Performance Beyond Expectations: Academic Resilience in South Africa

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PERFORMANCE BEYOND EXPECTATIONS: ACADEMIC RESILIENCE IN SOUTH AFRICA

Heleen Hofmeyr[1]

Abstract

Socio-economic status and educational outcomes are strongly linked across countries and education systems. However, a growing body of research documents the existence of students from disadvantaged socio-economic backgrounds who manage to achieve exceptional academic results. The present study, located in the South African context, uses data from the Progress In Reading Literacy Study (PIRLS) 2016 and the Trends in Mathematics and Science Study (TIMSS) 2015 to explore the factors at the individual and institutional level that are associated with exceptional academic performance in the face of socio-economic disadvantage The first research objective is to identify academically resilient students in the PIRLS 2016 and TIMSS 2015 datasets. I consider how these students are distributed across schools of differing quality, and how they perform relative to the median student in their school. My second research objective explores the ways in which these students differ systematically from their lower-achieving peers. The analytical strategy employed aims to identify factors at the level of the individual and the school that are associated with unusually high results in the absence of crucial inputs such as an affluent home background. Contributing to a growing body of literature that finds associations between student attitudes and academic achievement using large-scale assessment data, I find that the probability of exceptional reading performance in Grade 4 and mathematics performance in Grade 9 in South Africa is also strongly related to these variables. Like a number of existing studies, I find that the constructs aimed at capturing self-confidence, in particular, are strongly associated with the probability of academic resilience in both PIRLS and TIMSS.

1. Introduction

Socio-economic status (SES) and educational outcomes are strongly linked across countries and education systems. However, a growing body of research documents the existence of students from disadvantaged socio-economic backgrounds who manage to achieve exceptional academic results. The literature on exceptional academic performance in high-poverty contexts is primarily concerned with identifying the individual and institutional factors that underpin this ability to achieve good academic results despite adverse socio-economic conditions. Given that an estimated 390 million poor children globally are at risk of achieving minimum proficiencies in learning (UNICEF, 2018) it is important to explore what enables a small minority of poor students to overcome the risk factors associated with poverty and achieve good academic results.

The present study, located in the South African context, uses data from the Progress In Reading Literacy Study (PIRLS) 2016 and the Trends in Mathematics and Science Study (TIMSS) 2015 to explore the factors at the individual and institutional level that are associated with exceptional academic performance in the face of socio-economic disadvantage. The South African context is particularly suited to studying exceptional performance among socio-economically disadvantaged students for three reasons. First, the country's average performance was among the worst in PIRLS 2016 (Foy et

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al., 2016) and TIMSS 2015 (Mullis *et al.*, 2015). Second, South Africa's PIRLS and TIMSS scores were among the most unequal in the world, with SES being a major determinant of achievement. Lastly, even though South Africa is classified as an upper-middle-income country, income inequality is so pronounced that children on the lower end of the income distribution face severely under-resourced home and school environments that are akin to those faced by children in some of the poorest countries in the world (Case and Deaton, 2005). For these reasons, studying academic resilience in South Africa may provide crucial insights into the factors that are associated with academic success in contexts of poor average performance and resource constraints both at the home and school level.

The first research objective is to identify academically resilient students in the PIRLS 2016 and TIMSS 2015 datasets. I consider how these students are distributed across schools of differing quality, and how they perform relative to the median student in their school. My second research objective explores the ways in which these students differ systematically from their lower-achieving peers. The analytical strategy employed aims to identify factors at the level of the individual and the school that are associated with unusually high results in the absence of crucial inputs such as an affluent home background.

Contributing to a growing body of literature that finds associations between student attitudes and academic achievement using large-scale assessment data, I find that the probability of exceptional reading performance in Grade 4 and mathematics performance in Grade 9 in South Africa is also strongly related to these variables. Like a number of existing studies, I find that the constructs aimed at capturing self-confidence, in particular, are strongly associated with the probability of academic resilience in both PIRLS and TIMSS.

2. Student attitudes and achievement: Existing evidence

Student attitudes

Student attitudes are a well-established psychological construct in the education literature as they play an important role in moderating students' behaviour and effort in school (Petscher, 2010). Student attitudes have received increasing attention in education research in recent years because unlike students' cognitive abilities or home background, student attitudes are thought to be amenable to policy change (Singh, Granville and Dika, 2002). Despite the intuitive appeal of the notion that student attitudes matter for achievement, empirical studies of the relationship between student attitudes and academic achievement have yielded inconsistent results. This may be partly due to a lack of definitional clarity around the concept of student attitudes and the resultant catalogue of diverse psychological constructs that have been included under this umbrella. To complicate matters further, the association between student attitudes and achievement has been a subject of interest for researchers in psychology, sociology, education, and economics, and there is no consensus across – or within - these disciplines regarding what constitutes student attitudes, or how best to measure them. I therefore limit my review of the literature to studies that include measures of the specific constructs that are measured in the PIRLS and TIMSS student background questionnaires and are measured in a similar way, that is, as self-report questionnaire items.

Engagement in reading and mathematics lessons is one dimension of student attitudes toward learning that has received increasing attention as a determinant of achievement in these subjects in recent years. Engagement is thought to influence achievement as a mediator of students' motivation and attention in these subjects (Tse and Xiao, 2014). A number of studies find evidence of a positive association between self-reported engagement in reading lessons and reading achievement (Connell, Spencer and Aber, 1994; Twist, Schagen and Hodgson, 2007; Tse and Xiao, 2014; Vera, Valenzuela and Sotomayor, 2015a), as well as engagement in mathematics lessons and mathematics achievement

(Connell, Spencer and Aber, 1994; Borman and Rachuba, 2001; Ma and Xu, 2004; Ma and Kishor, 2006; House and Telese, 2016).

Enjoyment of reading and mathematics is another aspect of attitudes toward learning that is considered important for achievement in these subjects. Students who enjoy reading spend more time reading and have better concentration when reading (Malanchini *et al.*, 2017), which may account for the positive association between reading enjoyment and achievement found by a number of authors (see for example Wang and Guthrie, 2004; Twist, Schagen and Hodgson, 2007; Mol and Jolles, 2014; Tse and Xiao, 2014; McGeown *et al.*, 2015; and Malanchini *et al.*, 2017). Similarly, the positive association between enjoyment of mathematics and achievement (Reynolds and Walberg, 1992; Ma, 1997; Singh, Granville and Dika, 2002; Ma and Xu, 2004; Ma and Kishor, 2006; Zuze *et al.*, 2017) is often ascribed to increased involvement and attention during mathematics lessons as well as more time spent on mathematics (Singh, Granville and Dika, 2002).

Self-reported confidence in a subject is also thought to impact positively on achievement through its relationship with effort, where confidence is associated with a higher perceived payoff of exerting effort in a particular subject (Petscher, 2010). It is well-established in the education literature that self-reported confidence in reading is positively associated with reading performance (House, 2003; Twist, Schagen and Hodgson, 2007; Park, 2011; Van de Gaer *et al.*, 2012; Ibourk, 2013; Retelsdorf, Köller and Möller, 2014; Tse and Xiao, 2014; McGeown *et al.*, 2015; Francis *et al.*, 2017), and that the same relationship exists between confidence in mathematics and mathematics achievement (Borman and Overman, 2004; Azina and Halimah, 2012; Abu-Hilal *et al.*, 2013; Miscevic-Kadijevic, 2015; House and Telese, 2016; West *et al.*, 2016). Notably, the OECD study "Against the Odds: Disadvantaged students Who Succeed in School" showed that even when augmenting academic achievement models to include individual student characteristics *and* school-level factors, self-confidence in science remains the most consistent predictor of exceptional science achievement among disadvantaged students in almost all countries participating in PISA (OECD, 2011).

In addition to student attitudes toward specific subjects, student perceived school safety has also received attention as an important determinant of achievement, although less so than subject-specific attitudes toward school. Two constructs measured in the PIRLS and TIMSS student background questionnaires are of relevance here, namely sense of school belonging (measured with questions like "I feel safe at this school") and measures of the frequency of student bullying. There is a dearth of empirical evidence of the relationship between self-reported sense of belonging in school and achievement in reading and mathematics specifically, with the small number of existing studies on self-reported school belonging examining the relationship between this construct and academic achievement more generally. These studies find a positive association between students' sense of belonging at school and achievement (Sari, 2012; Topçu, Erbilgin and Arikan, 2016; Thomson *et al.*, 2017). Bullying is more widely studied as a determinant of achievement, with existing studies finding evidence of a negative association with the frequency of student bullying and academic achievement (Ponzo, 2012; Cosgrove and Creaven, 2013; Tse and Xiao, 2014; Sandoval-Hernandez and Bialowoski, 2016; Topçu, Erbilgin and Arikan, 2016; Thomson *et al.*, 2017; Zuze *et al.*, 2017).

Given these findings of the importance of student attitudes for academic achievement, the analysis in this paper seeks to determine which of these attitudes matter for achievement specifically among students from low socio-economic backgrounds in South Africa. Specifically, the analytical strategy aims to identify whether the student attitudes measured in the PIRLS and TIMSS student background questionnaires predict performance that exceeds expectations among socio-economically disadvantaged students.

3. Data

I include both PIRLS and TIMSS datasets in my analysis since information on academic performance in different subjects from students in different grades allows me to investigate whether the same factors are associated with exceptional performance across literacy and mathematics, and for students in different grades.

PIRLS Literacy 2016

PIRLS is an international large-scale literacy assessment conducted by the International Association of the Evaluation of Educational Achievement (IEA). PIRLS Literacy 2016 was administered by the Centre for Evaluation and Assessment (CEA) at the University of Pretoria. In addition to student assessment data, PIRLS collected contextual information from students, teachers, and school principals (Foy *et al.*, 2016). The school language policy of South Africa is currently implemented in such a way that the language of learning and teaching (LOLT) for the vast majority of students is their home language in grades 1-3, and from grade 4 there is a LOLT switch to English for the remaining school years (Spaull and Kotze, 2015). This means by grade 4 the majority of South African students would have had limited exposure to English, and consequently PIRLS was administered in all of South Africa's 11 official languages. PIRLS 2016 employed a two-stage stratified cluster sampling design so that a nationally representative sample of schools was chosen according to province and the school's language of instruction in the foundation phase (Howie *et al.*, 2017). Within the sampled schools, classes were randomly selected for participation. Sampled classes thus constitute the second-stage sampling units. All students in sampled classes present on the day of the assessment participated in the assessments. In 2016 the realised PIRLS sample consisted of 12,810 grade 4 students from 293 schools across South Africa. Unfortunately, there are significant proportions of missing data in PIRLS, especially in the home background questionnaire items. Since home background information is paramount in operationalising exceptional performance, missing data could not simply be dealt with using listwise deletion. Instead, a combination of different imputation methods and listwise deletion was used[2]. After imputation, the PIRLS sample consists of 12,762 students. When identifying exceptional performers and exploring the factors associated with exceptional performance, I further limit the analysis to the poorest 75% of students in the PIRLS sample[3]. This results in a PIRLS sub-sample of 9,572 students.

TIMSS 2015

TIMSS 2015 is also conducted by the IEA and was administered in South Africa by the Human Sciences Research Council (HSRC). TIMSS is only administered in English and Afrikaans, as students are expected to have fully made the switch to one of these languages by grade 9. Although TIMSS consists of both mathematics and science assessments, I consider only mathematics TIMSS scores in my analysis of exceptional performance. TIMSS collects the same contextual information from students, parents, teachers and principal as PIRLS (Mullis *et al.*, 2015). Students were sampled using the same two-stage stratified cluster sampling design as employed in PIRLS. The TIMSS 2015 realised sample consists of 12,514 grade 9 students[4] from 292 schools. The same missing data concerns present in PIRLS plague the TIMSS data, thus the same combination of listwise deletion and imputation methods was used to

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[2] See the Appendix for a more detailed description of the imputation methods employed.

[3] See Section 5 for a description of the operationalization of SES in this paper.

[4] Even though the TIMSS assessment is administered in grade 8 in most countries, participating countries can choose to administer the assessment in grade 9 if they suspect the assessment will be too difficult for Grade 8 students (Mullis *et al.*, 2015).

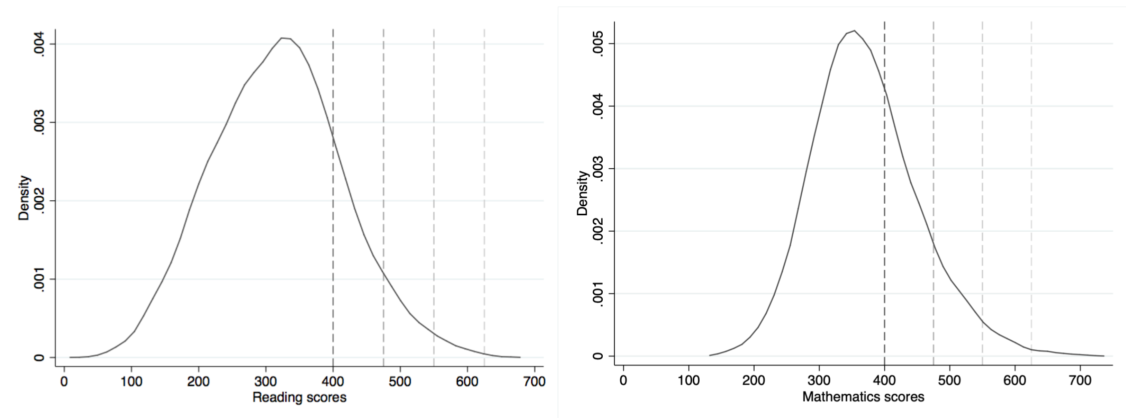
deal with missing information[5]. After imputation, the TIMSS 2015 sample consists of 12,419 students. When limiting the TIMSS sample to the poorest 75% of students for the analysis of exceptional performers, the resultant sub-sample consists of 9,316 students.

4. South Africa's overall performance in PIRLS and TIMSS

South Africa's poor performance in PIRLS and TIMSS is well-documented (see for example Mullis *et al.*, 2015; Howie *et al.*, 2016). Figure 1 shows the distribution of reading scores for the full PIRLS sample of 12,762 students, and the distribution of mathematics scores for the full TIMSS sample of 12,419. The dotted lines represent PIRLS and TIMSS international benchmarks, at 400, 475, 550 and 625 representing the low, intermediate, high and advanced benchmarks, respectively.

The figure shows that the majority of participating students in PIRLS (79.8%) did not reach the low international benchmark (10,183 students). Only 774 students (6.1%) reached the intermediate international benchmark, 164 students (1.3%) reached the high international benchmark, and only 18 students (0.05%) reached the advanced international benchmark. The mean reading score for the country is 318, making South Africa the worst performer out of the 50 countries participating in PIRLS (Foy et al., 2016). The picture is similar for South Africa's performance in the TIMSS mathematics assessment: 8,334 participating students (67.1%) did not reach the low international benchmark, and only 1,328 (10.7%) reached the intermediate international benchmark. 324 students (2.6%) reached the high international benchmark, and 61 students (0.5%) reached the advanced international benchmark of 625 points. South Africa achieved the second-lowest mathematics score in TIMSS 2015, at 372 points (Mullis *et al.*, 2015).

Figure 1: Distribution of South Africa's reading (Grade 4) and mathematics (Grade 9) scores



Notes: Kernel density distribution using epanechnikov; Sources: PIRLS 2016 and TIMSS 2015

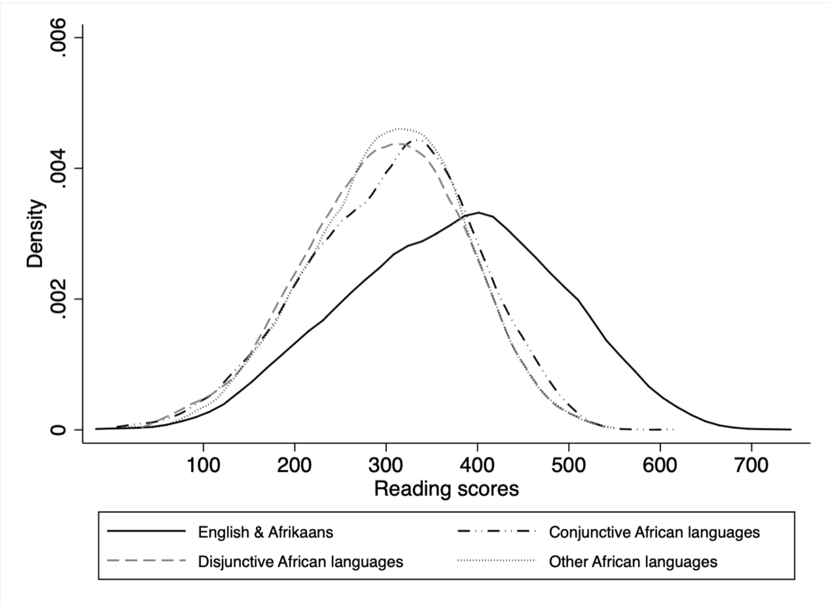
It is a remnant of the apartheid schooling system that South Africa's inequality in reading scores at the primary school level is strongly related to language of instruction. The apartheid education system consisted of multiple racially defined departments of education, and education policies deliberately aimed to deliver inferior quality education to black students compared to white students (Spaull, 2013; Van der Berg, 2008). Most schools with African languages as the LOLT would have been part of the Bantu education department during apartheid, and many of these schools still suffer the inertia of decades of limited resources and poor management (Van der Berg et al, 2011; Spaull, 2015). In this sense, LOLT can be considered a proxy for school disadvantage. The impact of this on school quality can be seen in Figure 2, which shows distributions of PIRLS reading scores by the language the test

[5] See the Appendix for a more detailed description of the imputation methods employed.

was written in. African languages were grouped according to their orthography, namely conjunctive (isiXhosa, Siswati, isiNdebele, isiZulu) and disjunctive (Sepedi, Setswana, Sesotho) orthographies (Spaull, Pretorius and Mohohlwane, 2018). Tshivenda and Xitsonga are classified as “other” African languages since they are not part of either of these language families.

It is clear from the figure that students writing the test in an African language performed much worse in PIRLS than students writing in English or Afrikaans. Given these different performance distributions by LOLT, and the fact that a school’s LOLT overlaps with contextual factors such as neighbourhood poverty and school resources, we might expect differences in the factors associated with exceptional performance based on the LOLT of the school. This question is explored in Section 6.

Figure 2: Distribution of PIRLS reading scores by test language (Grade 4)

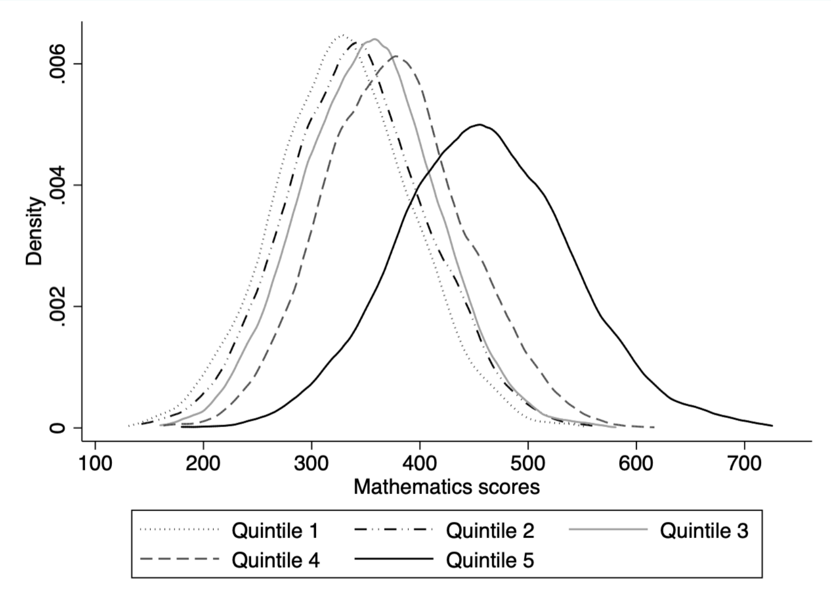


Notes: Kernel density distribution using epanechnikov, bandwidth = 13.4619; Source: PIRLS 2016

The same inequality in schooling outcomes exists at the high school level in South Africa, however in TIMSS language of instruction cannot be used as a proxy for apartheid-era education departments. School disadvantage in TIMSS is therefore measured as the SES of the school, categorised as five school quintiles[6], with the poorest 80% of students being in schools categorised as Quintile 1-4, and the wealthiest 20% of students attending Quintile 5 schools. Figure 3 shows the distribution of TIMSS mathematics scores by school quintile, and illustrates that a similar bimodal distribution exists, whereby the distribution of mathematics scores in Quintile 5 schools lies clearly to the right of mathematics scores in the bottom four school quintiles. Once again, given these differences in overall mathematics scores by school quintile, we might expect differences in the factors that are associated with exceptional performance in Quintile 1-4 schools compared to Quintile 5 schools. This is explored in Section 7.

[6] School quintiles were constructed using TIMSS data on student SES. School SES is measured as the mean student SES at the school level.

Figure 3: Distribution of TIMSS mathematics scores by school quintile (Grade 9)



Notes: Kernel density distribution using epanechnikov, bandwidth = 11.8405; Source: TIMSS 2015

5. Identifying exceptional performers

I define exceptional performance as academic achievement that exceeds socio-demographic expectations. Following Borman and Overman (2004), I use characteristics of students' home environments to define the "expectations" relative to which I compare students' performance in order to identify exceptional performers. This decision was informed by two considerations. First, given the strong association between student SES and academic achievement (internationally and especially in South Africa), I use SES and other home-background factors that may proxy for wealth to set expectations for academic achievement. Secondly, by using home-level variables to define exceptional performance (the first stage of the analytical strategy), I can model the probability of being an exceptional performer on individual- and school-level factors in the second stage of my analytical strategy. This is advantageous since student attitudes and school characteristics are more amenable to changes in policy and practice than home background factors. This allows me to identify factors that are associated with better academic achievement in low SES contexts that are more amenable to change through policy or practice.

To operationalise this definition, it is necessary to first obtain a predicted test score based on socio-economic background factors. This is done by regressing reading scores on student SES for the PIRLS sub-sample and mathematics scores on SES for the TIMSS sub-sample as per the following equation:

$$Y_{is} = \beta_0 + \beta_1 SES_{is} + \varepsilon_{is} \qquad (1)$$

Here Y_{is} represents either the reading or mathematics score of the ith student in school s. SES_{is} is a vector of the students' home background characteristics and its square, which is an index derived from both parents' education, an index of home possessions, and a binary variable indicating whether the student attends a school in a township or remote rural area or not[7] using principal components analysis (PCA). The residuals of the equation, ε_{is} (the difference between the actual value of Y and the predicted value of Y), represent the part of an individual student's reading or mathematics score that cannot be explained by these socio-economic factors.

To identify students whose test scores exceed expectations, it is necessary to specify some level of residual test performance above the predicted score as per equation (1). I set this level at 1.5 standard deviations above the mean residual reading score for the whole sample. To limit the sample of exceptional performers to students from poor socio-economic backgrounds, I add the further constraint that exceptional performers must be drawn from the bottom 75% of the asset index distributions in the PIRLS and TIMSS samples, respectively. Exceptional performers in the succeeding analysis are therefore students with asset index scores at or below the 75th percentile whose test scores lie 1.5 standard deviations above the mean, after accounting for the socio-economic background factors listed above.

Using this definition, I identify 553 exceptional performers in the PIRLS sample of 12,762, that is, 4.33% of the total sample of students. These students are distributed across 191 schools, that is, 71.27% of schools in the sample. Similarly, this operationalization of exceptional performance yields 555 exceptional performers in the TIMSS sample of 12,419 (4.47%), also distributed across 191 schools (69.0% of schools in the sample). It must be noted that, as is the case with any self-reported measures of SES, the SES is measured with error. The measurement error may be particularly large in the South African PIRLS and TIMSS data given that many missing values in the student background questionnaires had to be imputed. A limitation of this paper is therefore that some exceptional performers may be misidentified.

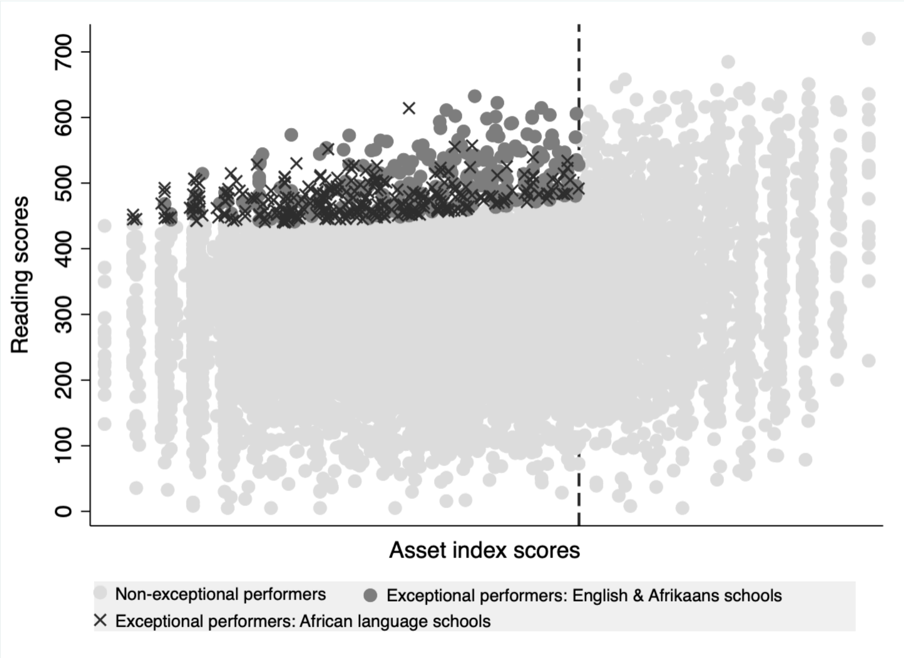
Figure 4 andFigure 5Figure 5 provide graphical representations of the reading and mathematics scores, plotted against asset index scores, for exceptional performers in PIRLS and TIMSS, respectively. Exceptional performers in African language schools and Quintile 1-4 schools in PIRLS and TIMSS, respectively, are represented by the crosses. Just over half (53.16%) of the exceptional performers in PIRLS attend African language schools (294 students), and 61.96% of exceptional performers in TIMSS (347 students) are drawn from Quintile 1-4 schools. The dotted lines represent the 75th percentile on the asset index in each sample, that is, the cut-off point that is used to limit both samples in the multivariate analysis.

The figures show that exceptional performers in both PIRLS and TIMSS achieved test scores above the low international benchmark (400 points). In PIRLS, reaching the low international benchmark constitutes having basic reading skills, in other words students could retrieve explicitly stated information and make straightforward inferences when reading the less difficult texts (Mullis *et al.*, 2017a). In TIMSS, reaching the low international benchmark means students have an elementary knowledge of whole numbers and basic graphs (Mullis *et al.*, 2015). The median reading score among exceptional performers in PIRLS is 482 points, that is, above the intermediate international benchmark of 475 points. At this level of reading proficiency, students are able to integrate and interpret story events and information, in addition to making basic inferences (Mullis *et al.*, 2017a). At 484 points, the median mathematics score among exceptional performers in TIMSS is also above the intermediate

[7] PIRLS does not collect direct information about whether students live in an urban or rural area. Given that urban/rural is an important sociodemographic divide in South Africa, it was decided to include information about the location of the school in the SES measure. Even though the school location variable captures information at the school level, and not the home, 70-80% of South African students in rural and township schools walk to school (Grant, 2014), indicating that they live in the same geographic area as their schools. In this sense school location can be considered a crude proxy for the type of geographic area of students' homes.

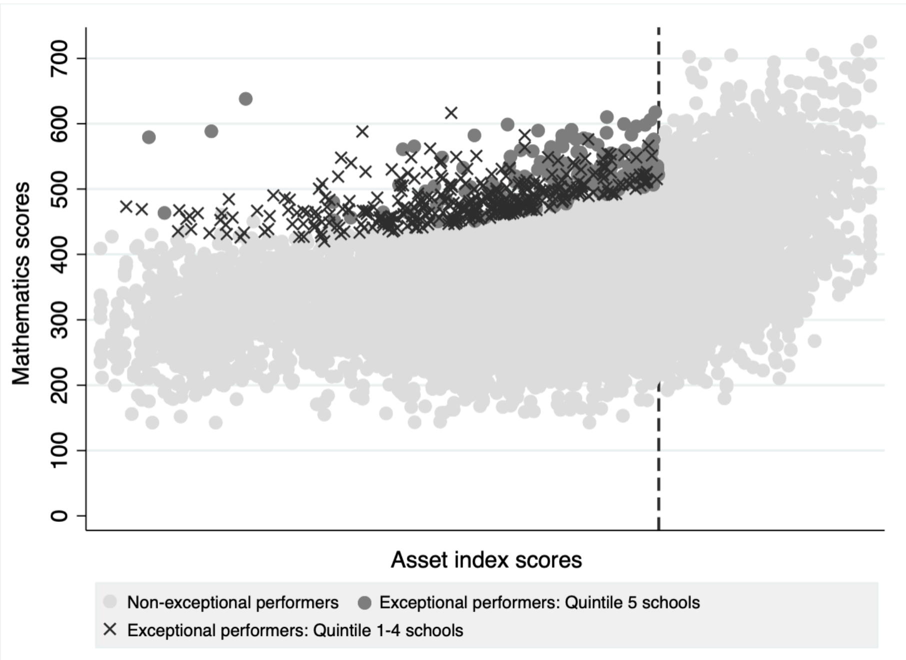
international benchmark. At this level of achievement, students “can apply basic mathematical knowledge in a variety of situations” (Mullis *et al.*, 2015).

Figure 4: Identifying exceptional performers in PIRLS 2016 (Grade 4)



Notes: The dotted vertical line represents the 75th percentile on the asset index. Source: PIRLS 2016.

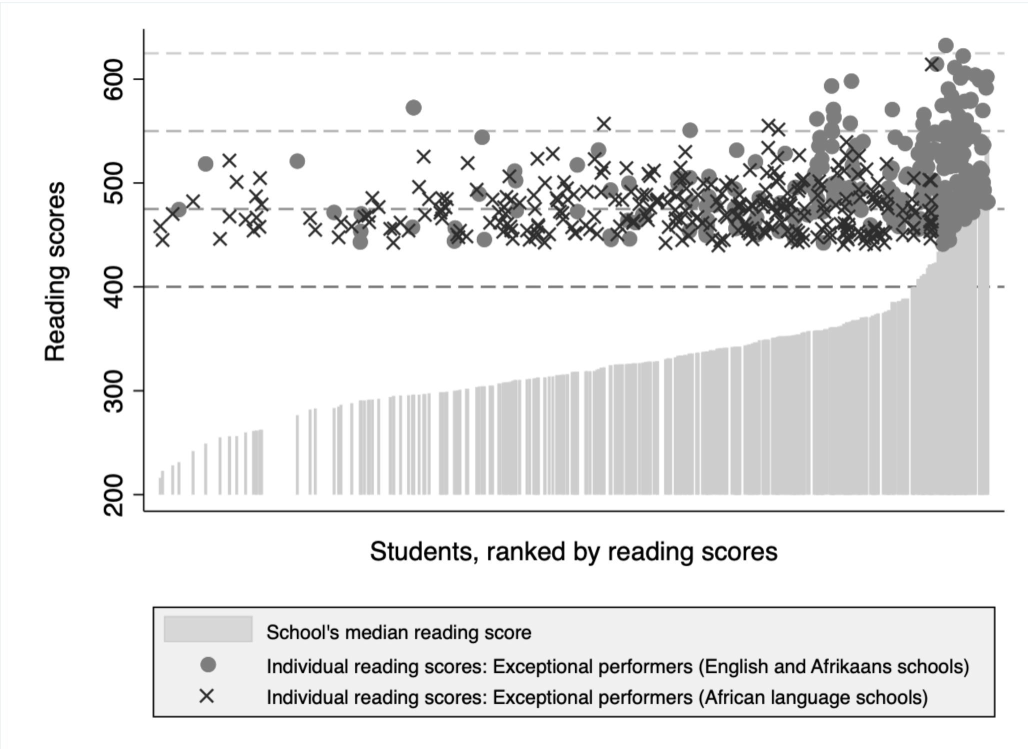
Figure 5: Identifying exceptional performers in TIMSS 2015 (Grade 9)



Notes: The dotted vertical line represents the 75th percentile on the asset index. Source: TIMSS 2015.

Figure 6 provides a graphical representation of the reading scores of exceptional performers in PIRLS, relative to the median reading score in their school. The crosses represent the reading scores of exceptional performers in African language schools, while the dark grey dots represent the reading scores of exceptional performers in English and Afrikaans schools. It is clear from the figures that there are exceptional performers even in schools with very poor average performance. In addition, exceptional performers in worse performing schools far outperformed the median student in their school, while the gap between exceptional performers' test scores and their school's median test score is much smaller for exceptional performers drawn from better performing schools. Indeed, Figure 6 shows that there are a number of exceptional performers in better performing schools whose reading scores were below that of the median student in their school[8]. This points to the important result that exceptional performers, as operationalized here, are not simply the top achievers in their schools. Rather, exceptional performers are those students whose reading scores exceed expectations, given their SES. Figure 7shows similar patterns in the mathematics achievement of exceptional performers in TIMSS.

Figure 6: Distribution of exceptional performers by school (PIRLS 2016)



[8] There are 17 exceptional performers in PIRLS (3.07%) and 36 exceptional performers in TIMSS (6.49%) whose assessment scores are equal to or below the median score of their school.

Figure 7: Distribution of exceptional performers by school (TIMSS 2015)

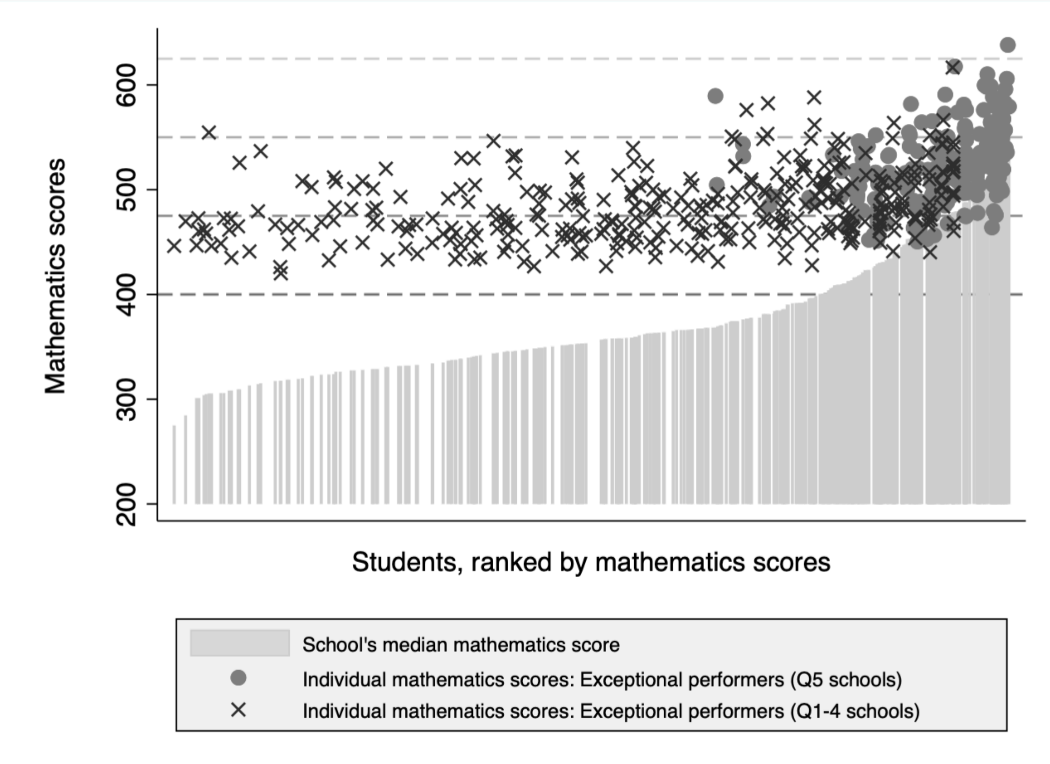


Table 1 shows descriptive differences in individual and school characteristics between exceptional and non-exceptional performers in the PIRLS and TIMSS data, respectively. The results in the table show that exceptional performers exhibit very different individual characteristics compared to their peers, in both the PIRLS and TIMSS sub-samples. Exceptional performers in PIRLS are younger, more likely to be girls, absent less often, experience bullying less often, have a higher sense of school belonging, report being more engaged in their reading lessons and have more confidence in reading than their peers. The only counterintuitive result in Table 1 is the lower score on the reading for enjoyment index for exceptional performers, relative to their peers. Possible reasons for this result are explored in section 7.

The schools attended by exceptional versus non-exceptional performers in PIRLS also differ significantly along a number of dimensions. In terms of LOLT, African language exceptional performers are underrepresented relative to the proportion of students in African language schools in the PIRLS sub-sample: Only 53% of exceptional performers are drawn from African language schools, while this proportion is 81% for the wider PIRLS sample. Schools producing exceptional performers appear to have more physical resources than schools without exceptional performers: These schools are more likely to have a library and at least one computer. Interestingly, exceptional performers are not significantly more likely to be taught by teachers who have at least a Bachelor's degree[9]. In general, the proportions of grade 4 language teachers who have at least a Bachelor's degree in this sub-sample of PIRLS is very low, at 35% for teachers of students in the comparison group, and an even lower 33%

[9] It must be noted that having a Bachelor's degree is age-related among South African teachers, since the qualifications framework for the teaching profession changed in 1996 so that a Bachelor's degree became a requirement for teachers entering the profession (Sayed, 2002).

for teachers of exceptional performers. School composition indicates the average student SES, which is the mean asset index[10] score at the school level. According to this measure, exceptional performers attend schools whose school bodies are wealthier, on average, than schools who did not produce any exceptional performers.

As is the case for PIRLS, exceptional performers in TIMSS are also younger than the comparison group of students. However, the difference in mean age between exceptional performers and the comparison group is much larger than in PIRLS. Exceptional performers in TIMSS are around 9 months younger than the comparison group, on average, while exceptional performers in PIRLS are only about 3 months younger than their peers in the comparison group. The larger age gap observed for the grade 9 TIMSS sample may be attributed to the cumulative effects of repetition over time, where overage learners are more prevalent in later grades (Branson, Hofmeyr and Lam, 2014; Van Wyk, 2015).

Exceptional performers in PIRLS are also absent less often, experience bullying less often, have a higher sense of school belonging, report being more engaged in their mathematics lessons, and have more confidence in mathematics, compared to their peers. Unlike exceptional performers in PIRLS who do not report enjoying reading more than their counterparts, those in TIMSS report enjoying mathematics more than their peers, a more intuitive result. also shows that girls are no more likely to be exceptional performers than boys. This is not altogether surprising since there were no significant gender differences in mathematics achievement for age appropriate students in the full South African TIMSS sample in 2015 (Zuze *et al.*, 2017).

The schools attended by exceptional performers also differ from the rest of the schools in the TIMSS sub-sample. These schools are less likely to be Quintile 1-4 schools, and more likely to have at least one computer. Interestingly, schools producing exceptional performers in TIMSS are not significantly more likely to have a library, and, as is the case in PIRLS, exceptional performers in TIMSS are not more likely to be taught by a teacher with at least a Bachelor's degree than non-exceptional performers.

[10] See Section 5 for a description of the construction of this index.

Table 1: Descriptive statistics: Exceptional versus non-exceptional performers

	PIRLS 2016 (Grade 4)		TIMSS 2015 (Grade 9)	
	Exceptional performers	Non-exceptional performers	Exceptional performers	Non-exceptional performers
Individual characteristics				
Female	0.71*** (0.02)	0.49 (0.01)	0.54 (0.02)	0.53 (0.01)
Age	10.00*** (0.03)	10.23 (0.01)	14.68*** (0.04)	15.45 (0.01)
Often absent	1.75*** (0.05)	2.26 (0.01)	1.28*** (0.03)	1.72 (0.01)
Frequency with which test language is spoken at home	0.87 (0.01)	0.90 (0.00)	0.43*** (0.02)	0.28 (0.00)
School safety & attitude indices				
Bullying index	2.02*** (0.03)	2.30 (0.01)	1.68*** (0.03)	1.85 (0.01)
School belonging index	2.60*** (0.02)	2.47 (0.01)	2.62*** (0.02)	2.55 (0.01)
Enjoyment index	1.31*** (0.02)	1.83 (0.02)	3.56*** (0.03)	3.29 (0.01)
Engagement index	2.76*** (0.02)	2.51 (0.01)	2.57*** (0.03)	2.53 (0.01)
Confidence index	2.25*** (0.03)	1.64 (0.01)	1.99*** (0.03)	1.54 (0.01)
School characteristics				
African language school (PIRLS) / Quintile 1-4 school (TIMSS)	0.53*** (0.02)	0.81 (0.01)	0.64*** (0.02)	0.92 0.00
School has a library	0.40*** (0.02)	0.29 (0.00)	0.43 (0.02)	0.40 (0.01)
School has at least one computer	0.37*** (0.02)	0.24 (0.00)	0.57*** (0.02)	0.41 (0.01)
Teacher has at least a Bachelor's degree	0.33 (0.02)	0.35 (0.01)	0.96 (0.01)	0.96 (0.00)
SES of the school body	0.63 (0.05)	-0.04*** (0.01)		
Mean test scores	490*** (1.58)	297 (0.90)	498*** (2.44)	346 (3.05)
School median	369*** (2.62)	308 (0.52)	417*** (2.43)	351 (3.22)
Observations	553	9019	555	8761

*Notes: Standard errors are in parentheses. Statistically significant at the following levels: *p<0.1, **p<0.05, ***p<0.01.*

6. Differences between exceptional performers by school type

Given the achievement differences in PIRLS between English and Afrikaans schools compared to African language schools highlighted in Section 4, we might expect exceptional performers to look very different, depending on whether they attend African language schools or English and Afrikaans schools. Table 2 shows differences in mean scores on a number of individual characteristics between exceptional performers who wrote the test in an African language and exceptional performers who wrote the test in English or Afrikaans. The results in the table suggest that there are indeed important differences between these two groups of exceptional performers. Firstly, the mean reading score of exceptional performers in English and Afrikaans schools is higher than that of exceptional performers in African language schools (546 compared with 498). However, it is important to keep in mind that the median reading performance of African language schools producing exceptional performers is almost a whole standard deviation (100 points) lower than the median reading scores of English and Afrikaans schools producing outliers, at 342 and 434, respectively.

This points to the important finding that differences in exceptional performers in African language schools' reading scores and the median reading score of their class are much larger than differences in reading scores between exceptional performers in English and Afrikaans schools and their school's median reading score. On average, exceptional performers in African language schools achieved reading scores 138 points higher than the median performer in their school, whereas exceptional performers in English and Afrikaans schools achieved scores 101 points higher than the median performer in their school.

Table 2 also shows that exceptional performers in African language schools are slightly younger, have a higher sense of school belonging[11], and are more engaged in reading than exceptional performers in English and Afrikaans schools. Interestingly, exceptional performers in African language schools scored lower on the index measuring reading enjoyment than those in English and Afrikaans schools. There are no statistically significant differences in gender, student absenteeism, mean scores on the bullying index, and mean levels of confidence in reading between exceptional performers in African language schools and their counterparts in English and Afrikaans schools.

As expected, African language schools producing exceptional performers differ significantly from those whose LOLT is English or Afrikaans. These African language schools are less likely to have a library or at least one computer, and exceptional performers in these schools are less likely to have a language teacher who has at least a Bachelor's degree. The school bodies of African language schools are also much poorer than those of English or Afrikaans schools producing exceptional performers.

Similar differences are observable between exceptional performers in TIMSS who attend Quintile 1-4 schools and their counterparts in Quintile 5 schools (Table 2): At 384 points, the median mathematics score of Quintile 1-4 schools producing exceptional performers is almost 100 points (one standard deviation) lower than that of Quintile 5 schools producing exceptional performers (479 points). The mean difference between the mathematics scores of exceptional performers and the median student in their school is much larger in Quintile 1-4 schools than in Quintile 5 schools, with exceptional performers in Quintile 1-4 schools scoring almost an entire standard deviation (95 points) higher than the median mathematics scores in their school, while Quintile 5 exceptional performers only scored 37 points higher than the median student in their school, on average.

There are also interesting differences in individual-level student characteristics between exceptional performers in Quintile 1-4 schools and those in Quintile 5 schools in TIMSS. As is the case for exceptional performers in African language schools in PIRLS, exceptional performers in Quintile 1-4 schools in TIMSS also have a higher sense of school belonging and report being more engaged in their mathematics lessons. Unlike exceptional performers in African language schools in PIRLS, however, those in Quintile 1-4 schools in TIMSS report enjoying mathematics more than their counterparts in Quintile 5 schools, and scored higher on the index measuring confidence in mathematics. Interestingly, Quintile 1-4 exceptional performers reported being bullied more often than those in Quintile 5 schools, which constitutes a somewhat counterintuitive result.

Table 2 also shows that Quintile 1-4 schools producing exceptional performers differ from Quintile 5 schools producing exceptional performers in terms of physical resources, where the former are less likely to have a school library and much less likely to have computers. There is no statistically

[11] See the Appendix for a description of this and other student-level variables included in the multivariate analysis.

significant difference in the proportion of exceptional performers in Quintile 1-4 schools whose mathematics teachers have at least a Bachelor's degree compared to exceptional performers in Quintile 5 schools.

Table 2: Differences between exceptional performers drawn from different types of schools in PIRLS and TIMSS

	PIRLS 2016 (Grade 4)		TIMSS 2015 (Grade 9)	
	African language	English & Afrikaans	Quintile 1-4	Quintile 5
Individual characteristics				
Female	0.74 (0.03)	0.68 (0.03)	0.53 (0.03)	0.58 (0.03)
Age	9.94** (0.05)	10.07 (0.05)	15.06 (0.05)	14.98 (0.05)
Often absent	1.76 (0.07)	1.75 (0.07)	2.28 (0.04)	2.26 (0.05)
Frequency with which test language is spoken at home	0.92*** (0.02)	0.81 (0.02)	0.36*** (0.03)	0.57 (0.03)
School safety and attitude indices				
Bullying index	2.05 (0.05)	1.99 (0.05)	1.71*** (0.03)	1.54 (0.04)
School belonging index	3.69*** (0.03)	2.51 (0.04)	3.70*** (0.03)	3.46 (0.04)
Enjoyment index	1.20*** (0.02)	1.42 (0.04)	3.66*** (0.03)	3.22 (0.05)
Engagement index	2.84*** (0.02)	2.68 (0.03)	3.69*** (0.03)	3.43 (0.05)
Confidence index	2.27 (0.04)	2.24 (0.05)	3.07*** (0.04)	2.89 (0.05)
School characteristics				
School has a library	0.30*** (0.03)	0.51 (0.03)	0.40** (0.03)	0.49 (0.04)
School has at least one computer	0.31*** (0.03)	0.44 (0.03)	0.48*** (0.03)	0.72 (0.03)
Teacher has at least a Bachelor's degree	0.24*** (0.03)	0.44 (0.03)	0.97 (0.01)	0.94 (0.02)
SES of school body	-0.06*** (0.05)	1.41 (0.07)		
Mean test scores	337*** (1.46)	404 (2.60)	468*** (2.44)	514 (3.05)
School median	342*** (2.13)	434 (4.03)	384*** (2.43)	479 (3.22)
Distance from school median	138*** (2.51)	101 (3.96)	95*** (2.61)	37 (2.96)
Observations	**294**	**259**	**347**	**213**

*Notes: Standard errors are in parentheses. Statistically significant at the following levels: *p<0.1, **p<0.05, ***p<0.01.*

7. Multivariate analysis

Estimating the probability of exceptional performance

Given these descriptive differences between exceptional performers and their peers, I consider whether these associations remain significant in a multivariate context. To do this, I follow the well-established and generally accepted convention in the literature (Sandoval-Hernandez and Bialowoski, 2016), of using a logistic regression model to estimate the probability of being an exceptional performer as a function of a number of a defined set of predictors.

The results from the logistic regressions are presented in Models 1 and 2 are logistic regressions that estimate the probability of exceptional performance in PIRLS, while Models 3 and 4 estimate the probability of exceptional performance in TIMSS. Coefficients are presented as odds ratios which reflect the odds of being an exceptional performer associated with a given score on the independent variable, relative to the reference category. For example, the coefficient of 1.861 on "Female" in the second column of Table 3 indicates that girls are 1.861 times as likely as boys to be exceptional performers. Coefficient values smaller than one indicate a negative association between a given covariate and the probability of being an exceptional performer. For example, the coefficient of 0.529 on the covariate measuring the frequency of student absenteeism in the second column of Table 3 indicates that being absent once every two weeks is associated with a 47.1% decrease in the probability of being an exceptional performer compared with the reference category, that is, being absent never or almost never.

Individual characteristics

The logistic regression results presented in Table 3 echo the descriptive differences between exceptional performers and their peers described in Section 0. Gender remains a strong predictor of exceptional performance in PIRLS, even when controlling for a number of covariates at the individual, home and school level, with girls being 1.718 times more likely than boys to be identified as exceptional performers in Model 2, which includes controls at both the individual and school level. This result is consistent with the fact that girls consistently outperform boys in reading in South Africa (Van Broekhuizen and Spaull, 2017), and with existing studies that find a gender gap in favour of girls when estimating the covariates of exceptional performance in reading (Finn and Rock, 1997; Cappella and Weinstein, 2001; Vera, Valenzuela and Sotomayor, 2015a; Wills and Hofmeyr, 2018) among socio-economically disadvantaged students. In the TIMSS data, the coefficient on being female remains insignificant in the multivariate context. This result adds to existing evidence of no gender differences in exceptional mathematics achievement among socio-economically disadvantaged students in the high school grades (Sandoval-Hernandez and Bialowoski, 2016; Agasisti et al., 2018).

Age remains significantly associated with exceptional performance in a multivariate context, with older students being less likely to be exceptional performers in both PIRLS and TIMSS. As expected given the larger age gap between exceptional performers and the comparison group in TIMSS (Table 1), age is a stronger predictor of exceptional performance in TIMSS: When controlling for covariates at both the individual and school level (Model 4), being one year older is associated with being 36.0% less likely (odds ratio of 0.64) to be an exceptional performer. The association between age and exceptional performance is less than half as big in PIRLS, with being one year older being associated with a 14.6% decrease in the probability of being an exceptional performer.

Similarly, self-reported student absenteeism maintains its significance as a predictor of exceptional performance when controlling for other covariates, with more frequent absenteeism being negatively associated with the probability of being an exceptional performer. This supports existing evidence of a negative association between student absenteeism and academic achievement in South Africa (Van der Berg and Louw, 2006; Shepherd, 2011).

The frequency with which the language of the test is spoken at home also emerges as a significant predictor of exceptional performance in three out of the four logistic regressions. Here the response categories were collapsed into a binary variable, with students who reported speaking the language of the test at home "almost" or "almost always" scoring one, and those who reported speaking it "sometimes" or "never" scoring zero. Interestingly, this variable loses its significance when controlling for school characteristics in PIRLS (Model 2). This may be due to the fact that many students in this sub-sample of PIRLS (89.38%) report "always" or "almost always" speaking the language of the test at home, which reflects the fact that PIRLS 2016 was administered in the school's LOLT in the foundation phase. In TIMSS, the proportion of students who "always" or "almost always" speak the language of the test at home is only 28.84%, reflecting the fact that English or Afrikaans is not the home language of the vast majority of students in this sub-sample of TIMSS. The results in Table 3 suggest students who are taught in their home language have an advantage in terms of the probability of being exceptional performers, with these students being 1.732 times as likely to be identified as such, compared to their peers who reported speaking the test language at home “sometimes” or “never”.

Student attitudes

Self-reported engagement in the subject in question is only significantly associated with academic resilience in PIRLS, not in TIMSS. This constitutes an interesting result in light of existing findings of the importance of student engagement for mathematics achievement, and provides some support for the notion that while engagement is associated with achievement in general, it is not a significant predictor of exceptional mathematics achievement for socio-economically disadvantaged students. A similar result emerges for the subject-specific enjoyment indices, where this construct is not a significant predictor in the full model specification of either the PIRLS or the TIMSS sub-sample.

Students’ confidence in reading in PIRLS and mathematics in TIMSS emerge as the student attitude indices with the strongest associations with exceptional performance. In PIRLS, being “very confident” in reading is associated with being 4.607 times as likely to be an exceptional performer, relative to students who are “not confident” in reading. Similarly, students who are “very confident” in mathematics in TIMSS are 4.839 times more likely to be identified as exceptional performers than students who are “not confident” in mathematics to be an exceptional performer in the full model specification in TIMSS (Model 4). This result echoes Stankov & Lee's (2014) conclusion, based on a review of five studies, that measures of self-confidence have the highest predictive power in studies that use large-scale assessment data to examine the relationship between self-reported confidence in students’ academic abilities and academic achievement.

Students’ self-reported sense of belonging at school is also only associated with exceptional performance in PIRLS, and only when students’ scores on this index amounted to having a “high sense of school belonging” relative to student who have “little sense of school belonging”. Such students are 1.411 times as likely as students who had “little sense of school belonging” to be identified as exceptional performers. This student attitude index is not significantly associated with exceptional performance in TIMSS, which constitutes a surprising result given existing studies that find a positive association between school belonging and achievement. Self-reported frequency of student bullying is associated with exceptional performance in three out of the four basic regressions, and only when students report being bullied “about weekly”. In PIRLS, such students are 34.6% less likely to be identified as exceptional performers, compared to students who report being bullied “never or almost never”. It is interesting that bullying is not significantly associated with the probability of being an exceptional performer in the full specification (Model 4) in TIMSS, given that other studies find a relationship with student bullying and achievement.

School characteristics

As expected, given large differences in the average performance of African language versus English and Afrikaans schools in PIRLS, students in English or Afrikaans schools are much more likely to be identified as exceptional performers. It is interesting that the SES of the school body also predicts exceptional performance, even after controlling for the LOLT of the school (odds ratio of 1.522). This suggests student body SES has a unique association with exceptional performance that is independent of the association between LOLT and exceptional performance. The association between the probability of exceptional performance and the SES of the school body is even stronger in TIMSS, where students in Quintile 5 schools are 7.427 times as likely as those in Quintile 1-4 schools to be identified as exceptional performers.

Of the two physical school resources controlled for in Models 2 and 4, only attending a school with at least one computer is significantly associated with the probability of exceptional performance in both PIRLS and TIMSS. Attending a school with a library is not significantly associated with the probability of exceptional performance in either PIRLS or TIMSS, after controlling for other factors. The coefficients on teacher qualifications reflect the descriptive statistics in Table 1, where there are no statistically significant differences between exceptional performers and their peers in terms of the proportions of students whose teachers have obtained at least a Bachelor's degree.

Differences in predictors of exceptional performance by school type

Given the descriptive differences between exceptional performers in African language schools compared with exceptional performers in English and Afrikaans schools highlighted in Section 6, it is likely that different covariates are associated with the probability of exceptional performance for these two groups of students, respectively. To investigate this hypothesis, I split the PIRLS sub-sample into students who wrote the test in an African language and those who wrote the test in English or Afrikaans and estimate the probability of exceptional performance for each of these subpopulations separately. The results from these estimations are presented in columns 6 (Model 5) and 7 (Model 6) of Table 3.

Comparing the coefficients of Models 5 and 6 illuminates important differences between the predictors of exceptional performance in African language schools compared to English and Afrikaans schools. First, the coefficient on being female, although still positive, is much smaller for English and Afrikaans schools (1.389 compared with 2.166 for African language schools). It therefore appears that girls in African language schools have a more pronounced advantage in terms of the probability of being exceptional performers than girls in English and Afrikaans schools. The association between age and exceptional performance also differs between African language and English and Afrikaans schools: While being a year older is associated with being less likely to be an exceptional performer in African language schools, this covariate is not significant for students in English and Afrikaans schools. The association between student absenteeism and exceptional performance does not differ by the LOLT of the school, with only students who are absent once a week or more, relative to those who are absent "never or almost never", being less likely to be identified as exceptional performers across school type. The frequency with which the language of the test is spoken at home is not significantly associated with exceptional performance in either African language schools or English and Afrikaans schools. This constitutes an interesting result, given statistically significant differences in the proportions of exceptional performers in African language schools (92%) and those in English and Afrikaans schools (81%), respectively, who "always" or "almost always" speak the test language at home (Table 2).

In terms of student attitudes, self-reported reading engagement remains an insignificant predictor of academic resilience when splitting the sample by LOLT of the school. By contrast, the coefficient on reading enjoyment gains significance when limiting the sample to students in African language schools. It is particularly notable that this coefficient is very large in Model 5, with students in African language schools who reported enjoying reading "very much" being 4.721 times more likely to be exceptional performers than their peers who reported that they do not enjoy reading. Self-reported confidence in reading remains a large and significant predictor of exceptional performers in Models 5 and 6, however the sizes of the coefficients differ slightly by school type.

Students' self-reported sense of belonging at school loses significance in Models 5 and 6. The fact that the coefficient on this variable is significant in Model 2 but loses significance in Models 5 and 6 may be explained by the significant difference in mean scores on this index among exceptional performers in African language schools (3.69) versus their counterparts in English and Afrikaans schools (2.51)

(Table 2). More frequent bullying is only significantly associated with a reduction in the probability of exceptional performance for students in English and Afrikaans schools, another interesting result. In these schools, students who report being bullied about weekly are 65.5% less likely to be exceptional performers, compared to students who report being bullied never or almost never.

Interestingly, the coefficient on attending a school with a library gains significance in Model 6, the only model where this variable is significantly associated with the probability of exceptional performance. By contrast, the coefficient on attending a school with at least one computer loses significance in Model 6.

It is noteworthy that the coefficient on the index indicating the SES of the school body loses significance completely in Model 5, but almost doubles in size in Model 6 compared to Model 2. These results suggest a one standard-deviation increase in this index is associated with being 2.187 times more likely to be an exceptional performer in English and Afrikaans schools, while there is no significant association between this index and exceptional performance in African language schools.

As is the case with exceptional performers in schools with different languages of instruction in PIRLS, there are significant descriptive differences between exceptional performers in Quintile 1-4 schools and those in Quintile 5 schools in TIMSS (Table 2). Once again, one might therefore expect different factors to be associated with exceptional performance in these different types of schools. To investigate this hypothesis, I employ a similar strategy with the TIMSS data as with the PIRLS data in Models 5 and 6, where I split the sub-sample into students in Quintile 1-4 schools and Quintile 5 schools, respectively, and estimate the probability of exceptional performance for each of these subpopulations separately. The results of these estimations are presented in columns 8 (Model 7) and 9 (Model 8) of Table 3, respectively.

The results in the table show that gender remains insignificant as a predictor of exceptional performance in both Quintile 1-4 and Quintile 5 schools in TIMSS. The coefficients on age remain very similar to those in Model 4, with older students still being less likely to be exceptional performers. The coefficient on student absenteeism in Model 7 is somewhat puzzling, with students in Quintile 1-4 schools who report being absent once every two weeks being 81.3% less likely to be identified as exceptional performers, and those who report being absent once a week or more only being 63.8% less likely to be identified as exceptional performers than their counterparts who report being absent “never or almost never”. The reason for the larger coefficient on being absent once every two weeks compared to being absent once a week or more is unclear[12].

The coefficient on the variable indicating that a student “always” or “almost always” speaks the language of the test at home retains its size and significance in Model 7 compared to Model 4. However, this coefficient decreases in both size and significance in Model 8. In other words, while being a home language English or Afrikaans speaker is strongly associated with the probability of being an exceptional performer in all schools, this association is slightly weaker for students in Quintile 5 schools. This might be partly explained by the larger proportion of exceptional performers in Quintile 5 schools who are home language English or Afrikaans speakers (57%), compared to exceptional performers in Quintile 1-4 schools (36%).

Self-reported student engagement in mathematics lessons remains an insignificant predictor of academic resilience when splitting the TIMSS sample by school type, however as is the case for PIRLS,

[12] A possible explanation might be that students are prone to social desirability bias in their responses on this particular item of the student questionnaire, where they provide a response that they perceive to be socially desirable, instead of a truthful response.

the enjoyment index gains significance when splitting the TIMSS sample in this way: Students in Quintile 1-4 schools who report enjoying mathematics “very much” are 2.978 times more likely to be exceptional performers. By contrast, there is no significant association between mathematics enjoyment and exceptional performance in Quintile 5 schools. The fact that the significance of the enjoyment indices in predicting exceptional performance in both PIRLS and TIMSS differs by school type constitutes an important finding. The coefficients on the confidence index in TIMSS also mirror those in PIRLS: Self-reported confidence in mathematics remains a significant predictor of exceptional performance when splitting the TIMSS sample into Quintile 1-4 and Quintile 5 schools, respectively. Students in Quintile 1-4 schools who are “somewhat” and “very” confident in mathematics are 1.479 and 4.377 times more likely to be exceptional performers, respectively, than students who are not confident in mathematics. Although the coefficient on the variable measuring confidence in mathematics is larger in Model 8 (i.e. when the regression is limited to Quintile 5 schools), a Wald test of significance indicates that the coefficients on the confidence index are not statistically significantly different between Models 7 and 8, suggesting the strength of the association between confidence in mathematics and the probability of exceptional performance is similar for students in Quintile 1-4 schools compared to students in Quintile 5 schools.

Self-reported sense of belonging at school remains an insignificant predictor of exceptional performance in both Models 7 and 8. Likewise, the frequency of student bullying remains not statistically significantly associated with exceptional performance in both Models 7 and 8, except for the coefficient on the variable indicating that students are bullied “about monthly”, which suggests that students who report being bullied about more likely are *more* likely to be exceptional performers than students who are bullied “never or almost never”. This is a surprising result, especially when considered alongside the negative association between student bullying and the probability of being an exceptional performer found in the PIRLS data. A potential explanation might be that the older students in TIMSS are more prone to social desirability bias compared to the students in PIRLS, and consequently that they are more reluctant to report being bullied. Unfortunately, social desirability bias will always plague survey data that relies on self-reported measures of student attitudes.

It is interesting to note that the only school-level covariate that retains its significance when splitting the TIMSS sub-sample in this way is the dummy indicating whether a school has at least one computer. As is the case for the African language sub-sample in PIRLS, this variable is positively associated with exceptional performance in Quintile 1-4 schools. The coefficients on the dummy variables indicating whether schools have a library and whether teachers have obtained at least a Bachelor’s degree remain insignificant in Models 7 and 8.

Table 3: Logistic regressions of exceptional performance

	PIRLS 2016 (Grade 4)		TIMSS 2015 (Grade 9)		PIRLS 2016 (Grade 4)		TIMSS 2015 (Grade 9)	
	(1) PIRLS	(2) PIRLS	(3) TIMSS	(4) TIMSS	(5) African language	(6) Eng & Afrikaans	(7) Quintile 1-4	(8) Quintile 5
Individual characteristics								
Female	1.824***	1.18***	0.996	0.958	2.166***	1.389*	0.856	1.122
	(4.71)	(4.29)	(0.03)	(0.34)	(4.40)	(1.77)	(0.94)	(0.59)
Age	0.893	0.862**	0.587***	0.644***	0.780***	0.948	0.628***	0.668**
	(1.58)	(1.98)	(6.76)	(5.94)	(2.62)	(0.44)	(5.41)	(2.64)
Absent: Once a month	0.875	0.934	0.701*	0.688*	1.035	0.847	0.770	0.559**
	(0.69)	(0.34)	(1.90)	(1.94)	(0.12)	(0.58)	(1.11)	(2.01)
Absent: Once every two weeks	0.529**	0.553**	0.331***	0.364***	0.644	0.587	0.187***	0.522
	(2.38)	(2.22)	(3.21)	(3.22)	(1.21)	(1.35)	(3.90)	(1.32)
Absent: Once a week or more	0.542***	0.584***	0.264***	0.326***	0.559***	0.629**	0.362***	0.203***
	(4.05)	(3.51)	(4.37)	(3.26)	(2.78)	(2.04)	(2.94)	(3.23)
Test language spoken at home: Always or almost always	0.640**	1.095	2.252***	1.732***	0.961	1.015	1.715***	1.666*
	(2.22)	(0.45)	(5.06)	(3.75)	(0.15)	(0.06)	(3.19)	(1.68)
School safety and attitude indices								
Bullying index: About monthly	0.967	0.949	0.916	1.108	1.345	0.725	1.481***	0.743
	(0.22)	(0.36)	(0.64)	(0.74)	(1.57)	(1.44)	(2.66)	(1.10)
Bullying index: About weekly	0.654***	0.588***	0.609**	0.726	0.836	0.445***	0.854	0.713
	(2.75)	(3.55)	(2.20)	(1.36)	(0.80)	(3.87)	(0.66)	(0.76)
School belonging index: Some sense of school belonging	0.776	1.165	0.717	0.798	1.679	1.376	1.093	0.714
	(1.19)	(1.51)	(0.81)	(0.56)	(0.89)	(1.21)	(0.20)	(0.55)
School belonging index: High sense of school belonging	0.829	1.411*	0.697	0.924	2.167	1.442	1.206	0.911
	(0.91)	(1.66)	(0.75)	(0.18)	(1.27)	(1.35)	(0.42)	(0.13)
Enjoyment index: Somewhat like reading (PIRLS) / mathematics (TIMSS)	1.114	1.170	0.953	1.260	3.419	1.003	1.683*	1.232
	(0.22)	(0.34)	(0.28)	(1.21)	(1.59)	(0.01)	(1.90)	(0.68)
Enjoyment index: Very much like reading (PIRLS) / mathematics (TIMSS)	1.127	1.335	1.119	1.660**	4.721**	1.033	2.978***	1.014
	(0.25)	(0.63)	(0.54)	(2.43)	(2.00)	(0.06)	(3.93)	(0.03)
Engagement index: Somewhat engaged in reading (PIRLS) / mathematics (TIMSS) lessons	2.185*	2.309*	0.928	0.993	0.682	1.929	1.272	0.794
	(1.70)	(1.79)	(0.30)	(0.03)	(1.39)	(1.46)	(0.78)	(0.63)
Engagement index: Very engaged in reading (PIRLS) / mathematics (TIMSS) lessons	2.704*	2.789**	0.702	0.781	*Omitted due to*	2.093	0.850	0.708
	(2.18)	(2.18)	(1.26)	(0.98)	*collinearity*	(1.58)	(0.46)	(0.88)
Confidence index: Somewhat confident in reading (PIRLS) / mathematics (TIMSS)	2.743***	2.665***	1.724***	1.795***	3.256***	2.418***	1.479**	2.472***
	(6.01)	(6.08)	(3.43)	(3.50)	(4.73)	(3.86)	(2.22)	(2.68)
Confidence index: Very confident in reading (PIRLS) / mathematics (TIMSS)	5.527***	4.607***	5.199***	4.839***	4.057***	5.834***	4.377***	5.462***
	(9.78)	(9.34)	(6.39)	(6.14)	(5.01)	(8.37)	(6.16)	(2.84)
School characteristics								
English or Afrikaans school (PIRLS) / Quintile 5 school (TIMSS)		3.356***		7.427***				
		(7.45)		(8.28)				
School library		1.286		0.844	1.198	1.648*	0.716	1.134
		(1.35)		(0.80)	(0.70)	(1.93)	(1.54)	(0.29)
School has at least one computer		1.463**		1.685**	1.748**	1.129	1.497*	2.107
		(2.05)		(2.30)	(2.31)	(0.44)	(1.83)	(1.41)
Teacher has at least a Bachelor's degree		0.846		1.476	0.767	0.767	1.084	1.580
		(0.97)		(1.27)	(1.26)	(0.98)	(0.20)	(0.93)
SES of school body		1.522***			0.923	2.187***		
		(0.13)			(0.78)	(6.27)		
Observations	9,572	9,572	9,316	9,316	7,086	1,952	8,428	888

***Notes**: Coefficients expressed in odds ratios. Standard errors are in parentheses and clustered at the school level. Significant at *p<0.1; **p<0.05; ***p<0.01. Reference categories: **Absent**: "Never or almost never"; **Test language spoken at home**: "Never" and "Sometimes"; **Bullying index**: "Never or almost never"; **School belonging index:** "Little sense of school belonging"; **Enjoyment index**: "Do not like reading (PIRLS) / Mathematics (TIMSS)"; **Engagement index**: "Not engaged in reading (PIRLS) / Mathematics (TIMSS) lessons"; **Confidence index**: "Not confidence in reading (PIRLS) / Mathematics (TIMSS)".*

Measurement challenges

One major limitation of the analysis presented here is that the associations reported are purely correlational. Even if we assume an association is causal, it is not possible to determine the direction of causality with the type of analysis presented here. This is particularly problematic since the direction of causality may be reversed, where students with better academic skills have better attitudes towards reading and mathematics, as measured by the school belonging, enjoyment, engagement and confidence indices. Existing studies that explore the relationship between student attitudes and academic achievement have produced different theoretical models such as the skill-development model and the self-enhancement model (Abu-Hilal *et al.*, 2013). According to the skill-development model, attitudes toward a domain (such as reading or mathematics) is the result of achievement in that domain. The self-enhancement model proposes the opposite direction of causality, whereby attitudes about a domain are the primary cause of achievement in that domain (Abu-Hilal *et al.*, 2013). Existing research has not been able to provide evidence as to which of these models better explains the observed relationship between student attitudes and achievement (Wang and Lin, 2008), making this a limitation that plagues all studies that explore this association.

Another measurement concern relates to the validity of self-report questionnaires as measures of student attitudes. Self-report questionnaires constitute the most common approach to assessing student qualities such as sense of belonging, student engagement, and self-confidence. However, as Duckworth and Yeager (2015) argue, responding to such questionnaire items requires a complex process of reflection on the part of students. Of particular concern for interpreting the results presented in Table 3 is that the very first stage of this process – reading and understanding questionnaire items – requires literacy. Given South Africa's poor overall results in PIRLS especially, it is worth trying to disentangle the effect of literacy from responses to student attitude items.

Of particular concern among respondents with low literacy is what Marsh (1984) calls negative items bias, which he defines as occurring "when a child responds inappropriately by saying 'true' to a negative statement when his or her responses to positive items have consistently indicated that the opposite response would be more appropriate, or vice versa" (Marsh, 1984: 37). Weems, Onwuegbuzie and Collins (2009) argue that negatively worded items are particularly difficult for poor readers to answer, since negative ideas occupy twice as much space in working memory as positive ideas. This presents a bigger problem for poor readers, since individuals with low reading ability experience semantic processing problems that limit their ability to generate inferences while engaged in the reading process (Weems, Onwuegbuzie and Collins, 2009). In light of these findings, a number of authors concur that negatively worded statements add confusion that results in such items "measuring the students' ability to read carefully rather than their objective-based skills" (Carey, 2001: 126).

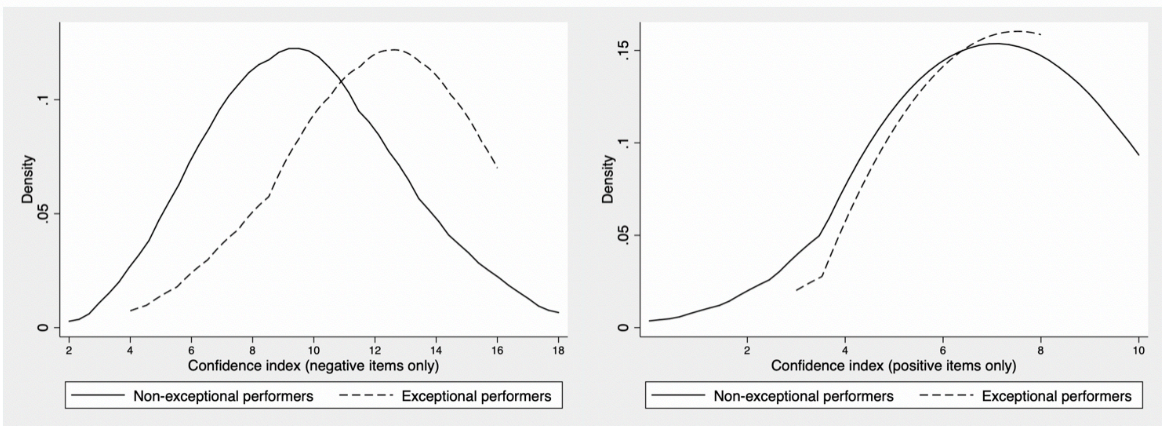
The index measuring confidence in reading is one of the only student attitude indices derived from the PIRLS and TIMSS student background questionnaires that includes negatively worded items, and the only attitude index that consists predominantly of negatively worded items. Given widespread concern about the validity of responses to negatively worded items in surveys, the fact that the only scale in PIRLS and TIMSS comprised predominantly of negatively worded items emerges as one of the strongest predictors of exceptional performance in reading and mathematics requires further investigation.

This situation is exacerbated by the fact that the potential effect of low literacy and that of low real levels of confidence in reading are indistinguishable. Students with low levels of literacy could respond "Agree a lot" to the statement "I am bad at reading" either because they understand the content of the question and know they struggle with reading, or because they do not understand the content of the question and answered “Agree a lot” to all the questions. Thus it is difficult to establish whether answers on items related to confidence in reading, especially negatively-worded items, are a true reflection of students’ perceptions of their reading ability (i.e. their confidence in reading), or simply due to their low levels of literacy. The same potential problem plagues the confidence in mathematics index in TIMSS 2015. Although TIMSS respondents are older and are expected to be better readers than PIRLS respondents, roughly 71% of students in the TIMSS sub-sample used in the analysis completed the questionnaire in a language not frequently used at home. We might therefore expect low literacy to plague the validity of the TIMSS background questionnaire items as well.

One way to test whether high scores on the student confidence index are simply reflective of higher literacy is to examine response patterns in the questionnaire items that comprise this scale. Specifically, it is instructive to compare student responses to positively and negatively worded items, given that negatively worded items are more difficult to answer and therefore require higher literacy. The distributions of scores on the positively and negatively worded items should look roughly similar if higher literacy is not driving higher scores on the confidence indices. For example, if the positively worded statement “Reading is easy for me” captures the same latent construct as the negatively worded statement “I am just not good at reading”, then the distributions of scales obtained by combining positively and negatively worded statements, respectively, should be roughly similar. These distributions are plotted in Figure 8 below.

It is clear from the figure that there is evidence of a systematic difference in the distributions of positively and negatively worded items comprising the confidence index in PIRLS: While the distribution of negatively worded items for non-exceptional performers lies clearly to the left of that for exceptional performers[13], the distributions of positively worded items are roughly similar for these two groups. This constitutes evidence that higher literacy among exceptional performers may be driving some of the association between confidence in reading and the probability of exceptional performance, and constitutes a major limitation of the results presented in Section 7.

Figure 8: Distributions of negatively and positively worded items in the confidence index: PIRLS 2016

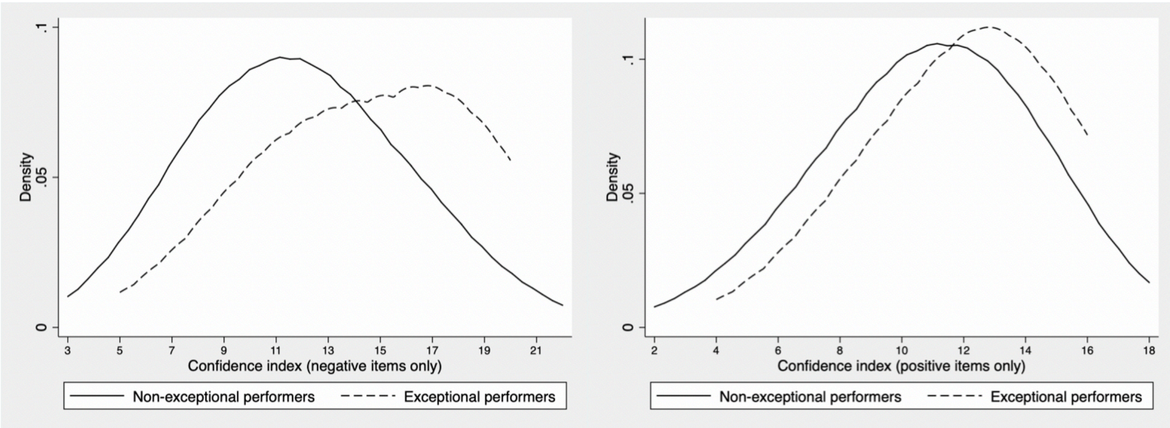


In light of the above, it is instructive to evaluate response patterns in the confidence index in TIMSS, given that these students are older and therefore low literacy is likely to be less of a concern than it is

[13] Since the negatively worded items are reverse-coded, this indicates that exceptional performers systematically scored higher on these items than the comparison group.

for the PIRLS sub-sample. Figure 9 shows the distributions of the negatively and positively worded items comprising the confidence in mathematics index in TIMSS. The figure shows much more similar distributions for the negatively and positively worded items comprising the confidence index, respectively. This provides some evidence that higher literacy among exceptional performers in TIMSS is less likely to drive the large association between confidence and the probability of exceptional performance than is the case for exceptional performers in PIRLS.

Figure 9: Distributions of negatively and positively worded items in the confidence index: TIMSS 2015



While the different distributions for positively and negatively worded items on the confidence in reading index in PIRLS provides cause for concern, it may also be that responses to the items comprising this index are true reflections of the latent construct they attempt to capture. Another way to test whether the large coefficient on the confidence index in PIRLS is driven by illiteracy among non-exceptional performers is to limit the comparison group to literate students and estimate the same logistic regression. When limiting the sample to students who reached the low international benchmark (a level at which students are able to retrieve explicitly stated information and make straightforward inferences when reading less difficult texts (Mullis *et al.*, 2017b)), the coefficient on the confidence index decreases in size but remains positive and maintains its significance. This provides some evidence that the association between confidence and exceptional performance observed in Table 3 are not entirely driven by higher literacy among exceptional performers. The fact that there is an equally large and significant association between confidence and exceptional performance in TIMSS, and little evidence of literacy differences between exceptional performers and the comparison group in the TIMSS data, provides more support for the notion that the large coefficient on student confidence in PIRLS is not entirely driven by literacy differentials between exceptional performers and the comparison group.

8. Discussion

Despite these measurement concerns related to student attitudes, a number of important conclusions emerge from the results presented here. Firstly, the descriptive results provide evidence of exceptional academic performance, even in schools that achieved very poor average results in PIRLS. Over half of the exceptional performers identified in the South African PIRLS data attended schools where the median student did not reach the low international reading benchmark. This suggests it is possible for a small minority of students to achieve good academic outcomes, even in contexts of very poor average performance.

Secondly, a number of interesting results emerge from the multivariate analysis. Notably, not only are girls much more likely to be exceptional performers in reading in grade 4, but this association is stronger among more socio-economically disadvantaged students, when writing the PIRLS test in an African language is used as a proxy for school disadvantage. This result echoes findings from Cappella and Weinstein (2001), Vera, Valenzuela and Sotomayor (2015) and Wills and Hofmeyr (2018) who find that disadvantaged girls are more likely to be exceptional performers in reading. The lack of a gender effect in predicting exceptional performance in TIMSS also constitutes a noteworthy result, given international studies that often find a female *disadvantage* when predicting exceptional mathematics performance in the high school grades (Cheung, 2016; Agasisti *et al.*, 2018). It is further noteworthy that the frequency with which the test language is spoken at home significantly predicts academic resilience in TIMSS; however, no such association exists in PIRLS. This suggests familiarity with English or Afrikaans may be advantageous for mathematics performance of socio-economically disadvantaged grade 9 students in South Africa.

Results from the multivariate analysis further suggest that peer SES as measured as the average of student SES at the school level is a significant predictor of exceptional performance in English and Afrikaans schools but not in African language schools. Given the low average levels of student SES in African language schools compared with English and Afrikaans schools, this result suggests a larger effect of peer SES in predicting exceptional performance in schools that have higher average levels of student SES.

Comparing the effect sizes of the different student attitude indices suggests confidence in reading and mathematics is the strongest predictor of exceptional performance in these subjects, respectively. This result adds to existing evidence of a strong relationship between self-confidence in a particular subject and achievement in that subject, and suggests this relationship holds when studying academic achievement that exceeds expectations among socio-economically disadvantaged students. This result should be interpreted with caution, however, given concerns raised in Section 7]

regarding the direction of causality between self-reported confidence and construct validity of the confidence indices.

The difference in the strength of the association between the subject enjoyment indices and exceptional performance by school type constitutes another interesting result. Specifically, it is interesting that this construct does not significantly predict exceptional performance in any of the model specifications except in the African language sub-sample in PIRLS and the Quintile 1-4 sub-sample in PIRLS. Given that these schools are more disadvantaged both in terms of resources and the SES of the school body, this result suggests grade 4 students who enjoy reading and grade 9 students who enjoy mathematics have an advantage in terms of the probability of being exceptional performers, but only in more disadvantaged school contexts. This adds to existing evidence that positive attitudes toward learning have a stronger association with achievement in schools that are characterised by lower functionality (McCormick *et al.*, 2015).

9. Conclusion

In this paper, I identified exceptional performers in PIRLS 2016 and TIMSS 2015 data for South Africa. Three key findings emerged. First, exceptional performers could be found even in schools with very low average levels of performance. Second, exceptional performers differ systematically from their peers along a number of dimensions. Third, students' confidence in reading and mathematics is strongly associated with the probability of exceptional performance in these subjects. While we cannot infer causality from these associations, the results presented here constitute an important first step in understanding how some students manage to overcome the risks to their academic success that result not only from their socio-economically disadvantaged home backgrounds, but also the low-quality schools they attend. Further research on the causes of exceptional performance in challenging contexts may aid in developing knowledge of how to support more students to do the same.

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APPENDIX

Construction and characteristics of SES index

Principal components analysis (PCA) was used to construct an SES index. The index includes variables indicating the presence of six items in the home, parental education and a dummy indicating whether the student attends a school located in a township or remote rural area. The home possession variables are: A computer or tablet at home; a study desk; own cell phone; a gaming console (e.g. Play Station); own bedroom; and internet at home.

Parental education was included in the SES index since education attainment of parents is considered a good proxy for SES. This variable was included as a dummy indicating whether parents have completed high school. The logic behind this decision was as follows: Parental education is collected as an ordinal categorical variable in the PIRLS data. In principal components analysis, ordinal categorical variables are treated as continuous variables, which creates problems for interpretation of coefficients on this index. One solution to this is to treat each category as a dummy variable, but these dummy variables will necessarily be correlated with each other, which will "confuse" the principal components analysis and result in an index that does not accurately capture SES (Taylor & Yu, 2009). While there are other methods for dealing with this problem, it was decided that including parental education as a dummy indicating high school completion provided the simplest solution, since analyses of labour market earnings in South Africa show large returns to high school graduation. It is thus expected that having a parent who has completed matric should contribute significantly to SES. In addition, including parental education as an ordinal categorical variable does not add to the correlation coefficient any more than adding parental education as a dummy indicating completion of high school does.

Imputation of missing data

Home possessions

Following Taylor & Yu (2009), missing data on the home possessions variables was dealt with by imputation on the assumption that students who did not provide an answer did not have access to the relevant possession at home. Zero imputation is justified when one can reasonably expect an unwillingness to give an answer to be more common amongst students who do not possess a particular item at home (Taylor & Yu, 2009: 16). In addition, missingness on the home possessions variables is negatively correlated with both reading scores and parents' education. This suggests failure to answer the home possessions questions was more likely among students of low SES.

Parental education

Missing information on mother and father's education was imputed as the mean of these variables at the school level. This consideration was primarily informed by the fact that the South African PIRLS data shows little variation in educational attainment of parents at the school level. There is evidence that this constitutes an appropriate method of dealing with missing information on parents' education: Proportions of parents who completed high school in this imputed dataset are very similar to estimates of this measure based on other nationally representative datasets. For example, according to estimates based on the National Income Dynamics Study (NIDS), between 42% and 44% of adults in the relevant age group have completed matric (Branson & Lam, 2009). The proportions of students whose mothers and fathers have completed matric are 44% and 43%, respectively, according to the imputed PIRLS data. This provides evidence that this method of imputing missing values for the parental education variables results in imputed data that is a fairly accurate reflection of parental education in the PIRLS sample.

Unfortunately, there are a number of instances in the South African PIRLS data where all students in a school have missing values for the parental education variables. Naturally mean parental education at the school level could not be used to impute these missing values, and these students were dropped from the analysis. This resulted in a loss of 1359 observations from the original sample of 12 810 (10.6%).

Table A1: Explanatory variables used in the multivariate analysis: PIRLS 2016 (Grade 4)

Variable	Questionnaire	Description	Response categories and codes
Individual characteristics			
Female	Student	Gender: Female	
Age	Student	Age in years	
Absent	Student	About how often are you absent from school?	1: Never or almost never 2: Once a month 3: Once every two weeks 4: Once a week
How often is the test language spoken at home?	Student		1: Never 2: Sometimes 3: Almost always 4: Always
Student attitudes			
Bullying index	Student	During this school year, how often have other students from your school done any of the following things to you? 1) Made fun of me or called me names 2) Left me out of their games or activities 3) Spread lies about me 4) Stole something from me 5) Hit or hurt me 6) Made me do things I didn't want to do 7) Shared embarrassing information about me 8) Threatened me	1: Almost never 2: About monthly 3: About weekly See http://timssandpirls.bc.edu/pirls2016/international-results/pirls/school-safety/student-bullying/ for a description of how student responses were combined into an overall bullying index.
Sense of school belonging (index)	Student	What do you think about your school? Tell how much you agree with these statements: 1) I like being in school 2) I feel safe when I am at school 3) I feel like I belong at this school 4) Teachers at my school are fair to me 5) I am proud to go to this school	Four-point Likert scale from "Agree a lot" to "Disagree a lot". See http://timssandpirls.bc.edu/pirls2016/international-results/pirls/school-climate/student-sense-of-belonging/ for a description of how student responses were combined into an overall index indicating students' sense of school belonging.

Table A1: Explanatory variables used in the multivariate analysis: PIRLS (Grade 4) (Cont.)

Variable	Questionnaire	Description	Response categories and codes
Reading enjoyment (index)	Student	What do you think about reading? Tell how much you agree with each of these statements: 1) I like talking about what I read with other people 2) I would be happy if someone gave me a book as a present 3) Reading is boring* 4) I would like to have more time for reading 5) I enjoy reading 6) I learn a lot from reading 7) I like to read things that make me think 8) I like when a book helps me imagine other worlds How often do you do these things outside of school? 1) I read for fun 2) I read to find out about things I want to learn *Reverse coded	Four-point Likert scale from "Agree a lot" to "Disagree a lot". 1: Never or almost never 2: Once or twice a month 3: Once or twice a week 4: Every day or almost every day See http://timssandpirls.bc.edu/pirls2016/international-results/pirls/student-engagement-and-attitudes/students-like-reading/ for a description of how student responses were combined into an overall index indicating how much students enjoy reading.
Reading engagement (index)	Student	How much do you agree with these statements about your reading lessons: 1) I like what I read about in school 2) My teacher gives me interesting things to read 3) I know what my teacher expects me to do 4) My teacher is easy to understand 5) I am interested in what my teacher says 6) My teacher encourages me to say what I think about what I have read 7) My teacher lets me show what I have learned 8) My teacher does a variety of things to help us learn 9) My teacher tells me how to do better when I make a mistake"	Four-point Likert scale from "Agree a lot" to "Disagree a lot". See http://timssandpirls.bc.edu/pirls2016/international-results/pirls/student-engagement-and-attitudes/students-engaged-in-reading-lessons/ for a description of how student responses were combined into an overall index indicating student engagement in reading lessons.
Confidence in reading (index)	Student	How well do you read? Tell how much you agree with each of these statements: 1) I usually do well in reading 2) Reading is easy for me 3) I have trouble reading stories with difficult words* 4) Reading is harder for me than many of my classmates* 5) Reading is harder for me than any other subject* 6) I am just not good at reading* *Reverse coded	Four-point Likert scale from "Agree a lot" to "Disagree a lot". See http://timssandpirls.bc.edu/pirls2016/international-results/pirls/student-engagement-and-attitudes/students-confident-in-reading/ for a description of how student responses were combined into an overall index indicating student confidence in reading.

Table A1: Explanatory variables used in the multivariate analysis: PIRLS 2016 (Grade 4) (Cont.)

School factors			
Variable	**Questionnaire**	**Description**	**Response categories and codes**
English or Afrikaans school		Dummy indicating whether test was written in English or Afrikaans	0: Test was written in isiNdebele, isiXhosa, isiZulu, Sepedi, Sesotho, Setswana, Siswati, Tshivenda, or Xitsonga 1: Test was written in English or Afrikaans
School library	Teacher	Dummy indicating the presence of a library at the school	
Teacher has at least a Bachelor's degree	Teacher	Dummy indicating whether the teacher has obtained at least a Bachelor's degree	
SES of school body	Student (derived)	Mean of student SES at the school level (standardised)	
School has at least one computer	Principal	Dummy indicating the school has at least one computer	

Table A2: Explanatory variables used in multivariate analysis: TIMSS 2015 (Grade 9)

Variable	Questionnaire	Description	Response categories and codes
Individual characteristics			
Female	Student	Gender: Female	
Age	Student	Age in years	
Absent	Student	About how often are you absent from school?	1: Never or almost never 2: Once a month 3: Once every two weeks 4: Once a week
How often is the test language spoken at home?	Student		1: Never 2: Sometimes 3: Almost always 4: Always
Student attitudes			
Bullying index	Student	During this school year, how often have other students from your school done any of the following things to you? 1) Made fun of me or called me names 2) Left me out of their games or activities 3) Spread lies about me 4) Stole something from me 5) Hit or hurt me 6) Made me do things I didn't want to do 7) Shared embarrassing information about me 8) Shared something embarrassing about me online 9) Threatened me	1: Almost never 2: About monthly 3: About weekly See http://timssandpirls.bc.edu/timss2015/international-results/timss-2015/mathematics/school-safety/student-bullying/ for a description of how student responses were combined into an overall bullying index.
Sense of school belonging (index)	Student	What do you think about your school? Tell how much you agree with these statements: 1) I like being in school 2) I feel safe when I am at school 3) I feel like I belong at this school 4) I like to see my classmates at school 5) Teachers at my school are fair to me 6) I am proud to go to this school 7) I learn a lot in school	Four-point Likert scale from "Agree a lot" to "Disagree a lot". See http://timssandpirls.bc.edu/timss2015/international-results/timss-2015/mathematics/school-climate/students-sense-of-school-belonging/ for a description of how student responses were combined into an overall index indicating students' sense of school belonging.
Enjoyment of mathematics	Student	How much do you agree with these statements about learning mathematics? 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 is one of my favourite subjects *Reverse-coded	Four-point Likert scale from "Agree a lot" to "Disagree a lot". See http://timssandpirls.bc.edu/timss2015/international-results/timss-2015/mathematics/student-engagement-and-attitudes/students-like-learning-mathematics/ for a description of how student responses were combined into an overall index indicating student enjoyment of mathematics lessons.

Table A2: Explanatory variables used in multivariate analysis: TIMSS 2015 (Grade 9) (Cont.)

Variable	Questionnaire	Description	Response categories and codes
Engagement in mathematics lessons	Student	How much do you agree with these statements about your mathematics lessons? 1) I know what my teacher expects me 2) My teacher is easy to understand 3) I am interested in what my teacher says 4) My teacher gives me interesting things to do 5) My teacher has answers to all my questions 6) My teacher is good at explaining mathematics 7) My teacher lets me show what I have learned 8) My teacher does a variety of things to help us learn 9) My teacher helps me to do better when I make a mistake 10) My teacher listens to what I have to say	Four-point Likert scale from "Agree a lot" to "Disagree a lot". See http://timssandpirls.bc.edu/timss2015/international-results/timss-2015/mathematics/student-engagement-and-attitudes/students-views-on-engaging-teaching-in-mathematics/ for a description of how student responses were combined into an overall index indicating student engagement in mathematics lessons.
Confidence in mathematics	Student	How much do you agree with these statements about mathematics? 1) I usually do well in mathematics 2) Mathematics is more difficult for me than any 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*	Four-point Likert scale from "Agree a lot" to "Disagree a lot". See http://timssandpirls.bc.edu/timss2015/international-results/timss-2015/mathematics/student-engagement-and-attitudes/students-confident-in-mathematics/ for a description of how student responses were combined into an overall index indicating students' confidence in mathematics.
School factors			
School library	Teacher	Dummy indicating the presence of a library at the school	
Teacher has at least a Bachelor's degree	Teacher	Dummy indicating whether the teacher has obtained at least a Bachelor's degree	
School has at least one computer	Principal	Dummy indicating the school has at least one computer	