985; Eccles, 1987; Wigfield, 1994). Existing literature finds a positive relationship between positive attitudes and achievement (Hyde et al., 1990; Eccles, 1987; Wigfield & Eccles, 2000). This relationship is also found to be reciprocal with improved performance being associated with improved attitudes towards the subject (Marsh & Martin, 2011). Consequently, students' positive attitudes towards mathematics are associated with a greater participation in advanced mathematics courses and more mathematics-related career choices (Ercikan et al., 2005; Wigfield, 1994). There is no consensus, however, on the relationship between gender and attitudes towards mathematics and the relationship has been found to differ by socioeconomic status (SES), across the performance distribution, and by country (Zuze et al., 2015; Berger et al., 2020). As such, the question we address in this paper is: How do attitudes towards mathematics interact with students' achievements by gender and by school status[7] in South Africa.

South Africa is an interesting case study for this analysis for several reasons. First is that South Africa's education system during apartheid was racially segregated with some subjects like mathematics denied to the majority black population (Unterhalter, 1991). It is therefore not surprising that even after more than two decades after the demise of apartheid, there are glaring inequalities in the schooling system both in terms of resources and performance (Pearson & Reddy, 2021; Motala, 2009). During the apartheid era, *Bantu education* focused on basic communication and mathematical skills, and it emphasized obedience, communal loyalty, and acceptance of allocated social roles (Martineau, 1997). The main goal of the *Bantu education* was to ensure that black Africans supplied cheap unskilled labour. In addition, other apartheid policies, such as the *Job reservation act,* were used as a tool to protect professional jobs for the minority white population and to justify the inferior education provided to the majority black South Africans (Seekings & Nattrass, 2008).

With regards to gender, South Africa is a historically patriarchal society and boys and girls were encouraged to pursue different subjects in school (Martineau, 1997). Education for black and white females continued to have a very narrow focus during the apartheid era which reflected traditional gender roles in the home and most women in senior secondary and tertiary education studied nursing and teaching (Unterhalter, 1991). Given that social and cultural norms are entrenched and take a long time to change, it is plausible that these norms, whether consciously or unconsciously,

[6] The gender employment gap in 2019 in South Africa was 12% (Casale et al., 2021).

[7] South African schools are classified into three categories namely, independent schools, public fee paying and public non fee schools. The fee status of the school is determined by the poverty level of the school's neighbourhood. Schools are categorized into five quintiles depending on the poverty level whereby quintile 1-3 are typically no fee schools while schools in quintiles 4 and 5 are fee paying schools. In this analysis we combine independent schools with fee paying schools because independent schools are tuition based and their social economic status is similar or closer to that of fee paying schools.

still affect student choices at school. Any analysis on gender in South Africa therefore must be sensitive to the intersection of gender, race, and class.

1.2 The South African Context

Although South Africa has achieved universal enrolment both at primary and secondary school level (Branson & Leibbrandt, 2013; Jansen, 2019), due to economic inequalities, school participation and completion rates differ by race, gender, and socioeconomic status (SES) (Zuze & Beku, 2019; Van der Berg & Gustafsson, 2019). Students from disadvantaged schools (no fee schools) lack basic resources and infrastructure needed for academic success (Cai et al., 2016). Moreover, this disadvantage starts early on during childhood as these students are less likely to access early childhood development programmes (Ashley-Cooper et al., 2019): early childhood is a key phase in development, creating the foundations upon which perceptions about one's abilities and aspirations are cultivated.

Students who do not do well in mathematics, the majority of whom are from disadvantaged schools, struggle to access STEM related fields (Asmal et al., 2020; Reddy et al., 2016). In the context of South Africa's STEM skills shortfall (Khuluvhe et al., 2021; Asmal et al., 2020), it is of great concern that the Trends in Mathematics and Science Study (TIMSS) average mathematics score for grade 9 students is still below the low[8] international benchmark (Reddy et al., 2021). While achievement is low for both boys and girls, recent findings from TIMSS reveal a continued narrowing of the gender gap in mathematics performance in South Africa (Reddy et al. 2021; Zuze & Beku 2019; Zuze et al. 2015).

South Africa has participated in the TIMSS study since 1995 and the results show that in 1995 and 1999, grade 9 boys outperformed girls in both mathematics and science (Reddy et al., 2015; Cai et al., 2016; Spaull & Makaluza, 2019). In 2011 and 2015, although the gender gap was not significant, girls marginally outperformed boys (Reddy et al., 2015; Zuze et al., 2018; Spaull & Makaluza, 2019). Further, results from TIMSS 2019 show that grade 9 girls outperformed grade 9 boys in mathematics and science and this time the gender gap was statistically significant (Reddy et al., 2021; Reddy & Mncwango, 2021).

Unpacking the reasons why student achievement remains low even though there have been improvements over time is crucial. Similarly, the question of why girls are less likely to select into STEM fields compared to boys, despite there being evidence of the narrowing of the gender gap in mathematics achievement is important to understand other persistent trends, such as the gendered occupational segregation.

[8] The TIMSS achievement scale for science and mathematics has a centre point of 500. Learners who achieve a score below 400 do not have the proficiency for the grade assessed. A score between 400 and 475 indicates some knowledge of the subject, a score between 475 and 550 the ability to apply subject knowledge, and a score above 550 the ability to apply knowledge and to reason. For South Africa, the average mathematics score for grade 9 students in 2019 was 389 below the TIMSS international low international benchmark of 400 (Reddy et al., 2021; Mullis et al., 2020).

This study is situated in the theory of social cognition and the expectancy value theory of achievement (Wigfield, 1994), where the proponents posit that students' attitudes and affect towards mathematics will influence their performance and participation in a career related to mathematics. We discuss the theoretical and empirical literature below.

1.3 Literature Review

In this section, we examine literature on the link between attitudes and mathematics achievement and gender differences in attitudes towards mathematics.

1.3.1 Theoretical literature on attitudes towards mathematics and achievement

Researchers and policy makers have been interested in gender differences in mathematics achievement for some time. Several theoretical models have been established with the aim of explaining student variation in academic performance and gender differences in mathematics. According to the expectancy value theory (Eccles 1987; Wigfield 1994; Wigfield & Eccles 2000), gender differences in mathematics and mathematics careers are a function of both social cognition and affect. According to this model, a child's perception of their parents' or teachers' beliefs about their ability in mathematics, their own beliefs about their ability in mathematics, and their expectations of success (perceived difficulty of tasks) will determine their choice in pursuing mathematics (Eccles 1987).

Fennema & Peterson (1985) proposed the autonomous learning behaviour model which posits that an individual's internal influences, that is, one's own beliefs about their ability in mathematics, and external influences, such as parental expectations, teacher expectations and societal stereotyping of mathematics, affect learning experiences and in turn their performance. The common theme between these two models is that aside from individual and family background, social cognition and affect matter for student performance.

Similarly, Ercikan et al. (2005) in their examination of factors that influence mathematics achievement and participation in advanced courses in mathematics in Canada, USA and Norway found that confidence was the strongest predictor of high achievement in Canada. The study also reported that positive attitudes towards mathematics were the strongest predictors of participation in advanced mathematics courses (Ercikan et al., 2005). Bandura et al. (1996) analysed the network of psycho-social influences through which self-efficacy beliefs affect academic achievement and concludes that children's beliefs in their own abilities help to regulate their own learning and influences their achievement.

1.3.2 Empirical literature on attitudes towards mathematics and achievement

Empirically, several studies from developed countries have tried to investigate the influence of attitudes towards mathematics and mathematics achievement. For example, Berger et al. (2020) applied latent profile analysis to the TIMSS 2015 data to examine the relationship between attitudes towards mathematics and science among grade 8 Australian students. Results from this analysis showed that positive attitudes towards mathematics were associated with higher achievement. Locally, in an analysis investigating individual and institutional factors explaining academic resilience[9] in South African schools, Hofmeyr et al. (2021) found a strong positive correlation between self-confidence in reading and mathematics and students' ability to achieve exceptional academic performance despite being from a disadvantaged background.

With respect to gender differences, Berger et al. (2020) report that girls were disproportionately less likely to have high self-confidence, high enjoyment (intrinsic motivation), and high intrinsic value (intrinsic utility) for mathematics. They also found that boys tended to have more positive attitudes (self-confidence, intrinsic motivation, and intrinsic utility) towards both mathematics and science and hence tended to benefit more from the positive relationship. These results are similar to other findings in the literature where even in situations where achievement between boys and girls is similar, boys report more positive attitudes in relation to mathematics (Else-Quest et al., 2010).

1.3.3 Other explanations for the gender gap in mathematics achievement

While the studies discussed above provide evidence that attitudes towards mathematics are important for achievement, other background factors have also been found to relate to achievement. For example, Hofmeyr (forthcoming) reports that while attitudes towards mathematics are important explanatory variables when investigating the gender gap in mathematics achievement, much of the gender gap in mathematics achievement for grade 5 and grade 9 students could be explained by the fact there were more overage boys than girls in the grade.

The issue of overage learners in South Africa is inextricably tied to high repetition rates, an issue that has received a lot of attention from researchers (Branson et al. 2014; Van der Berg 2019). Using national Education Management Information System (EMIS) data, Van der Berg et al. (2019) show that learners who are overage for their grade are less likely than underage or correct age for grade learners to pass that grade. In addition, their analysis found that the share of learners who are overage for their grade increases with each progressive grade with grade 1 having the lowest percentage of learners who are overage (12% in 2015) while higher grades have larger shares of overage learners (60% of grade 10 and 11 learners were overage in 2015) (Van der Berg et al., 2019).
The findings by Van der Berg et al. (2019) are supported by other studies using TIMSS data who find achievement being on average higher for correct age for grade learners (Cai et al., 2016; Hofmeyr, forthcoming). Using 2011 TIMSS data, Reddy et al. (2015) reported that younger girls outperformed boys of the same age, while age-appropriate boys outperformed girls.

Other than impacting achievement, age has also been found to influence attitudes. Eccles (1987), for example, finds that ability beliefs become more negative with age because as children grow older, they become better at understanding and interpreting feedback. Moreover, as children grow older, they become more realistic in their self-assessment (Eccles 1987).

[9] Academic resilience is the students' ability to achieve exceptional academic performance in the face of socioeconomic disadvantage.

Another factor that has been shown to influence both attitudes towards mathematics and achievement is parental education. Research finds that parental involvement affects students' attitudes towards mathematics (Ercikan et al. 2005; Fryer & Levitt 2010; Mejía-Rodríguez et al. 2021). This is because parents with higher educational qualifications are likely to be more positive about their own academic efficacy and therefore more likely to be involved in their children's studies by assisting with assignments and offering career advice. Bandura (1996) also suggests that a parent's sense of academic efficacy and aspiration will affect the child's achievement. Furthermore, parental education can be seen as a proxy for SES as parents with higher educational qualifications are more likely to be better off economically (Reddy et al., 2021) and in a position to provide more learning resources and an environment conducive for better learning.

Whether the language of learning is spoken at home has been found to be an important factor for student achievement (Hofmeyr et al., 2021; Cai et al., 2016). In South Africa, most students from no fee schools do not regularly speak either English or Afrikaans at home which are the two main languages of instruction from grade 4 onwards (Spaull & Pretorious, 2019; Mohohlwane, 2019). This means that these students are disadvantaged when writing the TIMSS assessment which is mostly conducted in English and Afrikaans.

1.4 The current study

Building on these findings, this study contributes to the literature by formally examining the association between attitudes towards mathematics and the gender gap in mathematics achievement using the recently available TIMSS 2019 data. Our analysis contributes to the literature on the link between attitudes towards mathematics and the gender gap in achievement in two ways. First, using ordinary least square (OLS) regressions, the study examines the effects of attitudes towards mathematics on achievement by gender and school type. This will enable us to understand if there are any gender or socioeconomic differences in how attitudes towards mathematics affect mathematics achievement. Second, while previous studies on the gender gap in mathematics achievement in South Africa have concentrated on mean differences (Hofmeyr 2021), this study uses a semi-parametric reweighting approach by DiNardo, Fortin and Lemieux (1996) (hereafter DFL) to compute the gender gap across the achievement distribution. This is because the mathematics gender gap favouring boys might be lower at the bottom of the distribution or at the median but higher at the top of the distribution (Pope & Sydnor, 2010; Penner & Paret, 2008; Fryer & Levitt, 2010). This male advantage at the top of the performance distribution has been cited as one possible reason for the underrepresentation of women in STEM careers (Pope & Sydnor, 2010).
While there are many ways of conceptualizing attitudes towards mathematics, in this paper, we utilize three measures of attitudes in TIMSS 2019. The first variable is confidence in mathematics which is from the TIMSS scale, *Student Confident in Mathematics*. This is related to a student's own beliefs about their self-efficacy in mathematics and includes items such as: "I usually do well in mathematics", "Mathematics is not one of my strengths", and "Mathematics makes me nervous" (see Table 5 in the appendix). The second variable we rely on is the TIMSS scale variable *Students Value Mathematics*. This relates to the student's extrinsic motivation in relation to mathematics and

includes items such as "I think learning mathematics will help me in my daily life" and "I need to do well in mathematics to get the job I want". The last variable is the TIMSS *Students Like Learning Mathematics scale*. This is related to the student's intrinsic motivation in relation to mathematics and includes items such as: "I enjoy learning mathematics", "Mathematics is boring", and "I like mathematics". For all the three variables, students respond to nine items using a 4-point Likert scale (0=disagree a lot; 1=disagree a little; 2=agree a little; 3=agree a lot). More about the variables is discussed in the data and methods section.

To this end, this study utilizes newly available TIMSS 2019 data to ask the following questions:

1. How do the attitudes towards mathematics of grade 9 boys and girls affect their mathematics achievement? Is the effect of attitudes towards mathematics on student achievement different for boys and girls?
2. How does the effect of attitudes towards mathematics affect the mean gender gap in mathematics achievement?
3. While mean differences are useful, research from developed nations shows that gender differences in achievement might differ at the extremes (Pope & Sydnor, 2010; Penner & Paret, 2008). Given this literature, how does the gender gap in mathematics achievement behave across the achievement distribution for grade 9 students in South Africa?

This paper is organised as follows: section two discusses the data and methods used in this analysis while the results are discussed in section three. The conclusions and policy implications are presented in section five.

2 Data and Methods

2.1 Data

We utilize the 2019 TIMSS data. The TIMSS study is an international, large-scale mathematics and science assessment conducted by the International Association for the Evaluation of Educational Achievement (IEA) (Mullis et al., 2020). In South Africa, TIMSS is administered by the Human Sciences Research Council (HSRC), and it is the longest, nationally representative trend measure of achievement in mathematics and science. South Africa has participated in TIMSS since 1995. In 1995, 1999 and 2003 South Africa participated at grade 8[10] level, and in 2003 both grade 8 and grade 9 students were tested. Grade 9 students were tested in 2011, 2015 and 2019. Due to comparability issues of measures over time, this analysis focuses on TIMSS SA 2019 data, and we only focus on mathematics achievement for grade 9 students.

TIMSS 2019 employed a two-stage, stratified cluster sampling design where, in the first stage, a nationally representative sample of schools was selected, stratified by school type and province

[10] Grade 8 students were targeted in the initial TIMSS assessments (1995, 1999), however, the overall low performance in these rounds prompted a decision to shift to testing grade 9 students to reflect the content knowledge and the curriculum coverage in South Africa (Reddy et al., 2015).

(Reddy et al., 2021). In the second stage, classes[11] within the sampled schools were randomly selected to participate in the assessment. All students present in the classes sampled participated in the assessment. The eventual 2019 sample was 20,829 grade 9 students from 519 schools across South Africa (Reddy et al., 2021).

Outcome Variable: *Plausible Values*

The dependent variable in this analysis is TIMSS mathematics achievement, a continuous variable recorded as a series of five plausible values. For practical reasons, the mathematics performance evaluation is drawn from the student item responses that represent a sample of the content domain questions, motivated by the intent to reduce the burden on each student's time. The approach adopted by TIMSS to capture the degree of uncertainty of mathematics achievement measurement at the student level is the use of plausible values: five scores drawn for everyone intended to reflect the magnitude of error of the individual's estimate (see Rubin, 1988; Beaton & Gonzalez, 1995). The plausible values therefore represent the range of mathematics abilities that a student might reasonably possess, conditional on the student's item responses (Martin et al., 2020).

The resulting individual level measurement error means that we must accommodate for correction of the standard error for robust inferences derived from the estimated population statistics. As such, in this analysis, for each mathematics achievement Y^j plausible value, and for each explanatory variable X_k, the regression coefficients β_k are computed with 150 Jackknife replicate weights for complex survey design. Implementing the ordinary least squares regressions sequentially five times will return, per regressor k five estimates, denoted $\beta^1 ... \beta^5$ with the respective standard errors. The final regression coefficient will be the average of the five coefficients. This analysis is implemented using the statistical software STATA through the user written command *pv* (Macdonald, 2019) which considers the IEA recommended formula (Martin et al., 2005) for calculating the standard error and the statistic of interest.

Explanatory variables

Attitudes towards mathematics

In this analysis, we are interested in how attitudes towards mathematics interact with gender and mathematics achievement. In addition to achievement scores, TIMSS provides background and contextual information associated with achievement through questionnaires completed by principals, teachers, and learners (Mullis et al., 2020). TIMSS measures student attitudes toward mathematics and science achievement through several scales and has done so since 1995 (Mullis et al., 2017). We utilize three learner questionnaire self-reported measures to define attitudes towards mathematics. These are *student confident in mathematics*, *student liking mathematics* and *student valuing mathematics*. The TIMSS context questionnaire has nine statements (see Table 5 in the appendix) with four response choices (ranging from 0=disagree a lot to 3=agree a lot). From the raw scores, the IEA combines these nine items into a single scale that is calibrated, such that the centre point is 10 (standard deviation of 2) at the mean score of the combined distribution of all TIMSS 2019 countries using

[11] One class is sampled or sometimes in big schools two classes were sampled.

Item Response Theory (IRT) scaling methods (Martin & Mullis, 2019). Also, for each measure, students were scored according to the nine responses and the scale was divided into three categories namely low, moderate, and high. For example, a student is classified as "**not being confident in mathematics (low)**" if the student responses correspond to "**disagreeing a little**" with five of the statements and "**agreeing a little**" with the other four statements on average. A student is classified as being "**very confident (high)**" in mathematics if their responses correspond to "**agreeing a lot**" with five of the statements and "**agreeing a little**" with the other four on average. A student is classified as **"having moderate confidence in mathematics (somewhat confident)"** if their responses correspond to any combination not classified as either high or low (see Mullis et al., 2020, for more details). In this analysis, we utilize these categorical variables. Note, however, that using the continuous variables does not substantively change the results (see Table 6 in the appendix for alternative regression results).

School type

For the multivariate analysis, we control for other variables that have been shown in the literature to influence mathematics achievement. School type is defined as a binary variable (1=no fee school, 0=fee paying school (independent schools are included in this category)).

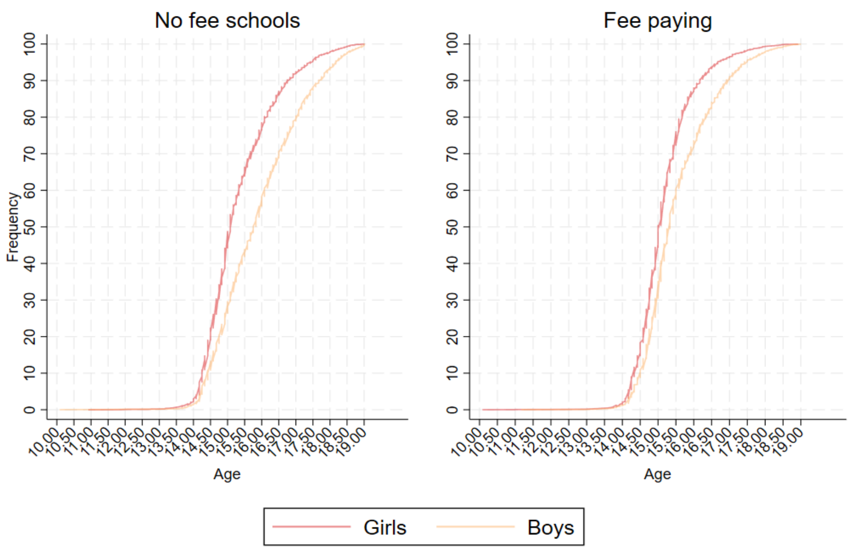
Language of learning and teaching (LOLT)

The language of learning and teaching variable details how often the language of the test is spoken at home. It is a categorical variable defined as (1=always (including almost always), 2=sometimes, 3=never).

Age

We include age as a dummy variable (1=15.5 years and below, 0=above 15.5 years (overage)). In our data, age is a continuous variable ranging between 10 and 19 years (see Figure 1). However, we found that in some cells there were too few observations, especially for younger ages, and this would impact the regression model. We therefore categorized age according to whether the student was older or had the correct age for that grade (age appropriate). There were only 226 observations below age 14 (1% of the sample), therefore we also included these students in the age appropriate for grade category. Figure 1 shows that boys are more likely to be overage, with over 50% of boys from no fee schools being older than 15.5 years compared to about 40% of boys from fee paying schools.

Figure 1: Grade 9 age distribution by gender TIMSS 2019



Notes: Author's own calculations from TIMSS 2019. Values weighted by survey weights.

Parental level of education

Parental level of education level is coded as a categorical variable (1=university education, 2=post-secondary but not university, 3=upper secondary, 4=lower secondary 5=primary or no schooling 6=don't know). We combined the lower secondary and primary or less categories. Also, during cleaning of the data, we discovered that out of 20,491 responses to this item, 3,938 students responded with '**don't know**'. Deleting this category would have meant losing about 19% of all the observations. A simple regression model revealed that this category was not statistically different from the *post-secondary but not university* category. Following Berger et al. (2020) who included this category in their analysis after reporting that 38% of Australian students did not know their parents' level of education, we did not drop this category. The final parental education level variable had 5 categories (1=university education, 2=post-secondary but not university, 3=upper secondary, 4=lower secondary/primary/ no schooling 5=don't know parent level of education).

For other missing values, which was less than 6% of the total observations, list wise deletion was applied leading to a final analysis sample of 19, 594 observations.

2.2 Analytic Strategy

a. Ordinary Least Square (OLS) regression

To analyse the effects of confidence in mathematics, valuing mathematics and liking mathematics on grade 9 students' achievement, we use ordinary least squares (OLS) regression method to estimate the models below. In the first group of regression models (equations 1 and 2), we regress the dependent variable, mathematics achievement (Y_i) on the three measures of attitudes towards mathematics ($confidence_i$, $value_i$ and $like_i$), separately by gender for the two school types (no fee schools and fee paying schools). This is the baseline model to help us understand the correlation between attitudes towards mathematics and mathematics achievement.

In the second group of regression models, we include other individual and background characteristics to see whether the importance of the attitudes towards mathematics is maintained.

$$Y_i^f = \beta_1^f + \beta_2^f confidence_i^f + \beta_3^f value_i^f + \beta_4^f like_i^f + \varepsilon_i^f \quad \ldots 1$$

$$Y_i^m = \beta_1^m + \beta_2^m confidence_i^m + \beta_3^m value_i^m + \beta_4^m like_i^m + \varepsilon_i^m \quad \ldots 2$$

$$Y_i^f = \beta_1^f + \beta_2^f confidence_i^f + \beta_3^f value_i^f + \beta_4^f like_i^f + \alpha_i^f X_i^f + \varepsilon_i^f \quad \ldots 3$$

$$Y_i^m = \beta_1^m + \beta_2^m confidence_i^m + \beta_3^m value_i^m + \beta_4^m like_i^m + \alpha_i^m X_i^m + \varepsilon_i^m \quad \ldots 4$$

The dependent variable Y_i is the average mathematics achievement for student *i* from the boy (m) or girl (f) group, while β_i and α_i represent the effects of individual and background characteristics on mathematics achievement while ε_i is the error term. Individual and background characteristics found in the literature to affect mathematics achievement are represented by X_i.

To analyse the gender gap in mathematics achievement, we regress the dependent variable, mathematics achievement (Y_i) on the gender (H_i) dummy to get the raw gender gap (γ). We then regress mathematics achievement (Y_i) on the gender dummy with all control variables (X_i).

$$Y_i = \alpha + H_i'\gamma + \varepsilon_i \quad \ldots 5$$

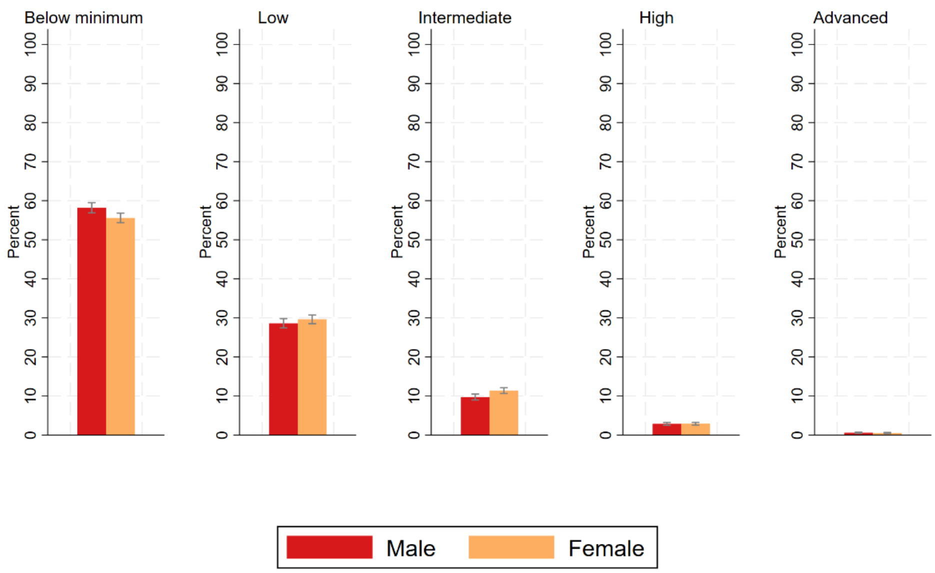
$$Y_i = X_i'\beta + H_i'\gamma + \varepsilon_i \quad \ldots 6$$

b. The gender gap across the achievement distribution: DFL aggregate decomposition

While the mean gender gap in mathematics is a useful statistic, research from other countries indicates that the gender gap is not uniform across the achievement distribution. We can also see this when looking at student performance by the share of students who attained a particular benchmark level. Figure 2 shows that the majority of grade 9 students scored below the minimum benchmark (below 400). Also, as shown in Figure 2, there are slightly more boys in the below minimum category and slightly more girls in the low (at or above 400 and below 475) and the intermediate level (at or above 475 and below 550). This gives an indication that the gender gap in mathematics achievement might differ across the test score distribution.

To examine the gender gap across the test score distribution, we adopt the DFL methodology by DiNardo et al. (1996) which allows us to construct a counterfactual distribution replacing the marginal distribution of characteristics (explanatory variables) for group A (grade 9 boys) with the marginal distribution of group B (grade 9 girls) using a reweighting factor $(\Psi(X))$. The reweighting approach allows us to answer the question, "**what the test score distribution of boys would be if they had the same background characteristics as girls**".

Figure 2: TIMSS Grade 9 performance at international benchmarks by gender



Notes: Author's own calculations from TIMSS 2019. Only the first plausible value (BSMIBM01) was used. Values weighted by survey weights. Students who score below 400 are below the minimum benchmark, low benchmark is between 400 and 475, the intermediate benchmark is between 475 and 550, between 550 and 625 is the high benchmark while 625 and above is the advanced benchmark.

The DFL reweighting method is similar to the propensity score reweighting method commonly applied in the program evaluation literature. It can also be seen as a generalization of the Oaxaca Blinder method (Oaxaca, 1973; Blinder, 1973) but instead of calculating the gender gap at the mean, DFL allows one to calculate the gender gap across the entire distribution. The main advantage of the DFL reweighting approach is that it is easy to implement (Fortin et al., 2011). Additionally, results from the treatment effect literature show that this method is efficient when using large datasets (Fortin et al., 2011; Hirano et al., 2003) and it provides consistent estimates of the explained and unexplained gap for any distributional statistic (Fortin et al., 2011). Formally, the method is described below.

Following DiNardo et al. (1996), let each individual observation in each test score distribution be a vector $Y_i(y_i, x, h)$ where (y_i) is the test score (mathematics achievement), x is a vector of background characteristics (confidence in mathematics, liking mathematics, valuing mathematics, age, parent education etc.) and h is the group indicator $h = g(girl), b(boy)$. Let the test score distribution of boys and girls be:

$$f_b(y) = \int f(y_b|x_b)dF(x_b) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots. (7)$$

$$f_g(y) = \int f(y_g|x_g)dF(x_g) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (8)$$

Where $f_b(y)$ is the grade 9 boys' conditional distribution of test scores and $f_g(y)$ is the conditional distribution of girls' test scores. The counterfactual distribution $f_b^c(y)$ for boys if they had the girls' background characteristics would be:

$$f_b^c(y) = \int f(y_g|x_g)\Psi(X)dF(x_g) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (9)$$

Where the reweighting factor $\Psi(X)$ which is the ratio of two marginal distribution functions of background characteristics (X) is expressed as:

$$\Psi(X) = \frac{dF_g(x)}{dF_b(x)} = \frac{\Pr(x|h = girls)}{\Pr(x|h = boys)} = \frac{\Pr(h = girl|x)}{\Pr(h = girl)} * \frac{\Pr(h = boy)}{\Pr(h = boy|x)}$$

We estimate a logit model $(\Pr(h = girl|x))$ describing the probability that an observation is from a girl given the background characteristics (X) and use the predicted probabilities to compute $\widehat{\Psi}(X)$. The gender gap in test scores can therefore be decomposed into the explained and the unexplained effect as follows:

$$\Delta_O^{f(y)} = f_g(y) - f_b(y) = \left(f_g(y) - f_b^c(y)\right) - (f_b^c(y) - f_b(y)) \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.10$$

Where $\Delta_O^{f(y)}$ is the overall difference in test scores between girls and boys ($f_g(y) - f_b(y)$) or the raw gender gap in test scores which has been decomposed into the component due to observable characteristics or the explained portion of the gap ($f_g(y) - f_b^c(y)$) and the component that is due to unobservable characteristics or the unexplained component ($(f_b^c(y) - f_b(y))$).

3 Results

3.1 Descriptive statistics of the analysis sample

In this section we discuss mean characteristics presented in Table 1 to make better sense of the regression results presented later.

Attitudes towards mathematics

Table 1 shows that the share of students who are **very confident** in mathematics is very low across board with only 6.9% of girls and 6.8% of boys who took the 2019 TIMSS grade 9 assessment reporting being **very confident** in mathematics. Disaggregating this by school type shows that a slightly higher share of students from fee paying schools (9.2% of girls and 8.7% of boys) report being **very confident** in mathematics compared to students from no fee schools (5.7% of girls and 5.9% of boys). Also, there is a larger share of boys (41.9% compared to 38.3% of girls) who report being **somewhat confident** in mathematics, while a larger share of girls (54.8% compared to 51.2% of boys) report **not being confident** in mathematics. This is consistent with the literature on gender differences regarding confidence towards mathematics (Berger et al., 2020; Mejía-Rodríguez et al., 2021).

A descriptive look at mathematics achievement and attitudes by gender and school type in Figure 3 follows the international trend where students who are **confident** in mathematics perform better than those who are **not confident** in mathematics.

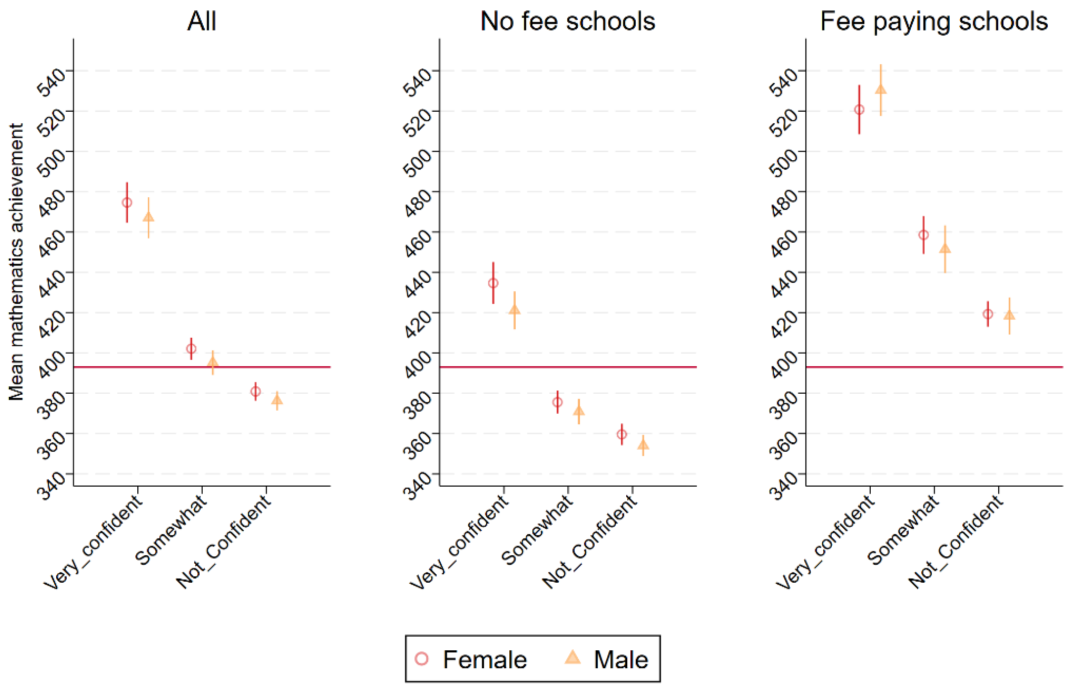
Table 1: Mean characteristics

	National		No fee schools		Fee paying schools	
	Girl	**Boy**	**Girl**	**Boy**	**Girl**	**Boy**
			Student confident in mathematics			
Very confident	**6.9%**	**6.8%**	5.7%	5.9%	9.2%	8.7%
Somewhat	38.3%	41.9%	40.1%	43.8%	35.0%	38.1%
Not confident	54.8%	51.2%	54.2%	50.2%	55.9%	53.3%
			Student values mathematics			
High value	70.5%	65.1%	71.7%	64.5%	68.2%	66.3%
Somewhat	25.3%	29.5%	24.5%	30.0%	26.8%	28.6%
Low value	4.2%	5.3%	3.9%	5.5%	**5.0%**	**5.1%**
			Student likes learning mathematics			
Like very much	35.9%	36.7%	39.2%	39.8%	29.6%	30.4%
Somewhat	43.3%	44.9%	44.0%	44.4%	42.0%	46.1%
Does not like	20.8%	18.4%	16.7%	15.8%	28.4%	23.5%
			Student age dummy (0=above 15.5 years)			
Appropriate age/younger	69.7%	49.4%	66.3%	43.9%	76.0%	60.5%
			Parent highest level of education			
Parent university	19.8%	18.2%	14.8%	13.9%	29.1%	26.7%
Parent upper sec sch	19.8%	19.8%	19.4%	19.9%	20.6%	19.5%
Parent other tertiary	**29.8%**	**29.5%**	33.6%	33.2%	22.8%	22.1%
Primary or lower	11.8%	12.8%	14.5%	15.9%	6.6%	6.4%
Don't know parent educ	18.8%	19.8%	17.7%	17.0%	20.9%	25.3%
			Language of test spoken at home			
Always	29.6%	26.6%	17.1%	15.2%	**52.8%**	**49.4%**
Sometimes	64.6%	64.3%	75.4%	74.0%	44.6%	44.8%
Never	5.9%	9.1%	7.6%	10.7%	2.6%	5.8%
			School type			
No fee (quintile1-3)	65.0%	66.8%				
			Mathematics Score			
Mathematics score	395.51	390.44	370.31	365.47	442.32	440.68
S.E	2.42	2.53	2.68	2.51	3.74	5.13
Observations	10605	8989	6222	5354	4383	3635

Notes to Table 1: Own calculations from TIMSS SA 2019. Values weighted by survey weights. The Pearson's chi-squared performed showed that the gender differences within each group are statistically significant at the 5% level except for the cells in bold. Test results available from the author.

Figure 3 also shows that there is a sizeable gap in achievement between students who report being **very confident** in their mathematics ability compared to those who are **not very confident**. For fee paying students, boys who are **very confident** in mathematics score higher than girls in the same category (**very confident**). For no fee schools, the scenario is reversed with girls who report being **very confident** in mathematics scoring higher than boys. This is an indication that even within gender, the SES and other background characteristics might influence both the performance and attitudes towards mathematics.

Figure 3: Confidence in mathematics ability and achievement by gender and school type

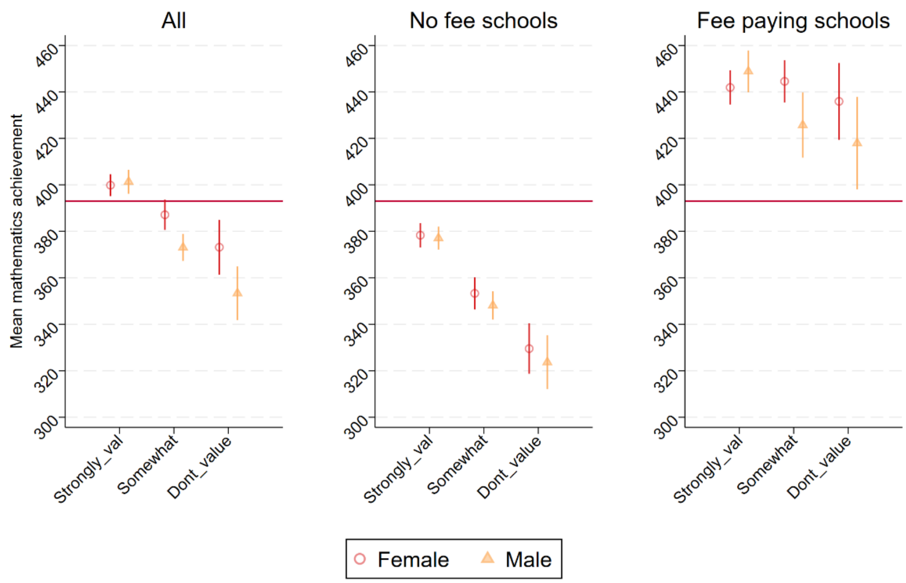


Notes: own calculations from TIMSS SA 2019. Values weighted by survey weights.

For **external motivation or valuing mathematics**, Table 1 shows that South African students have a high regard for mathematics. At the national level, 70.5% of all the girls report having a **high value** for mathematics while 65.1% of all boys **highly value** mathematics. Girls from no fee schools show the highest share of students who **value** mathematics (71.7%) followed by females from fee paying schools (68.2%). In contrast with having confidence in mathematics ability, very few students who took part in the TIMSS 2019 assessment reported **not valuing** mathematics across the board.

Figure 4 compares average mathematics achievement scores by the **valuing mathematics** index. Again, there seems to be a link between valuing mathematics and achievement: Students who **strongly value** mathematics record higher mathematics scores compared to those who **somewhat value** mathematics. This relationship seems monotonic except for girls in fee paying schools where girls who reported to **somewhat value** mathematics recorded higher average scores.

Figure 4: Valuing mathematics and achievement by gender and school type



Notes: own calculations from TIMSS SA 2019. Values weighted by survey weights.

Shifting to students **liking mathematics**, more students from no fee schools report that they like learning mathematics very much. Table 1 shows that 39.2% of female students and 39.8% of male students from no fee schools **like learning mathematics very much** compared to 30.4% and 29.6% of male and female students, respectively, from fee paying schools. Also, more students from fee paying schools report **not liking** mathematics. Figure 5 shows a positive relationship between liking mathematics and achievement. However, while students who **like learning mathematics very much** score higher in mathematics on average, this difference is marginal. Interestingly, compared to confidence in mathematics, the average scores in Figures 4 and 5 are lower an indication of less returns to **liking** and **valuing** mathematics compared to **having confidence** in one's mathematics ability. These relationships are investigated more formally using multivariate regression analysis. The results are presented in Tables 2 and 3 below.

Figure 5: Liking mathematics and achievement by gender and school type

Notes: own calculations from TIMSS SA 2019. Values weighted by survey weights.

The parental level of education

Parent highest education is similar for boys and girls within school types but differs between school types. More students from fee paying schools (29.1% of girls and 26.7% of boys) have parents with a university qualification while more students from no fee schools have parents with a tertiary education qualification but not university (33.6% of girls and 33.2% of boys). A significant share of students reported not knowing their parents' highest education level (18.8% of all the girls and 19.8% of all the boys in our sample). This is not unique to South Africa as Berger et al. (2020) analysing TIMSS 2015 similarly found that 38% of grade 8 Australian students reported not knowing their parent's highest qualification.

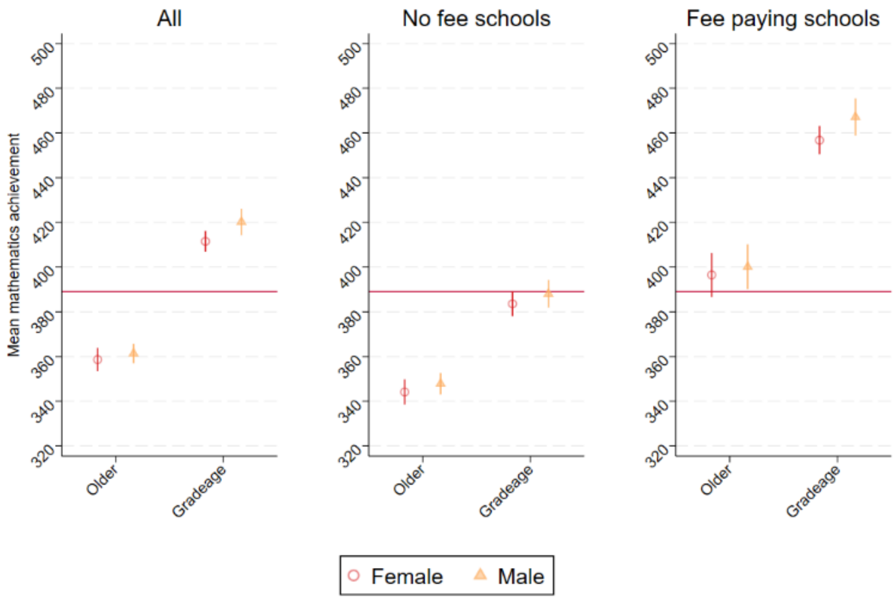
Language of test spoken at home

A large share of students (64.6% of girls, 64.3% of boys) only **'sometimes speak the language of the test at home'**. This is because students from no fee schools are the majority in the sample (66.8% of all boys and 65% of all girls in the sample are from no fee schools) and only 17.1% of girls and 15.2% of boys from these schools 'always use the language of the test at home'. This is contrasted against 52.8% of girls and 49.4% of the boys from fee paying schools who always speak the language of the test at home.

Age

Table 1 also shows that there are gender differences in age categories with boys more likely to be in the older category and girls more likely to be in the age-appropriate category. Figure 6 shows that for 2019, age-grade appropriate boys, on average, outperform girls regardless of the school type.

Figure 6: Mathematics achievement by gender and age



Notes: Author's own calculations from TIMSS 2019. Values weighted by survey weights.

3.2 Multivariate regression results: Attitudes and achievement

Table 2 presents results for the relationship between attitudes towards mathematics and achievement. Models 1, 3, 5 and 7 are the baseline models that only include the dependable variable (mathematics test scores) and the variables of interest, separately for boys and girls from the two types of schools.

The results show that positive attitudes towards mathematics have a positive relationship with mathematics achievement. The baseline models show that coefficients on **being very confident** in one's mathematics ability relative to **not being confident** are highest for fee paying students. Being **very confident** in mathematics improves mathematics scores for boys in fee paying schools by an average of 126.54 points compared to an increase of 114.04 points for girls. The coefficient for girls from no fee schools is 58.79 while the coefficient for boys from no fee schools is 53.51.

Table 2: Regression results: Attitudes towards mathematics and achievement

	No fee (quintile1-3) schools				Fee paying (quintile 4&5) schools			
VARIABLES	Girls		Boys		Girls		Boys	
	Model 1	**Mode2**	**Model 3**	**Model 4**	**Model 5**	**Mode 6**	**Model 7**	**Model 8**
Dependent variable=Student achievement scores								
	Student confident in mathematics (base=not confident)							
Very confident	58.79***	53.51***	48.67***	41.48***	114.04***	94.40***	126.54***	99.71***
	(4.99)	(4.79)	(4.55)	(4.80)	(6.97)	(5.54)	(7.14)	(5.70)
Somewhat confident	8.43***	8.23***	9.57***	8.72***	45.52***	36.01***	41.99***	31.31***
	(2.32)	(2.30)	(2.70)	(2.56)	(3.35)	(3.32)	(4.29)	(3.81)
	Student values mathematics (base=low value)							
High value	36.55***	32.30***	44.09***	38.12***	-8.36	-6.16	29.31***	19.70**
	(6.10)	(5.48)	(5.15)	(5.22)	(7.50)	(6.26)	(10.17)	(8.40)
Somewhat values	20.51***	19.45***	24.02***	21.98***	3.16	5.35	12.40	11.92
	(5.02)	(4.74)	(5.37)	(5.22)	(7.01)	(6.07)	(9.54)	(8.28)
	Student like in mathematics (base=not like)							
Like very much	15.06***	12.74***	8.59*	9.55**	-14.96**	-5.81	-41.82***	-19.54***
	(4.07)	(3.99)	(5.02)	(4.66)	(6.39)	(4.48)	(6.39)	(5.17)
Somewhat like	0.43	0.18	-4.15	-1.72	-3.32	1.09	-22.39***	-9.38*
	(3.36)	(3.38)	(4.78)	(4.61)	(3.94)	(2.73)	(6.82)	(4.86)
	Student age dummy (0=above 15.5 years)							
Appropriate age/younger		33.83***		33.98***		47.31***		48.98***
		(2.38)		(2.89)		(3.49)		(3.34)
	Parent highest level of education (base=primary or lower)							
Parent university		1.94		10.29*		37.26***		34.34***
		(5.82)		(5.85)		(5.58)		(7.20)
Parent upper sec sch		-0.88		2.19		9.49*		10.10
		(3.35)		(3.99)		(5.52)		(6.19)
Parent other tertiary		1.09		0.70		23.64***		21.97***
		(3.67)		(4.96)		(5.08)		(5.98)
Don't know parent educ		1.30		7.40*		28.55***		35.07***
		(4.25)		(4.10)		(6.30)		(6.32)
	Language of test spoken at home(base=never)							
LOLT always		28.51***		15.74***		51.30***		39.98***
		(6.39)		(5.64)		(15.33)		(10.53)
LOLT sometimes		14.05***		8.87**		16.57		0.19
		(5.42)		(4.05)		(12.21)		(7.27)
Constant	326.26***	292.64***	321.15***	297.52***	426.65***	330.83***	413.75***	339.82***
	(5.98)	(8.91)	(7.12)	(9.70)	(8.02)	(16.08)	(9.34)	(14.38)
Observations	6,222	6,222	5,354	5,354	4,383	4,383	3,635	3,635
R-squared	0.12	0.20	0.13	0.21	0.17	0.33	0.18	0.38
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1								

Notes: Author's own calculations using TIMSS SA 2019 grade 9 data. Complex survey methodology accounted for using survey weights.

Looking at the effect of valuing mathematics on achievement, the coefficient on **valuing mathematics very much** relative to **not valuing mathematics** is largest for boys from no fee schools. **Liking mathematics very much** is positively correlated with achievement for no fee schools' students while the relationship is strangely negative for students from fee paying schools.

In models 2, 4, 6 and 8 we include other background characteristics to check whether the relationship between attitudes towards mathematics and achievement is maintained. The results show that indeed the coefficients remain significant, although the magnitude reduces slightly across board. The implication here is that there is an indirect effect of attitudes towards mathematics through background characteristics. For example, speaking the language of the test at home could increase your confidence in your ability to tackle mathematics problems. Or, if we take parental education to be a proxy for SES, having parents with tertiary or university education means that the student is likely to get more help at home and greater resources to boost their mathematics abilities hence a more positive attitude towards mathematics.

Having looked at how attitudes towards mathematics affect performance separately by gender, we next examine the gender gap in mathematics achievement at the mean and later across the achievement distribution.

3.3 The gender gap at the mean

We present results for the gender gap at the mean. We start with the baseline model (model 1) where we regress the dependent variable (students' mathematics scores) on gender (female dummy 1=female 0=male) and the measures of attitudes towards mathematics. In the second model, we include individual and background characteristics. The gender dummy is positive and significant suggesting that, all else held constant, relative to boys, girls achieved a higher mathematics score. This is consistent with the descriptive analysis. The results also show that compared to **not being confident** in mathematics, **being confident** in mathematics is associated with higher mathematics scores. Also, **strongly valuing mathematics** as opposed to **not valuing mathematics** is positively associated with achievement. As seen in Table 2, **liking mathematics** as opposed to **not liking mathematics** is negatively associated with mathematics achievement for fee paying students. This is counter-intuitive and requires further investigation.

Table 3: Regression results: The mathematics gender gap at the mean

	No fee (quintile1-3) schools			Fee paying (quintile 4&5) schools			National		
VARIABLES	**Model 1**	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**	**Model 1**	**Model 2**	**Model 3**
Dependent variable=Student achievement scores									
			Without age			Without age			Without age
Female	4.84***	-4.28**	3.04*	1.64	-6.78***	0.50	5.07**	-5.32***	2.34
	(1.78)	(1.85)	(1.74)	(3.31)	(2.02)	(2.22)	(2.11)	(1.49)	(1.44)
Student confident in mathematics (base=not confident)									
Very confident		47.65***	52.80***		97.18***	103.57***		67.75***	73.33***
		(3.49)	(3.50)		(4.36)	(4.43)		(3.10)	(3.04)
Somewhat confident		8.48***	9.24***		33.96***	37.87***		17.60***	19.34***
		(1.74)	(1.71)		(2.95)	(2.79)		(1.58)	(1.49)
Student values mathematics (base=low value)									
High value		34.97***	39.34***		6.23	11.57**		24.97***	29.93***
		(4.23)	(4.31)		(4.73)	(5.08)		(3.15)	(3.29)
Somewhat values		20.49***	22.03***		8.10*	9.99**		16.36***	18.10***
		(4.07)	(4.13)		(4.71)	(4.97)		(3.03)	(3.16)
Student like learning mathematics (base=not like)									
Like very much		11.29***	11.02***		-12.74***	-16.33***		2.47	1.19
		(3.27)	(3.20)		(3.53)	(3.86)		(2.83)	(2.91)
Somewhat like		-0.66	-2.08		-4.23	-5.89*		-2.33	-3.95
		(3.02)	(3.02)		(2.86)	(3.37)		(2.31)	(2.43)
Student age dummy (0=above 15.5 years)									
Appropriate age/younger		33.90***			48.63***			39.81***	
		(2.20)			(2.54)			(1.74)	
Parent highest level of education (base=primary or lower)									
Parent university		6.15	11.89**		36.16***	46.94***		15.71***	22.86***
		(5.03)	(5.54)		(4.08)	(4.02)		(3.43)	(3.77)
Parent upper sec sch		0.58	3.60		9.61**	14.12***		1.49	4.97**
		(2.37)	(2.58)		(4.08)	(3.78)		(2.19)	(2.36)
Parent other tertiary		1.01	5.47*		22.94***	32.01***		5.49**	11.13***
		(2.94)	(3.09)		(3.66)	(3.80)		(2.50)	(2.65)
Don't know parent educ		4.27	7.01**		32.09***	42.43***		12.45***	17.49***
		(2.97)	(3.27)		(4.39)	(4.39)		(2.63)	(2.86)
Language of test spoken at home (base=never)									
LOLT always		21.89***	23.59***		44.10***	51.89***		36.13***	40.25***
		(4.62)	(4.91)		(10.54)	(12.42)		(4.92)	(5.40)
LOLT sometimes		11.00***	12.87***		6.47	10.46		10.41***	12.96***
		(3.50)	(3.80)		(6.98)	(8.44)		(3.40)	(3.73)
Language of test spoken at home(base=never)									
No fee (quintile1-3)								-55.36***	-58.76***
								(4.36)	(4.83)
Constant	365.47***	297.69***	304.57***	440.68***	340.17***	351.45***	390.44***	351.64***	362.75***
	(2.51)	(7.17)	(7.42)	(5.13)	(12.62)	(13.49)	(2.53)	(7.52)	(8.02)
Observations	11,576	11,576	11,576	8,018	8,018	8,018	19,594	19,594	19,594
R-squared	0.00	0.21	0.14	0.00	0.35	0.28	0.00	0.40	0.34
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1									

Notes: Author's own calculations using TIMSS SA 2019 grade 9 data. Complex survey methodology accounted for using survey weights.

In model 2, where we regress mathematics achievement on gender, attitudes, and background characteristics, we notice several key points. One is that the raw gender gap in favour of girls is not significant in fee paying schools. Second, once we include background characteristics, the coefficient for female is no longer positive. The results show that once we control for other individual and background characteristics, girls from no fee schools score about 4.28 points *less* than boys, while girls from fee paying schools score about 6.78 points *less* than boys. The implication here is that girls and boys who sat for the TIMSS 2019 assessment differ characteristically and thus just comparing means might not give the complete picture.

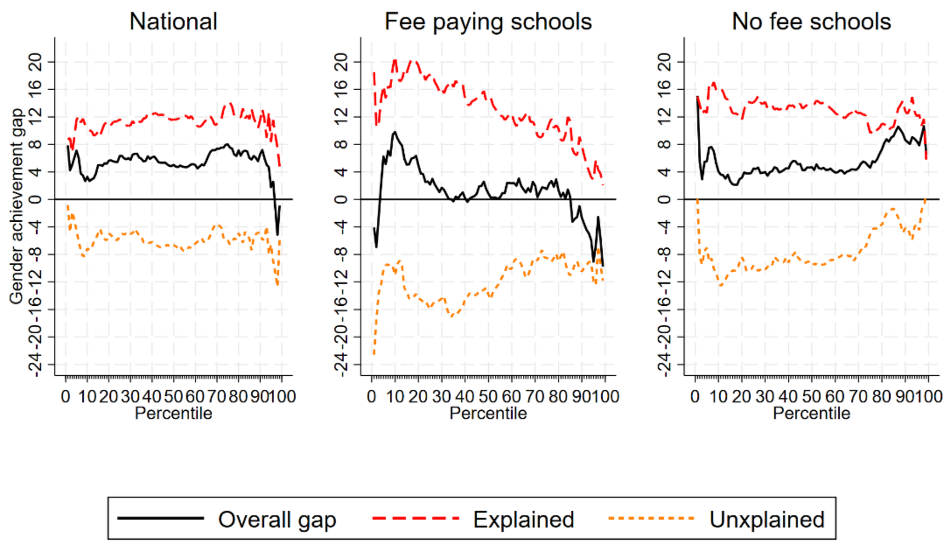
Third, the coefficients on the background characteristics are consistent with the literature. For example, older students achieve lower scores compared to younger students and relative to fee paying schools, no fee schools students achieve lower scores. This is consistent with research that finds that students who stay in school longer, i.e., those that have repeated earlier grades, are weaker than those who move through school faster (Van der Berg et al., 2019). It is well documented that schools in South Africa are highly unequal in terms of resources and that students who attend no fee institutions are disadvantaged (Van der Berg & Gustafsson, 2019; Cai et al., 2016). Comparing model 2 for no fee schools and fee paying schools, results show that for fee paying schools, the effect of parental education on students' achievement increases monotonically with each level of education. For students from no fee schools, however, the effect is not significant for any category. **Always speaking the language of the test at home** improves scores and this explains, in part, why students in no fee schools fair worse than students from fee paying schools who are more likely to speak the language of the test at home.

Reflecting on the literature on age and student achievement in South Africa and the high proportions of boys who are overage, in model 3 we exclude age as an explanatory variable to test the effect on the gender gap. Results show that the gender gap is now again positive but is only significant at the 10% level for students in no fee schools. This result suggests that a large portion of the change in the raw gap from positive to negative is due to a higher share of boys being overage, especially in no fee schools.

3.4 The gender gap across the achievement distribution: DFL decomposition

In this section, we discuss the results on the gender gap across the achievement distribution. The results of the logit models used to calculate the reweighting factors are presented in Table 4 in the appendix. The coefficients show that, relative to **not being confident in mathematics**, girls are less likely to be **very confident** or **somewhat confident in mathematics**. Also, girls are less likely to **like mathematics very much** or **somewhat like mathematics** relative to **not liking mathematics**. On valuing mathematics, girls are more likely to have a **high value for mathematics** relative to **not valuing mathematics**.

Figure 8: Gender gap across the achievement distribution



Source: own calculation from TIMSS 2019. Complex survey methodology accounted for using survey weights.

Figure 8 presents the results of the aggregate decomposition of the gender gap in mathematics achievement using the DFL methodology. The **raw gap** also labelled in the figure as the **'overall gap'** is the gender gap in mathematics before controlling for any individual characteristics. The **explained gap** is the gap due differences in characteristics between boys and girls. The **unexplained gap** is the gap due to unobservable characteristics. For this result, the gender gap was calculated as boy scores subtracted from the girl scores therefore a positive gap is in favour of girls. The **explained gap** is positive and larger than the **raw gap** meaning that the gender gap in mathematics is fully explained by the differences in observable characteristics between boys and girls. What this means is that if boys had the same background and individual characteristics as girls, they would have higher scores in mathematics.

A look at the gender gap across the achievement distribution shows that for students in fee paying schools, girls do better than boys at the bottom of the distribution and then the gap closes towards the middle and widens again at the top of the distribution where boys do better. In contrast, for students in no fee schools, girls do better across the achievement distribution, and, in fact, the girl advantage improves towards the top of the distribution. This result is interesting because while fee paying schools (quintile 4 & 5) display a trend consistent with developing nations where boys do better at the top of the distribution (Doris et al., 2013; Fryer & Levittt, 2010; Penner & Paret, 2008), students from no fee schools (quintile 1-3) display a different trend where girls do better across the distribution. This result for the gender gap in fee paying schools can help us explain why the raw gender gap at the mean was insignificant: The girl advantage is only at the bottom of the distribution. That girls from no fee schools have an advantage across the achievement distribution is not unique to South Africa. Legewie & Diprete (2012) also find a pro-girl gap among lower SES students. The question is why this is the case. One explanation is that there are more overage boys in this group than in the fee paying group.

4 Discussion and Conclusion

This analysis set out to investigate the relationships between attitudes and mathematics achievement for grade 9 boys and girls in South Africa using the TIMSS 2019 assessment. Several interesting results emerged from this analysis. The first is that having confidence in mathematics and valuing mathematics are positively correlated with mathematics achievement for both boys and girls. Important to note is that these results do not imply a causal relationship. Recalling the reciprocal relationship between attitudes towards mathematics and achievement (Marsh & Martin, 2011), it is also likely that students who score highly in mathematics become more confident in their mathematical ability. Students from fee paying schools benefit the most from having confidence in their mathematics abilities. While we find very high returns **to being confident in mathematics**, only a small share of boys and girls are actually **very confident** in mathematics. We note also that girls are overrepresented in the category that report **'not being confident in mathematics'**. The policy implication is that there is need for female role models that have excelled in mathematics and programmes that normalize mathematics as a subject that all students can excel in.

On the gender gap analysis, results show that once individual and background characteristics are controlled for, the gender gap in mathematics achievement actually favours boys. This suggests that mean characteristics fundamentally differ between grade 9 boys and girls and that the gender gap favouring girls is not necessarily because they are doing better but rather because there is a larger share of boys in the overage category resulting in a mismatch in average comparisons. This is a caution against simply comparing means, especially in a high inequality country like South Africa. As detailed by Zuze & Beku (2019), gender equity requires that steps be taken to improve the performance of both boys and girls and to understand why boys are being left behind. Descriptive analysis further showed that female performance is not homogeneous and differs by school type.

The school type which can be seen as a proxy for SES also plays an important role for performance. The high level of inequality between schools is well documented (Reddy et al., 2015; Zuze et al., 2018; Zuze & Beku, 2019; Van der Berg & Gustafsson, 2019). Disadvantaged students need more support in terms of resources and role models if achievement is to be improved further.

A look at the gender gap across the achievement distribution revealed that while the mean is an informative statistic, in an environment with many disparities between schools in the form of access to resources, the mean gap might not reflect the true differences. That is, the boys and girls in our sample are not homogeneous and they differ according to school type, and SES, in turn, also impacts gender differences as well. This means that the measures taken to improve the attitudes towards mathematics and close the gender gap in mathematics achievement might need to be tailored towards the needs of a particular group of students.

For students in no fee schools, girls outperform boys across the distribution and the gap widens as one moves from the bottom to the top of the achievement distribution. While it might seem like the girls are doing better, given that these schools have the lowest achievement scores and a larger share of overage boys, the gender gap in favour of girls is an indication that more needs to be done to enable boys move faster through school and to improve performance for both boys and girls.

For fee paying students, the results show that girls only outperform boys at the bottom of the distribution, but this advantage declines towards the middle of the distribution and disappears at the top of the distribution. This is consistent with literature from developed nations which finds that girls are underrepresented at the top of the mathematics achievement distribution (Pope & Sydnor, 2010; Penner & Paret, 2008). Internationally, the underrepresentation of girls in STEM fields is attributed to the fact that boys outperform girls at the top of the achievement distribution. This is partly because stereotypes about STEM fields give the impression that these fields are very competitive and thus only those at the top of the mathematics achievement distribution should join them. The policy implication here is that to increase the number of girls in STEM there is need to counter these stereotypes and support girls who show interest in the STEM fields.

The relationship between liking mathematics achievement was sometimes negative and other times positive. Moreover, it was significant at times and insignificant at others. The conclusion from this analysis is that the relationship between liking mathematics and achievement requires further investigation. The result is, however, similar to the result by Hofmeyr et al. (2019) who used TIMSS 2015 to analyse exceptional performance of students from disadvantaged schools and reported that mathematics enjoyment was not statistically significant as a determinant of exceptional performance in mathematics. Future analysis will involve a deeper investigation of this relationship

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Appendix

Table 4: Logit regression results for calculating the reweighting factor

	Model 1	Model 2	Model 3
VARIABLES	All	No fee	Fee paying
Logit Model : *Pr(girl=1|X)*			
Very confident	-0.25***	-0.35***	-0.08
	(0.07)	(0.09)	(0.10)
Somewhat confident	-0.19***	-0.19***	-0.13**
	(0.04)	(0.05)	(0.06)
High value	0.35***	0.47***	0.13
	(0.09)	(0.12)	(0.13)
Somewhat values	0.11	0.16	0.03
	(0.09)	(0.12)	(0.13)
Like very much	-0.22***	-0.23***	-0.22**
	(0.06)	(0.07)	(0.09)
Somewhat like	-0.20***	-0.14**	-0.29***
	(0.05)	(0.07)	(0.07)
No fee (quintile1-3)	0.09**		
	(0.04)		
Appropriate age/younger	0.86***	0.92***	0.74***
	(0.03)	(0.04)	(0.06)
University	-0.05	-0.06	-0.17
	(0.06)	(0.08)	(0.11)
Upper secondary	-0.02	-0.02	-0.10
	(0.06)	(0.07)	(0.11)
Other tertiary	-0.10*	-0.12*	-0.16
	(0.06)	(0.07)	(0.11)
Don't know parent educ le	-0.13**	0.02	-0.44***
	(0.06)	(0.07)	(0.11)
Always	0.43***	0.40***	0.72***
	(0.08)	(0.09)	(0.15)
Sometimes	0.38***	0.30***	0.72***
	(0.07)	(0.08)	(0.15)
Constant	-1.45***	-1.48***	-1.37***
	(0.12)	(0.14)	(0.20)
Observations	28,583	16,930	11,653
Robust standard errors in parentheses			
*** p<0.01, ** p<0.05, * p<0.1			

Source: own calculation from TIMSS 2019. Complex survey methodology accounted for using survey weights.

Table 5: TIMSS 2019 attitudes towards mathematics items

Students like learning mathematics Learner Q16 (2019))	
1	I enjoy learning mathematics.
2	I wish I did not have to study mathematics*
3	Mathematics is boring*.
4	I learn many interesting things in mathematics.
5	I like mathematics.
6	I like any schoolwork that involves numbers.
7	I like to solve mathematics problems.
8	I look forward to mathematics class.
9	Mathematics in one of my favourite subjects.
Students confident in mathematics: Learner Q19 (2019)	
1	I usually do well in mathematics.
2	Mathematics is more difficult for me than for many of my classmates*.
3	Mathematics is not one of my strengths*.
4	I learn things quickly in mathematics.
5	Mathematics makes me nervous*.
6	I am good at working out difficult mathematics problems.
7	My teacher tells me I am good at mathematics.
8	Mathematics is harder for me than any other subject*.
9	Mathematics makes me confused*.
Students value mathematics: Learner Q20 (2019)	
1	I think learning mathematics will help me in my daily life.
2	I need mathematics to learn other school subjects.
3	I need to do well in mathematics to get into the university of my choice.
4	I need to do well in mathematics to get the job I want.
5	I would like a job that involves using mathematics.
6	It is important to learn about mathematics to get ahead in the world.
7	Learning mathematics will give me more job opportunities when I am an adult.
8	My parents think it is important that I do well in mathematics.
9	It is important to do well in mathematics.

*Source: TIMSS 2019 learner questionnaires. *Reversed*

Table 6: Regression results using continuous scales of attitudes towards mathematics

	No fee schools			Fee paying schools			National	
Dependent variable =mathematics achievement								
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**	**Model 7**	**Model 8**
VARIABLES	**Girls**	**Boys**	**Combined**	**Girls**	**Boys**	**Combined**		**without age**
Female			-3.92**			-4.70**	-4.37***	3.51**
			(1.92)			(2.19)	(1.54)	(1.48)
Confidence	11.48***	9.75***	10.71***	27.88***	31.18***	29.38***	18.61***	20.33***
	(1.49)	(1.63)	(1.18)	(1.73)	(1.71)	(1.20)	(0.96)	(0.95)
Value	6.77***	10.41***	8.57***	-1.53	4.55**	1.40	6.26***	7.78***
	(1.51)	(1.16)	(1.03)	(2.21)	(2.09)	(1.84)	(1.04)	(1.11)
Like	3.93***	3.51**	3.78***	-8.93***	-13.85***	-11.25***	-2.22*	-2.96**
	(1.35)	(1.72)	(1.23)	(1.79)	(2.39)	(1.65)	(1.15)	(1.21)
	Student age dummy (0=above 15.5 years)							
Appropriate age/younger	35.08***	34.54***	34.82***	47.86***	48.52***	48.62***	40.28***	
	(2.43)	(2.88)	(2.24)	(3.28)	(3.60)	(2.44)	(1.72)	
	Parent highest level of education (base=primary or lower)							
Parent university	1.59	9.62*	5.79	35.31***	35.14***	35.39***	15.05***	22.30***
	(5.96)	(5.80)	(5.13)	(5.96)	(7.82)	(4.13)	(3.41)	(3.76)
Parent upper sec sch	-0.80	2.00	0.70	8.32	10.41	9.13**	1.18	4.75*
	(3.54)	(3.97)	(2.51)	(5.86)	(6.72)	(4.33)	(2.29)	(2.45)
Parent other tertiary	0.53	0.58	0.75	21.67***	22.31***	22.15***	4.98**	10.73***
	(3.77)	(4.86)	(3.03)	(5.29)	(6.66)	(3.90)	(2.53)	(2.70)
Don't know parent educ	1.27	6.91*	4.17	25.98***	35.47***	30.83***	11.91***	17.05***
	(4.37)	(3.99)	(2.99)	(6.69)	(6.72)	(4.46)	(2.68)	(2.91)
	Language of test spoken at home(base=never)							
Always	29.65***	16.27***	22.86***	52.08***	39.22***	44.06***	37.33***	41.60***
	(6.67)	(5.91)	(4.88)	(13.58)	(9.61)	(9.52)	(4.86)	(5.34)
Sometimes	14.70***	8.93**	11.45***	15.45	-0.92	5.42	10.88***	13.55***
	(5.56)	(4.18)	(3.62)	(10.48)	(6.63)	(6.21)	(3.36)	(3.65)
	School type							
No fee (quintile1-3)							-56.10***	-59.60***
							(4.46)	(4.95)
Constant	329.80***	337.54***	335.69***	349.65***	364.47***	360.86***	384.01***	398.90***
	(8.30)	(5.75)	(5.03)	(12.91)	(11.64)	(10.32)	(6.71)	(7.37)
Observations	6,222	5,354	11,576	4,383	3,635	8,018	19,594	19,594
R-squared	0.18	0.21	0.19	0.32	0.39	0.35	0.39	0.33
Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1								

Source: own calculation from TIMSS 2019. Complex survey methodology accounted for using survey weights.