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Do "better" teachers and classroom resources improve student achievement? A causal comparative approach in Kenya, South Africa, and Swaziland

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ABSTRACT

We use the 2007 SACMEQ data to make traditional "upwardly biased" estimates of teacher and classroom resource correlates of 6th grade student achievement in Swaziland, Kenya, and South Africa using an OLS model, and a "less biased causal" approach using a student fixed effects model. Our fixed effects model exploits the fact that most students in all three countries have different teachers for reading and mathematics. Each student is therefore subject to the "treatment" of different teacher characteristics and classroom resources, yielding a relatively unbiased but rather "stringent" estimate of teacher and classroom effects. Our results suggest that: (a) several important identifiable teacher characteristics and classroom resources affect student achievement in each country; that (b) those characteristics and resources may differ from one national context to another, between male and female students, and across socioeconomic groups of students; and that (c) the "upwardly biased" results generally differ from the "less biased causal" results. We discuss and attempt to explain these differences.

1. Introduction

African students do poorly on international and national tests that benchmark learning against developed country standards in reading and mathematics. Their reading and math performance is certainly linked to their low level of family academic resources. The schools they attend are also often woefully inadequate to deliver quality education. Yet, some teachers and schools in Africa are effective in raising students' academic skills. There are also some countries in Africa whose students as a whole score much higher than students in other African countries, even accounting for differences in students' family and community academic resources (Spaull, 2011; Carnoy et al., 2015a,b). What are the sources of this greater effectiveness? Are some school resources more effective than others in improving student learning?

In this paper, we analyze empirically the relationship between school inputs and student outcomes in three African countries to find which teacher and school resources may be important for raising student achievement in various national education contexts. This is not an easy task. For one, the teaching-learning process is complex, and the relations between teachers, parents, and administrators are imbedded in each society's political history. The development of educational expectations and standards are themselves products of that history (Carnoy and Levin, 1985; Carnoy and Samoff, 1989; Carnoy et al., 2007).

Social scientists have gradually developed models of classroom inputs and student outputs (Levin, 1980) to include specific teaching practices and curriculum variation, as well as social context. While not completely satisfactory, better specifications have improved empirical estimates of how classroom and school resources can improve students' performance on tests. The vast majority of these studies focus on teachers and teaching, for good reason. Teachers are the key contact that students have with the schooling process. If teachers have higher levels of subject matter knowledge (Hill et al., 2005), are focused on instruction (Darling Hammond, 1997), and teach a high quality curriculum providing students greater opportunity to learn (Schmidt et al., 2001), student are likely to learn more.

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A second difficulty in estimating the relation between school resources and student learning – particularly in developing countries where longitudinal data on students in school are not available – is that most research attempting this has to rely on information at a single point in time in the student's academic trajectory. Such studies provide valuable information on how student background and educational stratification relate to student performance (for example, Hungi, 2011), but yield biased estimates of the relation between student learning outcomes and classroom/school resources, such as teacher characteristics or opportunity to learn. Student performance (the outcome variable) is generally the result of cumulated learning with various teachers. That relation is usually confounded by selection bias—"better" teachers tend to select into schools with higher performing students and more motivated families tend to send their children to "better" schools, those with higher performing/higher family resource students and more able teachers who are likely to provide more opportunity to learn for their students.

Thanks to the increasing availability of data on schools, teachers, and student achievement, some studies in African countries have been able to exploit longitudinal data to estimate learning gains for individual students associated with particular teachers and to measure opportunity to learn during a particular year of schooling (Fuller et al., 1994; Carnoy et al., 2012, 2015a; Spaull, 2011; Taylor and Taylor, 2013). These show that the role of teaching quality (experience, education), teacher content knowledge, and opportunity to learn (time on task, textbook availability) are important in improving student achievement. Experimental studies in Africa have also estimated the causal effect of particular educational interventions on student achievement (see McEwan, 2015; for a summary of such studies). They show that literacy interventions and some forms of incentives for teachers and students may work to improve student learning, even though most have no effect.[1] Despite their advantage of identifying a causal relation between intervention and outcome, the drawback of most of these intervention studies is that they are situational—they are limited to a particular intervention in a particular set of schools and often do not produce the same outcome in a different context (McEwan, 2015)

When students are exposed to different teachers teaching different (tested) subjects, more sophisticated statistical methods of cross section data can also allow for causal analysis.

In a significant contribution to the literature, Shepard (2015) used a correlated random errors variant of fixed effects models developed by Metzler and Woessmann (2012) to analyze the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ) 2007 survey of 6th graders for South Africa. Specifically, Shepard estimates the effect that one important teacher quality indicator, higher teacher subject knowledge (as measured by subject test score), had on student achievement.

In this paper, we use a similar methodology—a student fixed effects model and a student fixed effect/teacher fixed effect model—to extend the SACMEQ causal analysis in two directions: (a) We estimate the causal effect that a number of teacher characteristics in addition to teacher subject knowledge, including experience, training, and gender, as well as the causal effect of several other school inputs, notably the availability of textbooks and principal supervision of teachers, have on student achievement. (b) We compare how these variables effect achievement in three historically different African countries. A comparative analysis helps us address the broader question of possible differences in how teacher and other inputs affect student achievement across developing countries.[2]

To make this comparison, we focus on two neighboring southern African countries, Swaziland and South Africa, and one relatively high scoring eastern African country, Kenya. We chose these three countries because they represent a variety of African economic and educational situations: a relatively large, high-income (PPP$ 13,500), multi-ethnic, low average student achievement country (although very high variation among regions) marked by years of segregationist policies (South Africa); a small, lower income (PPP$ 9,700 per capita) ethnically homogenous neighbor (Swaziland), economically closely tied to the South African economy, whose students score considerably higher on average in both math and reading than South Africa's; and another relatively large, very low-income (PPP $3,200) multi-ethnic country with high student achievement (Kenya).[3]

This variety in country size, wealth, and education policies permits us to discuss whether different classroom factors are likely to be more important for student achievement in some contexts than others. The main advantage of the SACMEQ data is that they are national, are fairly large samples, and contain many data on teacher characteristics and some data on classroom conditions, although very little on classroom processes. Also, in most 6th grades in the three countries, different teachers teach reading and mathematics, the two main subjects tested by SACMEQ.[4] The principal disadvantage of the SACMEQ data is that they are cross-sectional. They only measure student achievement at one point in time, at the end of 6th grade.

We first estimate traditional ordinary least squares (OLS) cross-section production functions of 6th grade performance. To reduce selection bias somewhat, we estimate student achievement within three different levels of family academic resources (FAR). Even so, there is considerable variation of student ability within FAR group, and we have no measure of individual student performance in earlier grades, nor of (unobserved) family motivation—both are sources of bias in our estimates of teacher and other school effects on student 6th grade performance. We consider these cross-section estimates of teacher and other classroom/school resource effects as "traditional upwardly biased estimates" of how much resources could impact student outcomes in Kenya, Swaziland, and South Africa. We also use the cross-section data to estimate the relation between teacher/other classroom/school resources and

[1] In general, studies show that many measureable classroom resources have small or no causal impact on student performance (see Clotfelter et al., 2007, 2010).

[2] It is important to note at the outset that "national" models such as we estimate may hide considerable possible variation in the effects that classroom factors may have on student achievement in different types of schools or among administrative regions/states within a country (see Carnoy et al., 2015b). There is large variation in average SACMEQ scores among provinces within South Africa, for example, driven in part by average socio-economic differences, but also in part by the quality of resources going into schools in the different provinces, and the quality of the administration of education among them. Further research could assess these differences within provinces were student and school samples randomized in each province.

[3] Income distribution in South African is one of the most unequal of any countries in the world (Gini coefficient is equal to 0.63). Swaziland's economy is also marked by rather high ncome inequality, with a Gini coefficient equal to 0.49, but Kenya's income distribution is more equal, with a Gini equal to 0.42. Some studies argue that more unequal income distribution is related to more unequal quality of education and that this contributes negatively to student performance (Adamson, 2010).

[4] We would have liked to include Botswana, also South Africa's neighbor, in the study, but only 15% of students in the Botswana sample have different teachers for mathematics and reading. We were able to estimate a student fixed effects/teacher fixed effects model for Botswana that we can make available to readers upon request.

the school average of students' FAR—this allows us to assess the degree of possible bias from student FAR stratification across schools.

In addition to these cross section OLS estimates, we exploit the fact that in many of the 6th grades sampled by SACMEQ, students have a different teacher for mathematics and reading (language). This allows us to estimate a student fixed effects model in which each student is "treated" by two different teachers, each teacher with different characteristics, each with different classroom resources, and each with a potentially different relation to the school principal. The student fixed effects model essentially eliminates cumulative bias and selection bias because it estimates differential classroom "treatments" on the same student. Since male and female students and students from different socio-economic levels may have different "gender and socio-economic proclivities" for math and reading test performance (see Steele and Aronson, 1995, for girls' "math fear" and other forms of "stereotype threat"), we also estimate the student fixed effect models across gender and socio-economic groups.

Since each student can only be exposed to math and reading teachers in the same school, the student fixed effect model necessarily limits its estimated effects to the variation in teacher and other classroom/school resources in each school. If teachers in the same school have rather similar characteristics and have similar resources in their classrooms, the estimated differential effects of such resources on student achievement may be small. Nevertheless, there is evidence in developed countries such as the U.S. that most of the variation in teacher "quality" occurs with schools rather than between schools (Rivkin et al., 2005). Further, we show that there is considerable variation in the inter-teacher differences in most of the variables in our model (Appendix Table A1), and interesting similarities and dissimilarities across countries in the effect that certain variables have on student achievement.

In addition, we argue that the existing differences in teacher and classroom characteristics within schools reflect a particular reality in each country. Because of the considerable stratification between types of schools, a typical student in Africa (as in most countries) tends to be "structurally" bound by social class, urban/rural location, and spatial stratification within cities and towns to a limited set of teacher characteristics set by the type of school he or she attends or the neighborhood of the school attended. It can be argued that for most students, the variance in teacher or school resources within a school probably represents the degree of improvement in teacher characteristics and resources that could be made available to these stratified groups of students in any set of reforms implemented in the short or medium run. We therefore consider our student fixed effects estimates as "conservative unbiased estimates" of the effects of teacher and other classroom resources.

Our results suggest that: (a) several teacher characteristics and classroom resources affect student achievement in each country[5]; (b) those characteristics and resources are not necessarily the same from one national context to another or across student gender and social class; and, as expected, (c) the "traditional biased" results generally differ from the "conservative unbiased" results.

The paper proceeds as follows: in the following section, we provide a brief overview of the contrasting educational contexts in Swaziland, Kenya, and South Africa; in Section 3, we describe our data; in Section 4, we present our empirical strategy; in Section 5, we present the results of our analysis; and in Section 6, we discuss the policy implications of our results and conclude.

2. Brief contextual background

As in the rest of the world, the process of education in these three African countries' classrooms is couched in the context of their significantly different histories. South Africa, Swaziland, and Kenya were all at one time English colonies, but their historical separation from English colonial legacies and their subsequent educational developments varied enormously. Their different political histories are crucial for understanding differences in performance in schools the three countries. Even in the pre-1960s colonial era, the British government instituted control of the curriculum and methods of teaching through standard examinations of the then protectorate Swaziland and the then colony Kenya. This policy was intended to align curriculum, teacher training and accountability in the education sector, although only a small proportion of Swazi and Kenyan students attended more than a few years of primary education. Swaziland experienced a peaceful transition to independence in 1968, remaining a kingdom to this day, and Kenya, a much less peaceful transition in 1963, but was established as and remains a multi-racial, multi-tribal democracy.

After independence, like most newly independent developing countries, Swaziland and Kenya embarked on implementing educational projects and plans. Both officially adopted racially integrated education. Teacher training was organized in teacher training colleges distributed around the country. Education was expanded—more rapidly in Kenya, more gradually in Swaziland. Swaziland diversified its curriculum to include more practical subjects (Booth, 1997), but as in Kenya, retained primary school leaving examinations, required to enter lower secondary education; lower secondary examinations required to enter secondary school; and secondary school leaving exams modeled on the English O-level and A-level exams.

South Africa's education system had a completely different history. In the long period of Apartheid, South African education was run as a dual, completely segregated system within South Africa, and under the government's Bantustan policy (see Chisholm, 2012), the vast majority of Blacks received their education "outside" South Africa in separately governed (but white South African controlled) Bantustan education systems. After 1994, the Bantustan systems were dissolved and South African education racially integrated, but the system is still largely stratified along class and partially racial lines (Spreen and Vally, 2006), and Model C (former white) schools, although now integrated, are legally able to raise considerably more resources from students' families and hence to provide more resource-rich environments (Motala and Sayed, 2009). A number of curriculum and accountability reforms were implemented, but the system still feels the effects of both Apartheid and the struggle against Apartheid, particularly because schools were one of the front lines of that struggle. The teachers' union played a leading organizing role in the 1970s and 1980s and still retains its self-definition as an important front-line political actor. Older teachers in the system who were trained in Apartheid-era Bantustan teachers' colleges continued to dominate the teaching force. Thus, Swaziland and Kenya had head starts of several decades in reforming their education systems and did not face either a history of explicit resource starvation of Africans' education by an Apartheid government, nor a five-decade struggle to overthrow *legalized* racial segregation.

The education systems in Swaziland and Kenya are financed and operated by their central ministries, although Kenya has many private schools and community-financed and operated Harambee

[5] Shepard's (2015) finds significant, positive but small coefficients for her one variable of focus in South Africa, teacher knowledge. We find teacher knowledge to have a less consistent and smaller effect on student performance than some other variables across all three countries.

schools. Although South Africa's national Ministry can mandate national-level reforms, the educational system is run by the provinces, and there is enormous variation in the quality of management at the provincial level.

3. Data

3.1. Background to the SACMEQ study

The Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ) was launched in 1995. For various reasons, the SACMEQ Ministers decided that the assessment of pupil achievement in reading and mathematics should focus on Standard 6 (one year before the final year of primary schooling in most countries). They developed reading and mathematics tests from a careful analysis of the official school curricula, school syllabi, and textbooks used in SACMEQ school systems. The SACMEQ III Project commenced in 2006 and was completed during 2011. The tests employed modern Item Response Theory methods to undertake item analyses and test-scoring procedures and a two-stage sampling design. In the first stage, schools in the defined target population were sampled on a "probability-proportional-to-size" (PPS) basis from sampling frames that individual countries submitted to the SACMEQ Coordinating Centre. The PPS sampling technique meant that relatively large schools had a higher probability of being selected than smaller schools. In the second stage of sampling learners were sampled from all the Grade 6 classes in each of the sampled schools using computer-generated random numbers. The test scores were transformed so that pupils from both the SACMEQ II and III Projects were placed on a single scale with the SACMEQ II scores anchored to a mean of 500 and a standard deviation of 100.

The SACMEQ Project Also collected information on the usual student characteristics and family background – age, gender, language spoken in the home, parents' education, articles in the home – plus whether and how much preschool education the student had, student absenteeism, and student grade repetition. The SACMEQ survey has particularly detailed data on a number of teacher characteristics, the main focus of our analysis. These included their age, gender, socio-economic level, their number of years of teacher training, academic qualifications, their experience in teaching grade 6, in-service courses attended, and their scores on mathematics and reading tests, given to every teacher in the sample. Furthermore, the survey collected data on the availability of classroom furniture and classroom equipment in standard 6 classrooms, textbook availability, the availability of a teacher's guide to the curriculum, the frequency of teacher absenteeism (according to the principal), and the frequency of principal classroom observations and advisement.

Table 1 shows that Kenya was among the highest scoring countries in the SACMEQ region and made some gains in mathematics but not reading in the six years between SACMEQ II (early 2000s) and III; Swaziland was among the middle high scoring countries, scoring relatively better in reading than in math, and made large gains between SACMEQ II and III; and South Africa was among the lower scoring countries in the region and 6th grade students made statistically insignificant gains on SACMEQ III.

Table 1
SACMEQ II (2001) and SACMEQ III (2007): Mean Student Reading and Mathematics Scores, by Country.

Country	Reading				Mathematics			
	SACMEQ II		SACMEQ III		SACMEQ II		SACMEQ III	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Botswana	521.1	3.47	534.6	4.57	512.9	3.15	520.5	3.51
Kenya	**546.5**	**4.97**	**543.1**	**4.92**	**563.3**	**4.64**	**557**	**3.98**
Lesotho	451.2	2.93	467.9	2.86	447.2	3.24	476.9	2.61
Malawi	428.9	2.37	434	2.63	432.9	2.25	447	2.89
Mauritius	536.4	5.51	573.5	4.92	584.6	6.32	623.3	5.83
Mozambique	516.7	2.29	476	2.83	530	2.08	483.8	2.29
Namibia	448.8	3.13	497	2.99	430.9	2.94	471	2.51
Seychelles	582.0	3.1	575	3.1	554.3	2.68	551	2.45
South Africa	**492.3**	**9.00**	**495**	**4.55**	**486.1**	**7.19**	**495**	**3.81**
Swaziland	**529.6**	**3.74**	**549**	**2.98**	**516.5**	**3.41**	**541**	**2.39**
Tanzania	545.9	5.03	578	3.4	522.4	4.2	553	3.51
Zanzibar	478.2	1.49	536.8	3.11	478.1	1.26	489.9	2.35
Uganda	482.4	6.12	479	3.46	506.3	8.17	482	2.93
Zambia	440.1	4.47	434	3.37	435.2	3.54	435	2.45
Zimbabwe	n/a	n/a	507.7	5.65	n/a	n/a	519.8	4.98

Source: SACMEQ, 2001 and 2007.

4. Empirical strategy

Our principal objective in this paper is to estimate how much student learning can be improved by improving teacher capacity (teaching experience, subject knowledge, in-service training) and, in addition, other school inputs—specifically, the availability of textbooks, teaching guides and other books for teachers, and the frequency of principal feedback on teachers' teaching. A considerable literature convincingly argues that many of these inputs do contribute to higher student achievement. Recent discussion on the effectiveness of school inputs in raising student outcomes shows that students with more effective teachers perform better on achievement tests (for example, Sanders and Rivers, 1996; Rockoff, 2004; Rivkin et al., 2005; Nye et al., 2004; Boyd et al., 2006 Rivkin et al., 2005; Nye et al., 2004; Boyd et al., 2006). Some analysts have argued that pedagogical skills, teacher motivation and classroom resources are all important inputs into the student learning process, but sufficient teacher content knowledge of the subject being taught is a necessary condition for student learning (Taylor, 2008; Hill et al., 2005). Other studies suggest that greater teacher experience contributes significantly to student achievement (Ferguson and Ladd, 1996; Clotfelter et al., 2007; Rockoff, 2004; Rivkin et al., 2005 Rivkin et al., 2005). Teacher absenteeism continues to receive wide attention. Higher teacher absenteeism has been found to lead to lower student performance in mathematics and reading standardized tests (Finlayson, 2009). However, in some cases it has been found to be unrelated to student performance (Robinson, 2008). There is some evidence from developing countries that textbook availability has an impact on student learning (Fuller, 1987; Heyneman et al., 1981), but other experimental, research shows an impact of introducing textbooks only for higher scoring students (Glewwe et al., 2009).[6] Very recent research on teacher-principal interaction suggests that principal observation of classroom teaching when accompanied by feedback to teachers has a significant positive effect on student performance (Grissom et al., 2015).

When we introduce a number of teacher and other resource variables into a function that purports to "explain" students' learning outcomes, there is concern that without a coherent theory of learning we likely misestimate the relation of these resources to student outcomes. One way we deal with it is to estimate the effect on outcomes of various model specifications. We find very small

[6] Glewwe et al. explain this result by noting that the academic difficulty of the textbooks and the fact that they were in English made them ineffective for most students in the sample (English was their third language). More generally, the results of this textbook randomized trail and the mixed results for the impact of other inputs on achievement suggest that it is important for researchers to have a clear understanding of how inputs interact—in this case, curriculum design (textbooks) with teacher capacity/preparation as well as with student language knowledge—to produce or fail to produce student learning.

differences in results for the variables we ultimately include.[7] Furthermore, there is already an extensive literature cited above that estimates the effects of teacher characteristics, out of school lessons, and the availability of textbooks on student achievement. Our results are generally consistent with that literature.

Using the SACMEQ questionnaire data, we initially test for possible selection bias in the assignment of "better" teachers to higher social class students or vice versa. We then turn to the relationship between student performance on the SACMEQ mathematics and reading tests and teacher and other classroom inputs. We employ a standard production function model that attempts to explain student learning by a combination of academic resources that students bring to school and the resources that schools use to teach students various subjects, such as mathematics and language arts (reading). Our focus is on the effect of teacher and other classroom resources, but the model "controls" for student resources. The student resources we use include a variety of student characteristics (gender, grade repetition, absenteeism) student family characteristics (a student SES index developed by SACMEQ, language spoken at home, parents' education), and family investment in the student before and outside school (preschool education, tutoring outside school). We also estimate the heterogeneity of teachers' and classroom inputs on student achievement for male and female students separately and for students with different levels of family academic resources (the SACMEQ composite SES index).

The basic production function model for each subject (mathematics, reading) is the following:

$$y_{ij} = T_{ij}\alpha + X_{ij}\beta + u_i \quad (1)$$

where y_{ij} is the SACMEQ score of student i in classroom j either in mathematics or reading;

T_{ij} is a vector of treatment variables (teacher characteristics, other classroom resources) that vary across students in classrooms j;

X_{ij} is a vector of student characteristics that vary across students in classrooms j;

u_i is a student-specific error term (that represents unobservable variation across students).

Due to the correlation of student error terms within – as opposed to between – schools, we estimate cluster-corrected Huber-White estimators for Eq. (1), in which students are considered to be clustered in classrooms.[8]

Estimating the impact of teacher characteristics and other school inputs on student performance can be complicated by selection bias. Traditional (e.g. ordinary least squares or OLS) analyses of the relationship between school inputs and student outcomes often do not account for non-random assignment of students to schools. Students are generally not randomly assigned to teachers who have differing characteristics and teaching practices (Clotfelter et al., 2010). The non-random assignment of students makes it more difficult to estimate unbiased impacts of teaching practices on student achievement. To address issues of selection bias, researchers have used different types of student fixed effects models (Dee, 2005, 2007; Dee and Cohodes, 2008; Clotfelter et al., 2010; Schwerdt and Wuppermann, 2011; Van Klaveren, 2011). Following Clotfelter et al. (2010) we implement a cross-subject student fixed effect model that utilizes variation within the same student but across different subjects to identify the impact of different teachers with different characteristics/practices. The cross-subject student fixed effect model is derived from the traditional education production function:

$$y_{is} = T_{is}\alpha + x_{is}\beta + z_i\Upsilon + u_i + \varepsilon_{is},\ I = 1,\ \ldots.\ \text{N},\ s = 1,\ \ldots\text{S} \quad (2)$$

where N is the number of individuals;

S is the number of subjects (in our case S = 2);

y_{is} is the SACMEQ score of student i in subject s;

T_{is} is a vector of treatment variables (teacher characteristics, other classroom resources) that vary across students and subjects;

x_{is} is a vector of student characteristics that vary across students and subjects;

z_i is a vector of school, family, student, teacher and classroom characteristics that vary only across students but not across subjects;

u_i is a student-specific error term (that represents unobservable variation across students);

ε_{is} is an error term that varies across both students and subjects.

Traditional OLS approaches produce biased estimates α of the impact of the treatment T_{is} on the outcome y_{is} if the error term $(u_i + \varepsilon_{is})$ is correlated with both the treatment and the outcome.

The cross-subject student fixed effects model attempts to control for the problematic correlation between the error term that varies across students but not across subjects and the treatment and outcome variables. In particular, by subtracting from each variable in Eq. (2) the within student cross-subjects average of that variable the model effectively eliminates $z_i\Upsilon$ and u_i (observable and unobservable factors that were constant across subjects but not across students):

$$y_{is} - \overline{y_i} = (T_{is} - \overline{T_i})\delta + (x_{is} - \overline{x_i})\phi + (\varepsilon_{is} - \overline{\varepsilon_i}), \quad (3)$$

where $\overline{y_i} = \frac{1}{S}\sum_{s=1}^{S} y_{is}$, $\overline{x_i} = \frac{1}{S}\sum_{s=1}^{S} x_{is}$, $\overline{T_i} = \frac{1}{S}\sum_{s=1}^{S} T_{is}$, $\overline{\varepsilon_i} = \frac{1}{S}\sum_{s=1}^{S} \varepsilon_{is}$.

The above model (3) produces unbiased estimates of δ under a few assumptions. The first assumption is that coefficients for each variable are equal across the two subjects (Dee, 2005). This implies that the way in which the treatment (and other teacher characteristics) affects student achievement is the same across subjects.[9] The second assumption is that the error term $(\varepsilon_{is} - \overline{\varepsilon_i})$ in Eq. (2) is uncorrelated with the regressors $(T_{is} - \overline{T_i})$. This means that unobserved student, classroom, or teacher characteristics that vary across subjects are not correlated with the teacher/classroom resources and student achievement (Schwerdt and Wuppermann, 2011).

The cross-subject student fixed effects model may not address biases stemming from the non-random assignment of teaching characteristics/practices to students with greater abilities in mathematics or reading (Clotfelter et al., 2010). Unfortunately, the SACMEQ data do not allow us to control for students' previous ability (test scores or grades) in each subject. Thus, we cannot test for this possible bias directly. Nevertheless, we can get at part of this bias by estimating the model for boys and girls separately,

[7] For example, we eliminated the years of teacher training variable because it was highly correlated with teacher pre-service education.

[8] Cluster correction to estimate unbiased standard errors is standard practice in the economics of education literature—an alternative to hierarchical linear model estimates.

[9] This means, for example, that teacher subject knowledge or pre-service education or experience or the availability of a textbook is equally important for reading and mathematics. It is possible to argue that this is not the case—particularly when we are estimating the effect of specific characteristics of teachers. If the coefficients were not equal, our estimates using this methodology would be biased. Nevertheless, there is at least some evidence that teacher "quality" (teacher fixed effects as a whole) impact students' reading and mathematics scores more or less equally, although for some characteristics, such as teacher experience, the size of the effect and its pattern across years of experience depends on whether the outcome measure in reading is vocabulary acquisition or reading comprehension, and in math, whether it is math computation or math concepts (Rockoff, 2004). An argument could also be made that the linear relation of teacher subject knowledge to student outcomes is not equal in the components of reading and math.

testing for the probability that boys generally do better than girls in math, and girls better than boys in reading. If teachers with higher math ability, for example, have more or fewer boys in their classes, separating the estimates would reduce bias. Similarly, estimating models by student social class may reduce bias since higher SES students do relatively better in reading than math compared to lower SES students and teacher characteristics are not assigned randomly to higher and lower social class students.

Student fixed effects estimates are subject to the extant variation of teacher and classroom resources in the same school. Nevertheless, Appendix Table A1 shows, for each variable we use in the fixed effect regressions, the mean differences (estimated by averaging the differences across students in each country's sample) and standard deviations of the differences. For some variables, the mean differences are small, but generally the variation in the differences is large enough to provide valid estimates of the effects on student achievement.

We focus our student fixed effects analysis on those schools where different teachers teach reading and mathematics. However, we are also able to test in South Africa and Swaziland whether the same teacher with different math and reading ability and different textbook access in each subject has a differential effect on student test score in the two subjects. (Kenya has too few students with the same teacher in both subjects). This provides a student *and* teacher fixed effects estimate, and allows us to test whether the same student exposed in two subjects to the same teacher with differing subject matter ability (test scores) and using varying materials in the two subjects produces different results. According to the SACMEQ data, other characteristics of the teacher are equal in the two subjects (pre-service education, experience, in-service training, absenteeism).

Furthermore, as we have noted, our estimation strategy is based on national samples, and this may hide important variations in the effects on student achievement of teacher characteristics and other variables in different types of schools and in different administrative regions or states within a country. Further research could focus on intra-national differences in the effects of teacher and other variables on achievement were the regional samples random. We do not attempt estimate cross-regional heterogeneity. We may capture the effects across types of schools, however, when we estimate variation in results across three SES groups within each country, since schools are generally rather stratified by student socio-economic background, and South Africa and Kenya are good examples of countries with high levels of SES stratification.

Table 2
Kenya, Swaziland, and South Africa SACMEQ Samples: Number of Observations, Means, and Standard Deviations of Student Characteristics and Classroom Characteristics, 2007.

Variable	South Africa		Swaziland		Kenya	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Student Characteristics and Family Academic Resources						
Student test score in Reading	492.27	127.43	549.39	64.31	543.11	102.97
Student test score in Mathematics	493.00	106.74	541.47	60.61	557.11	91.62
Female student (y/n)	0.508	0.571	0.500	0.508	0.497	0.533
Student never speaks English home (y/n)	0.239	0.476	0.237	0.444	0.098	0.333
Student speaks English home sometimes (y/n)	0.615	0.571	0.700	0.444	0.752	0.466
Student speaks English home most of the time (y/n)	0.081	0.286	0.047	0.190	0.100	0.333
Student speaks English home all the time (y/n)	0.065	0.286	0.016	0.127	0.050	0.266
Student SES	9.535	3.333	8.352	3.111	6.470	2.931
Number of books in home	21.153	68.384	13.779	39.232	16.769	81.056
Highest Level of Parents Education: primary or less (y/n)	0.257	0.476	0.269	0.444	0.358	0.533
Highest Level of Parents Education: some or all secondary (y/n)	0.344	0.476	0.345	0.508	0.368	0.533
Highest Level of Parents Education: some or all higher (y/n)	0.298	0.476	0.277	0.444	0.250	0.466
Highest Level of Parents Education: unknown or no parents (y/n)	0.100	0.381	0.109	0.317	0.024	0.133
Preschool was not taken (y/n)	0.266	0.476	0.342	0.508	0.053	0.266
Few months of preschool taken (y/n)	0.049	0.190	0.029	0.190	0.025	0.133
1 year of preschool taken (y/n)	0.330	0.476	0.431	0.508	0.496	0.533
2 years of preschool taken (y/n)	0.155	0.381	0.147	0.381	0.292	0.466
3 or more years of preschool taken (y/n)	0.200	0.476	0.051	0.190	0.134	0.333
Pre-school education taken (years)	2.973	1.619	2.535	1.270	3.429	0.999
Student repeated grades (y/n)	0.293	0.476	0.563	0.508	0.480	0.533
Student was not absent (y/n)	0.633	0.571	0.807	0.381	0.595	0.533
Student was absent 1 day a month (y/n)	0.161	0.381	0.098	0.317	0.148	0.400
Student was absent 2 days a month (y/n)	0.089	0.286	0.048	0.190	0.101	0.333
Student was absent 3 or more days a month (y/n)	0.116	0.381	0.047	0.190	0.156	0.400
Extra lessons in Reading outside school hours (y/n)	0.095	0.286	0.032	0.190	0.589	0.533
Extra lessons in Mathematics outside school hours (y/n)	0.098	0.286	0.033	0.190	0.641	0.533
Textbooks in Class						
Students had no Reading textbooks in class (y/n)	0.108	0.381	0.000	0.000	0.025	0.200
Reading Textbook shared with 2 or more students (y/n)	0.157	0.381	0.006	0.063	0.555	0.533
Reading Textbook shared with 1 student (y/n)	0.276	0.476	0.002	0.063	0.228	0.466
Personal Reading textbook used (y/n)	0.459	0.571	0.992	0.063	0.192	0.400
Students had no Mathematics textbooks in class (y/n)	0.271	0.476	0.000	0.000	0.030	0.200
Mathematics Textbook shared with 2 or more students (y/n)	0.120	0.381	0.000	0.000	0.570	0.533
Mathematics Textbook shared with 1 student (y/n)	0.232	0.476	0.001	0.063	0.232	0.466
Personal Mathematics textbook used (y/n)	0.377	0.571	0.998	0.063	0.168	0.400
Classmates' characteristics						
% Classmates with at least 1 parent having higher than secondary education	0.325	0.344	0.308	0.289	0.253	0.253
Classmates average SES	9.476	2.706	8.347	2.137	6.435	2.178
Number of Observations	9071		4030		4436	

Source: SACMEQ 2007 microdata, South Africa, Swaziland, and Kenya.

5. Results

5.1. Sample means of student, classroom, and teacher characteristics

Tables 2 and 3 present the means and standard deviations of all the variables we use in our analysis in South Africa, Swaziland, and Kenya. Table 2 presents the student and classroom characteristics, and Table 3, the means and standard deviations of teacher characteristics. Student test scores are about one-half a standard deviation higher in Swaziland and Kenya than in South Africa in reading and mathematics. Yet, student SES (SACMEQ index) is somewhat higher in South Africa than Swaziland and much higher

Table 3
South Africa, Swaziland, and Kenya: SACMEQ Samples: Number of Observations, Means, and Standard Deviations of Teacbers' Characteristics, by Subject Taught, 2007.

Variable	South Africa		Swaziland		Kenya	
	Mean	St. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Reading Teachers' Characteristics						
Teacher test score	755.02	89.84	767.46	62.53	791.44	60.01
Female teacher (y/n)	0.686	0.465	0.696	0.444	0.465	0.533
Teacher has primary education (y/n)	0.237	0.473	0.006	0.063	0.006	0.067
Teacher has junior secondary education (y/n)	0.016	0.095	0.000	0.000	0.015	0.133
Teacher has senior secondary education (y/n)	0.119	0.378	0.064	0.254	0.669	0.533
Teacher has A-level education (y/n)	0.161	0.378	0.598	0.508	0.272	0.466
Teacher has 1st degree of tertiary education or higher (y/n)	0.467	0.567	0.332	0.444	0.039	0.200
Teacher trained to teach this subject (y/n)	0.855	0.378	0.757	0.444	0.895	0.400
0-2 years of teacher training (y/n)	0.130	0.378	0.220	0.444	0.887	0.333
3 years of teacher training (y/n)	0.438	0.567	0.549	0.508	0.018	0.133
More than 3 years of teacher training (y/n)	0.431	0.567	0.230	0.444	0.095	0.333
0-5 years of teaching experience (y/n)	0.115	0.378	0.364	0.508	0.329	0.533
6–10 years of teaching experience (y/n)	0.104	0.284	0.206	0.381	0.099	0.333
11–15 years of teaching experience (y/n)	0.273	0.473	0.184	0.381	0.133	0.333
16–20 years of teaching experience (y/n)	0.201	0.473	0.086	0.317	0.249	0.466
21–25 years of teaching experience (y/n)	0.168	0.378	0.116	0.317	0.074	0.266
More than 25 years of teaching experience (y/n)	0.139	0.378	0.045	0.190	0.116	0.333
Number of days spent on in-service courses in last 3 years	17.640	61.067	3.966	6.983	29.946	78.858
Teacher's guide available (y/n)	0.867	0.378	0.983	0.127	0.953	0.266
Library/reference books for teachers available (y/n)	0.563	0.567	0.292	0.444	0.781	0.466
Principal never advise teacher on teaching (y/n)	0.102	0.284	0.115	0.317	0.021	0.133
Principal advise teacher on teaching once a year (y/n)	0.077	0.284	0.055	0.254	0.010	0.133
Principal advise teacher on teaching once a term (y/n)	0.336	0.473	0.489	0.508	0.201	0.400
Principal advise teacher on teaching once a month (y/n)	0.460	0.567	0.335	0.444	0.711	0.466
Teacher is a principal (y/n)	0.025	0.189	0.006	0.063	0.057	0.266
There is no education resource center (y/n)	0.599	0.567	0.035	0.190	0.271	0.466
Teacher visited resource center during school year (y/n)	0.291	0.473	0.396	0.508	0.417	0.533
Teacher workload (hours/week)	30.337	13.707	27.493	9.967	31.177	8.592
Number of days teacher was absent during a school year	19.662	21.269	8.189	14.728	11.602	16.318
Mathematics Teachers' Characteristics						
Teacher test score	762.83	114.10	811.828	90.773	898.379	98.578
Female teacher (y/n)	0.578	0.553	0.522	0.508	0.273	0.466
Teacher has primary education (y/n)	0.225	0.473	0.018	0.127	0.017	0.133
Teacher has junior secondary education (y/n)	0.019	0.189	0.006	0.063	0.029	0.200
Teacher has senior secondary education (y/n)	0.093	0.284	0.046	0.190	0.634	0.533
Teacher has A-level education (y/n)	0.171	0.378	0.643	0.508	0.282	0.533
Teacher has 1st degree of tertiary education or higher (y/n)	0.492	0.567	0.287	0.444	0.038	0.200
Teacher trained to teach this subject (y/n)	0.701	0.473	0.759	0.444	0.868	0.400
0-2 years of teacher training (y/n)	0.104	0.284	0.227	0.444	0.869	0.333
3 years of teacher training (y/n)	0.409	0.567	0.587	0.508	0.030	0.200
More than 3 years of teacher training (y/n)	0.488	0.567	0.185	0.381	0.101	0.333
0-5 years of teaching experience (y/n)	0.126	0.378	0.305	0.444	0.247	0.466
6-10 years of teaching experience (y/n)	0.098	0.284	0.267	0.444	0.171	0.400
11-15 years of teaching experience (y/n)	0.268	0.473	0.210	0.381	0.143	0.400
16-20 years of teaching experience (y/n)	0.258	0.473	0.109	0.317	0.207	0.466
21-25 years of teaching experience (y/n)	0.144	0.378	0.093	0.317	0.101	0.333
More than 25 years of teaching experience (y/n)	0.105	0.284	0.016	0.127	0.130	0.333
Days spent on in-service courses in last 3 years	12.241	39.892	5.822	11.744	25.634	63.739
Teacher's guide available (y/n)	0.811	0.473	0.980	0.127	0.935	0.333
Library/reference books for teachers available (y/n)	0.528	0.567	0.255	0.444	0.815	0.466
Principal never advise teacher on teaching (y/n)	0.109	0.378	0.139	0.317	0.028	0.200
Principal advise teacher on teaching once a year (y/n)	0.072	0.284	0.061	0.254	0.013	0.133
Principal advise teacher on teaching once a term (y/n)	0.326	0.473	0.460	0.508	0.226	0.466
Principal advise teacher on teaching once a month (y/n)	0.461	0.567	0.323	0.444	0.702	0.466
Teacher is a principal (y/n)	0.033	0.189	0.017	0.127	0.031	0.200
There is no education resource center (y/n)	0.624	0.567	0.029	0.190	0.303	0.533
Teacher visited resource center during school year (y/n)	0.256	0.473	0.436	0.508	0.411	0.533
Teacher workload (hours/week)	29.745	12.005	26.664	10.475	31.500	8.925
Number of days teacher was absent during a school year	19.685	20.702	7.636	12.443	8.700	9.524
Number of Observations	8936		4030		4436	

Source: SACMEQ 2007 Microdata, South Africa and Botswana.

than in Kenya, books in the home is also higher in South Africa, but parents' education is similar in South African and Swaziland, but higher than in Kenya. South African pupils were more likely to have been in pre-school than Swaziland pupils, but much less so than Kenyans and much more likely to be absent from school than Swazis, but less likely than Kenyans. On the other hand, in terms of classroom supplies, pupils in Swaziland were much more likely than either South Africans or Kenyans to have a textbook that they did not have to share with other pupils. The percent with their own textbooks is so high that we drop this variable for Swaziland in our analysis. Kenyan pupils were much more likely to take math and reading lessons outside of school than pupils in either Swaziland or South Africa.

Teacher characteristics also differ considerably between Swaziland, Kenya, and South African classrooms. Both reading and mathematics teacher test scores were significantly lower in South Africa than in the other two countries. South African teachers' reported pre-service preparation was more polarized than the generally secondary or A-level education taken by teachers in Swaziland and Kenya, and teachers in South Africa tended to be much older (more years of teaching experience). Further, principals were reported to have advised teachers on teaching more often in Swaziland and particularly in Kenya than in South Africa, and, notably, South African teachers reported being absent an average 20 days during the school years, many more than reported teacher absences in Swaziland and Kenya.

5.2. The relationship of teacher characteristics to student characteristics

Before turning to typical school production function ordinary least square (OLS) estimates of student achievement as a function of teacher and classroom characteristics, controlling for student characteristics (Eq. (1)), we apply a simple check for the non-random assignment of students to teachers (and vice-versa) in each of the three countries we study. If students of initially higher academic ability (unobserved, but proxied by students' SES, language spoken at home, and preschool taken) attend higher resourced schools, estimated teacher and school resource effects from cross-section estimates are much more likely to be upwardly biased.

The results for teacher test scores and absences in Table 4 suggest that South Africa's cross-section OLS estimates of student achievement are very likely to be upward biased, and Swaziland's results are much less likely to be biased, and Kenya's, somewhat likely to be biased. We related two teacher variables—teachers' test score and days of teacher absence to several measures of student family resources that could impact student capacity to achieve academically before and during schooling in the 6th grade. The student variables include gender, how much English the student speaks at home (the language of instruction in the 6th grade in all three countries is English), the student's SES index, and how much pre-school the student attended.

Table 4
South Africa and Botswana SACMEQ Samples: Teacher Subject Test Score and Absenteeism Related to Student Characteristics, 2007.

Variable	South Africa				Swaziland				Kenya			
	Reading		Mathematics		Reading		Mathematics		Reading		Mathematics	
	Teacher Reading Test OLS	Teacher Absence OLS	Teacher Math Test OLS	Teacher Absence OLS	Teacher Reading Test OLS	Teacher Absence OLS.	Teacher Math Test OLS	Teacher Absence OLS	Teacher Reading Test OLS	Teacher Absence OLS	Teacher Math Test OLS	Teacher Absence OLS
Female student (y/n)	−0.02	0.17	0.00	0.05	0.01	0.17	0.04	−0.11	−0.02	0.39	−0.02	−0.14
	(0.02)	(0.33)	(0.02)	(0.40)	(0.03)	(0.27)	(0.03)	(0.17)	(0.03)	(0.39)	(0.04)	(0.23)
Student speaks English home sometimes (y/n)	0.13**	−1.89*	0.06	−1.75**	0.03	−1.26	−0.09	−0.50	−0.16	−0.38	0.13	−0.41
	(0.05)	(1.14)	(0.06)	(0.88)	(0.08)	(1.07)	(0.09)	(0.62)	(0.11)	(1.55)	(0.11)	(0.70)
Student speaks English home most of the time (y/n)	0.56***	−5.28***	0.33***	−3.66***	0.11	−0.00	0.13	1.41	−0.09	−0.24	0.04	−0.63
	(0.10)	(1.65)	(0.10)	(1.33)	(0.15)	(2.19)	(0.14)	(2.66)	(0.13)	(1.83)	(0.15)	(0.98)
Student speaks English home all the time (y/n)	0.64***	−4.98***	0.56***	−3.75**	0.07	−1.81	0.01	−1.61	−0.08	−1.81	−0.08	−0.81
	(0.09)	(1.60)	(0.17)	(1.91)	(0.17)	(1.95)	(0.17)	(1.36)	(0.17)	(1.38)	(0.22)	(1.09)
Student SES	0.28***	−2.71***	0.26***	−2.47***	−0.00	0.79*	−0.04	0.45	0.07	−0.89	0.10**	−0.94**
	(0.03)	(0.58)	(0.03)	(0.66)	(0.04)	(0.42)	(0.04)	(0.31)	(0.04)	(0.62)	(0.05)	(0.36)
Few months of preschool taken (y/n)	0.04	0.47	0.11**	0.56	−0.02	−0.23	0.14	0.31	0.23	−1.51	−0.07	−1.68
	(0.08)	(1.17)	(0.06)	(0.85)	(0.11)	(1.31)	(0.09)	(0.74)	(0.15)	(2.57)	(0.14)	(1.25)
1 year of preschool taken (y/n)	0.03	−0.35	−0.00	0.31	−0.04	0.05	−0.03	0.20	−0.16*	−2.70	0.07	−0.66
	(0.04)	(0.81)	(0.04)	(0.77)	(0.07)	(0.73)	(0.06)	(0.44)	(0.09)	(2.06)	(0.10)	(1.04)
2 years of preschool taken (y/n)	0.16***	−2.71**	0.16***	−0.71	0.12	−0.65	−0.07	−0.33	−0.04	−1.04	0.13	−0.87
	(0.05)	(1.09)	(0.05)	(0.87)	(0.10)	(1.29)	(0.09)	(0.91)	(0.09)	(2.35)	(0.11)	(1.15)
3 or more years of preschool taken (y/n)	0.23***	−5.30***	0.18***	−3.68***	−0.11	0.32	−0.04	−0.80	−0.04	−1.47	0.04	−1.73
	(0.06)	(1.25)	(0.06)	(0.93)	(0.12)	(1.49)	(0.12)	(0.88)	(0.10)	(2.27)	(0.11)	(1.19)
Constant	−0.26***	22.94***	−0.20**	21.88***	−0.02	9.08***	0.05	7.99***	0.24*	13.69***	−0.16	10.03***
	(0.07)	(1.36)	(0.08)	(1.19)	(0.11)	(1.83)	(0.11)	(1.10)	(0.13)	(3.18)	(0.15)	(1.42)
Observations	8088	8936	7872	8936	4030	4030	4007	4030	4191	4436	4071	4436
R-squared	0.17	0.05	0.15	0.04	0.00	0.00	0.01	0.00	0.02	0.01	0.02	0.01

Note: Reference variables: Student never speaks English at home; No preschool taken. Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.Source: SACMEQ 2007 Microdata, South Africa and Botswana.

Table 5
South Africa and Botswana SACMEQ Samples: OLS Estimates of Teacher Characteristics on Student Standardized Mathematics Scores, by Student SES Index Levela, Controlling for Student and Classroom Characteristics, 2007.

Variable	South Africa			Swaziland			Kenya		
	Parents w/ Low SES	Parents w/ Middle SES	Parents w/ High SES	Parents w/ Low SES	Parents w/ Middle SES	Parents w/ High SES	Parents w/ Low SES	Parents w/ Middle SES	Parents w/ High SES
1. Student Controls									
Female student (y/n)	0.03	0.02	−0.09**	−0.18***	−0.11**	−0.24***	−0.23***	−0.28***	−0.23***
	(0.03)	(0.03)	(0.04)	(0.07)	(0.06)	(0.05)	(0.06)	(0.05)	(0.05)
Student speaks English home sometimes (y/n)	0.16***	0.21***	0.20***	0.14**	0.14**	0.10	0.09	0.14*	0.26***
	(0.04)	(0.04)	(0.07)	(0.07)	(0.06)	(0.08)	(0.08)	(0.08)	(0.10)
Student speaks English home most of the time (y/n)	0.05	0.14*	0.28***	0.06	0.30	0.17	0.11	0.20*	0.25*
	(0.07)	(0.08)	(0.10)	(0.19)	(0.21)	(0.16)	(0.12)	(0.11)	(0.13)
Student speaks English home all the time (y/n)	−0.09	0.31***	0.51***	−0.16	−0.08	−0.26	−0.20	−0.03	0.01
	(0.09)	(0.11)	(0.10)	(0.16)	(0.20)	(0.19)	(0.15)	(0.10)	(0.14)
Highest Level of Parents Education: primary or less (y/n)	−0.13	0.06	−0.01	0.11	0.02	−0.43**	0.32	0.01	−0.23*
	(0.08)	(0.05)	(0.15)	(0.30)	(0.09)	(0.19)	(0.20)	(0.07)	(0.13)
Highest Level of Parents Education: some or all secondary (y/n)	−0.08	0.02	−0.12***	0.18	0.16**	−0.22***	0.15	0.00	−0.10*
	(0.08)	(0.04)	(0.04)	(0.31)	(0.08)	(0.06)	(0.21)	(0.06)	(0.05)
Highest Level of Parents Education: unknown or no parents (y/n)	−0.04	−0.03	−0.14	0.15	0.02	−0.14	0.37	−0.13	0.23
	(0.09)	(0.06)	(0.11)	(0.31)	(0.13)	(0.09)	(0.25)	(0.17)	(0.16)
Few months of preschool taken (y/n)	−0.03	0.05	0.08	−0.13	−0.19	0.25	−0.15	0.13	−0.26
	(0.07)	(0.07)	(0.10)	(0.16)	(0.13)	(0.19)	(0.14)	(0.17)	(0.16)
1 year of preschool taken (y/n)	−0.02	0.05	0.15**	0.08	0.12*	0.09	0.00	0.37***	0.12
	(0.04)	(0.05)	(0.07)	(0.07)	(0.06)	(0.08)	(0.10)	(0.10)	(0.09)
2 years of preschool taken (y/n)	0.04	0.04	0.21***	0.03	0.19*	0.18**	−0.03	0.39***	0.20*
	(0.06)	(0.05)	(0.07)	(0.15)	(0.10)	(0.09)	(0.11)	(0.10)	(0.11)
3 or more years of preschool taken (y/n)	0.02	0.11**	0.33***	−0.05	0.09	0.34***	0.11	0.20*	0.11
	(0.05)	(0.05)	(0.06)	(0.20)	(0.15)	(0.13)	(0.13)	(0.11)	(0.11)
Student repeated grades (y/n)	−0.11***	−0.30***	−0.38***	−0.21***	−0.09	−0.32***	−0.20***	−0.14***	−0.21***
	(0.03)	(0.04)	(0.05)	(0.06)	(0.06)	(0.06)	(0.06)	(0.04)	(0.05)
Student was absent 1 day a month (y/n)	0.03	−0.03	0.02	0.07	0.04	0.00	0.09	−0.03	−0.10
	(0.04)	(0.05)	(0.05)	(0.09)	(0.10)	(0.10)	(0.08)	(0.06)	(0.07)
Student was absent 2 days a month (y/n)	−0.03	−0.07	0.06	0.30**	0.09	−0.14	−0.17**	−0.21***	−0.15*
	(0.06)	(0.06)	(0.08)	(0.13)	(0.14)	(0.12)	(0.08)	(0.08)	(0.08)
Student was absent 3 or more days a month (y/n)	0.03	−0.06	−0.02	0.15	−0.15	0.15	−0.09	−0.21***	−0.29***
	(0.05)	(0.05)	(0.07)	(0.12)	(0.12)	(0.14)	(0.08)	(0.06)	(0.09)
Textbook shared with two or more students (y/n)	−0.06	−0.18***	−0.23**	–	–	–	0.06	0.09	−0.00
	(0.05)	(0.05)	(0.08)	–	–	–	(0.08)	(0.07)	(0.07)
Textbook shared with 1 student (y/n)	0.06	0.05	−0.04	–	–	–	0.16*	0.15*	0.07
	(0.05)	(0.05)	(0.06)	–	–	–	(0.09)	(0.08)	(0.08)
Students had no textbooks in class (y/n)	−0.07	0.02	−0.08	–	–	–	−0.25*	−0.07	−0.58***
	(0.06)	(0.06)	(0.07)	–	–	–	(0.14)	(0.10)	(0.21)
Extra lessons in subject outside school hours taken (y/n)	0.15	−0.02	−0.15**	0.46*	−0.05	0.28	0.09	0.07	0.01
	(0.09)	(0.06)	(0.08)	(0.24)	(0.20)	(0.19)	(0.07)	(0.06)	(0.07)
Classmates' average test score in a subject	0.00*	0.00***	0.00***	−0.00	0.00	0.00	0.00***	0.00***	0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
2. Teacher/Classroom Resources									
Teacher test score (z-score)	0.05	0.10**	0.12***	−0.01	0.05	0.06	0.01	0.03	0.08**
	(0.04)	(0.04)	(0.03)	(0.05)	(0.04)	(0.04)	(0.04)	(0.03)	(0.03)
Female teacher (y/n)	0.05	0.08**	−0.04	0.02	−0.03	−0.10	0.16**	0.10	0.09
	(0.05)	(0.04)	(0.05)	(0.09)	(0.07)	(0.08)	(0.07)	(0.06)	(0.07)
Teacher trained to teach this subject (y/n)	−0.09	−0.04	0.03	0.23**	0.08	0.12	−0.02	−0.08	−0.08
	(0.06)	(0.06)	(0.06)	(0.11)	(0.10)	(0.09)	(0.13)	(0.09)	(0.14)
Teacher has primary education (y/n)	0.02	0.04	0.01	0.42**	0.21	0.83**	−0.17	−0.01	0.34
	(0.08)	(0.06)	(0.08)	(0.19)	(0.25)	(0.36)	(0.18)	(0.18)	(0.22)
Teacher has junior secondary education (y/n)	−0.09	−0.13	−0.02	–	–	–	−0.01	−0.03	0.55***
	(0.13)	(0.11)	(0.18)	–	–	–	(0.27)	(0.26)	(0.16)
Teacher has senior secondary education (y/n)	0.00	−0.05	−0.15*	0.16	−0.11	0.22	−0.04	−0.10*	0.11
	(0.10)	(0.07)	(0.08)	(0.15)	(0.14)	(0.40)	(0.08)	(0.06)	(0.08)
Teacher has 1st degree of tertiary education or higher (y/n)	0.06	−0.01	0.06	0.20*	0.20**	0.16**	0.18	0.00	−0.02

Table 5 (*Continued*)

Variable	South Africa			Swaziland			Kenya		
	Parents w/ Low SES	Parents w/ Middle SES	Parents w/ High SES	Parents w/ Low SES	Parents w/ Middle SES	Parents w/ High SES	Parents w/ Low SES	Parents w/ Middle SES	Parents w/ High SES
	(0.07)	(0.05)	(0.07)	(0.11)	(0.09)	(0.08)	(0.17)	(0.14)	(0.10)
6-10 years of teaching experience (y/n)	0.10	0.10	0.07	0.05	0.07	0.21*	0.15	0.09	0.34***
	(0.08)	(0.08)	(0.09)	(0.12)	(0.11)	(0.11)	(0.12)	(0.09)	(0.12)
11-15 years of teaching experience (y/n)	−0.01	0.06	−0.04	0.16	0.24**	0.15	0.27**	0.06	0.20*
	(0.08)	(0.09)	(0.10)	(0.11)	(0.11)	(0.11)	(0.12)	(0.09)	(0.11)
16-20 years of teaching experience (y/n)	−0.01	0.02	−0.06	−0.05	0.03	0.09	−0.06	−0.12	0.16
	(0.07)	(0.07)	(0.09)	(0.14)	(0.12)	(0.13)	(0.11)	(0.09)	(0.10)
21-25 years of teaching experience (y/n)	−0.08	−0.01	−0.00	−0.55	−0.18	0.02	−0.02	−0.05	0.10
	(0.07)	(0.08)	(0.10)	(0.34)	(0.22)	(0.18)	(0.13)	(0.10)	(0.10)
More than 25 years of teaching experience (y/n)	0.05	0.08	−0.00	−0.57	−0.31	−0.08	−0.06	0.05	0.00
	(0.10)	(0.09)	(0.11)	(0.42)	(0.68)	(0.18)	(0.17)	(0.12)	(0.11)
Number of days spent on in-service courses during last 3 years	−0.00	−0.00*	0.00	−0.00	0.00	0.00	0.00	−0.00	−0.00*
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Teacher's guide available (y/n)	0.04	−0.05	−0.08	−0.03	−0.05	0.02	−0.23	−0.51***	−0.17
	(0.08)	(0.10)	(0.14)	(0.34)	(0.26)	(0.16)	(0.18)	(0.15)	(0.12)
Library/reference books for teachers available (y/n)	0.05	0.08*	0.14**	−0.07	−0.03	0.19**	−0.07	0.07	0.11
	(0.05)	(0.04)	(0.06)	(0.10)	(0.09)	(0.09)	(0.09)	(0.09)	(0.10)
Principal never advise teacher on teaching (y/n)	0.03	−0.02	−0.05	0.07	0.14	−0.01	0.11	0.09	−0.16
	(0.06)	(0.06)	(0.08)	(0.14)	(0.11)	(0.11)	(0.18)	(0.12)	(0.17)
Principal advise teacher on teaching once a year (y/n)	0.09	−0.03	−0.12	−0.05	0.01	−0.09	0.33**	−0.23***	−0.14
	(0.13)	(0.07)	(0.10)	(0.16)	(0.14)	(0.15)	(0.16)	(0.08)	(0.24)
Principal advise teacher on teaching once a month (y/n)	0.06	0.04	0.07	−0.03	0.06	0.09	−0.05	0.06	0.04
	(0.06)	(0.04)	(0.05)	(0.10)	(0.10)	(0.10)	(0.10)	(0.06)	(0.07)
Teacher is a principal (y/n)	0.03	−0.02	−0.11	0.09	−0.14	0.00	0.07	0.28	0.03
	(0.07)	(0.10)	(0.12)	(0.38)	(0.36)	(0.23)	(0.30)	(0.25)	(0.13)
Number of days teacher was absent during a school year	−0.00	−0.00	−0.00***	0.00	0.00	0.00	−0.00	−0.01***	−0.01*
	(0.00)	(0.00)	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Constant	−1.53***	−2.17***	−2.02***	0.03	−0.30	0.05	−1.79***	−1.60***	−2.44***
	(0.55)	(0.42)	(0.29)	(1.06)	(1.02)	(0.65)	(0.63)	(0.43)	(0.38)
Observations	2496	2527	2017	1142	1197	1367	1060	1458	1259
R-squared	0.10	0.24	0.44	0.07	0.06	0.12	0.14	0.17	0.27

We used a standardized version of the SACMEQ SES index, each in South Africa, Swaziland, and Kenya, to construct three more or less equal size SES group—low, middle, and high. Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Reference variables: student never speaks English at home; highest level of parents education some college or more; student had no preschool education; student was never absent from school; student had personal textbook; teacher had A-level education; teacher has 0–5 years of experience; principal advises teacher once per term.Source: SACMEQ 2007 microdata, South Africa, Swaziland, and Kenya.

Table 4 shows that teachers in South Africa who are less likely to be absent from school teach students who speak more English at home, whose parents have higher SES, and students who have taken two or three years of pre-school. Teachers with higher subject test score tend to teach students who speak English at home most or all the time, whose parents have higher SES, and who have taken at least two years of pre-school. To the contrary, in Swaziland, these relations are very weak, at least for these two measures of teacher quality. In Kenya, there is also a tendency for teachers who teach higher SES students to have higher test scores and be absent less often, but these relationships are much smaller than in South Africa.

The Table 4 results draw a sharp contrast between the stratification of classrooms/schools in the three countries, especially between South Africa and Swaziland. Teacher subject knowledge and presence in school are more equally distributed in Swaziland and even Kenya than in South Africa.

5.3. Cross-section OLS estimates of student achievement in mathematics

The OLS estimates focus on mathematics achievement. We control for a number of student variables that are correlated with unobserved initial ability, but we know from longitudinal studies of student achievement that there is considerable variation in achievement among students with similar family academic resources (see, for example, Murnane et al., 1995; Carnoy et al., 2015a).

That said, the cross-section OLS estimates in Table 5 could be seen as a "upwardly biased" estimate of teacher and classroom effects on student achievement. The upward bias, according to the indications in Table 4, is probably greatest in South Africa and smallest in Swaziland. To strengthen our controls for possible selection of teachers on students with data available to us, we parameterize student family resources (the SACMEQ SES index) and estimate student achievement within three approximately equal size SES groups. In addition to showing the possible heterogeneity of the relation between classroom resources and student achievement across SES groups, we posit that the selection bias of students on schools is likely to be lower within student family resource groups, particularly in the lowest SES group, where there are fewer choices of schools of varying quality. For example, many of the lower SES students in our samples attend schools in rural areas, where there is essentially no school choice.

The results in Table 5 show interesting similarities and differences among countries in how student characteristics relate

Table 6
South Africa and Botswana: Student Cross-Subject Fixed Effect Estimates of Teacher Quality on Student Achievement, Classes with Different Teachers for Mathematics and Reading, by Gender, 2007.

Variable	All (Girls + Boys)			Boys Only			Girls Only		
	South Africa	Swaziland	Kenya	South Africa	Swaziland	Kenya	South Africa	Swaziland	Kenya
Teacher test score (z-score)	0.03	0.03	−0.02	0.03	0.02	−0.01	0.03	0.04	−0.03
	(0.02)	(0.03)	(0.02)	(0.02)	(0.04)	(0.02)	(0.02)	(0.03)	(0.02)
Female teacher (y/n)	0.03	0.15**	0.04	0.01	0.08	−0.04	0.05*	0.22***	0.12***
	(0.03)	(0.06)	(0.04)	(0.03)	(0.07)	(0.04)	(0.03)	(0.07)	(0.04)
Teacher trained to teach this subject (y/n)	−0.08**	−0.06	−0.00	−0.11***	−0.08	−0.04	−0.04	−0.04	0.05
	(0.03)	(0.07)	(0.06)	(0.04)	(0.08)	(0.07)	(0.04)	(0.08)	(0.08)
Teacher has primary education (y/n)	0.06	0.23	0.10	0.07	0.25	0.27**	0.05	0.19	−0.10
	(0.04)	(0.17)	(0.08)	(0.05)	(0.17)	(0.13)	(0.05)	(0.19)	(0.11)
Teacher has junior secondary education (y/n)	−0.01	–	−0.01	0.10	–	0.01	−0.11	–	−0.04
	(0.07)	–	(0.14)	(0.09)	–	(0.14)	(0.10)	–	(0.15)
Teacher has senior secondary education (y/n)	−0.00	−0.18	−0.03	−0.01	−0.13	0.01	0.01	−0.23*	−0.07*
	(0.05)	(0.13)	(0.03)	(0.06)	(0.15)	(0.04)	(0.06)	(0.13)	(0.05)
Teacher has 1st degree of tertiary education or higher (y/n)	0.07**	−0.12*	0.05	0.09**	−0.19**	0.09	0.06	−0.05	0.03
	(0.04)	(0.07)	(0.09)	(0.04)	(0.07)	(0.10)	(0.04)	(0.08)	(0.10)
6-10 years of teaching experience (y/n)	−0.11**	−0.01	−0.01	−0.10**	0.04	−0.00	−0.10*	−0.05	−0.03
	(0.05)	(0.07)	(0.04)	(0.05)	(0.08)	(0.05)	(0.06)	(0.09)	(0.06)
11-15 years of teaching experience (y/n)	−0.10**	−0.02	−0.01	−0.08*	0.00	0.03	−0.11**	−0.05	−0.07
	(0.04)	(0.08)	(0.05)	(0.05)	(0.09)	(0.06)	(0.05)	(0.10)	(0.06)
16-20 years of teaching experience (y/n)	−0.14***	−0.14	0.06	−0.10*	−0.15	0.09	−0.18***	−0.13	0.02
	(0.04)	(0.10)	(0.05)	(0.05)	(0.11)	(0.06)	(0.05)	(0.12)	(0.05)
21-25 years of teaching experience (y/n)	−0.04	−0.02	0.09	0.01	0.01	0.10	−0.10**	−0.05	0.07
	(0.05)	(0.11)	(0.06)	(0.05)	(0.12)	(0.07)	(0.05)	(0.14)	(0.07)
More than 25 years of teaching experience (y/n)	−0.05	0.17	−0.05	−0.02	0.12	−0.01	−0.07	0.24	−0.11*
	(0.04)	(0.19)	(0.06)	(0.05)	(0.23)	(0.07)	(0.05)	(0.20)	(0.06)
Number of days spent on in-service courses during last 3 years	0.00**	−0.00	−0.00	0.00	−0.00	−0.00	0.00***	−0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Teacher's guide available (y/n)	0.06	−0.27	0.29	0.10	−0.25	0.25*	0.02	−0.26	0.29
	(0.07)	(0.20)	(0.22)	(0.09)	(0.22)	(0.13)	(0.07)	(0.23)	(0.33)
Library/reference books for teachers available (y/n)	0.05	−0.07	0.06	0.06	−0.11	0.15**	0.04	−0.03	−0.05
	(0.03)	(0.09)	(0.05)	(0.04)	(0.10)	(0.06)	(0.04)	(0.10)	(0.07)
Principal never advise teacher on teaching (y/n)	0.00	0.03	0.02	0.01	0.11	0.06	−0.01	−0.04	−0.03
	(0.05)	(0.10)	(0.07)	(0.06)	(0.13)	(0.07)	(0.05)	(0.11)	(0.12)
Principal advise teacher on teaching once a year (y/n)	0.08	0.01	−0.07	0.12	−0.01	−0.28***	0.04	0.02	0.06
	(0.07)	(0.11)	(0.09)	(0.08)	(0.11)	(0.11)	(0.06)	(0.15)	(0.10)
Principal advise teacher on teaching once a month (y/n)	−0.01	0.02	−0.06	−0.00	0.07	−0.11**	−0.02	−0.03	−0.01
	(0.03)	(0.09)	(0.05)	(0.03)	(0.11)	(0.05)	(0.04)	(0.10)	(0.05)
Teacher is a principal (y/n)	−0.07	−0.05	−0.05	−0.08	−0.10	−0.25***	−0.06	0.01	0.14
	(0.05)	(0.16)	(0.09)	(0.06)	(0.22)	(0.09)	(0.06)	(0.18)	(0.10)
Number of days teacher was absent during a school year	−0.00	−0.00	0.00	−0.00**	−0.00	0.00	−0.00	−0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Textbook shared with two or more students (y/n)	0.01	–	0.02	0.03	–	−0.02	−0.00	–	0.07
	(0.03)	–	(0.04)	(0.05)	–	(0.06)	(0.04)	–	(0.06)
Textbook shared with 1 student (y/n)	0.01	–	0.02	−0.00	–	−0.02	0.02	–	0.08
	(0.03)	–	(0.04)	(0.03)	–	(0.06)	(0.03)	–	(0.06)
Students had no textbooks in class (y/n)	−0.01	–	0.03	0.03	–	−0.03	−0.06*	–	0.11
	(0.03)	–	(0.07)	(0.03)	–	(0.09)	(0.03)	–	(0.10)
Extra lessons in subject outside school hours taken (y/n)	−0.06*	0.23	0.09*	0.01	0.34*	0.09	−0.10**	0.22	0.08
	(0.04)	(0.22)	(0.04)	(0.05)	(0.18)	(0.06)	(0.04)	(0.27)	(0.06)
Classmates' average test score in a subject	−0.00	−0.01***	−0.00**	−0.00**	−0.01***	−0.00	0.00	−0.00**	−0.00**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	11522	6080	7222	5666	3030	3744	5856	3050	3478
R-squared	0.03	0.04	0.02	0.04	0.06	0.04	0.04	0.04	0.05
Number of individual pupils	5761	3040	3611	2833	1515	1872	2928	1525	1739

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; Reference variables: student had personal textbook; teacher had A-level education; teacher has 0-5 years of experience; principal advises teacher once per term.Source: SACMEQ 2007 microdata, South Africa, Swaziland, and Kenya.

to math performance: girls score much lower in math in Swaziland and Kenya, but generally not in South Africa; English language spoken at home has a positive and similar effect on math test scores in all three countries, greatest for higher SES students, whereas students who repeat grades, not surprisingly, universally have lower achievement. Years of pre-school are positively related to achievement, especially among higher SES students (for whom there may be greater opportunity to learn more challenging curriculum when they enter school with greater academic ability), and student absenteeism seems to have little or no relation to student performance except in Kenya.

According to these OLS results, the teacher characteristics and school resources that seem to matter for students' mathematics achievement are higher teacher mathematics scores, at least for South African middle and higher SES students and Kenyan higher SES students; the availability of textbooks – at least one for two

students – is positively and significantly correlated with student mathematics achievement except in Swaziland, where virtually all students have their own textbook; in Swaziland, having a teacher with a higher education degree; in some cases (South African middle SES students and Kenyan lower SES students). having a female teacher; for lower SES students in Swaziland not having a teacher with many years of experience, yet for middle SES students in Swaziland and middle and higher SES students in Kenya, having a teacher with more than 5 years of experience has positive effects on math achievement. Notably, teacher experience in South Africa, which varies considerably in the SACMEQ sample, is not related to student math outcomes in these OLS estimates. Notably as well, the high level of teacher absence in South Africa appears to have a significant negative relation with student math achievement only for higher SES students; and although teacher absence is less prevalent in Kenya, it is more of a factor for both middle and higher SES students' math performance.

These OLS results suggest that improving lower SES students' math scores in South Africa through adding teacher and other resources in the schools seems less likely than in Swaziland or Kenya, where there are at least a few resource correlates of higher student performance (younger teachers and teacher trained to teach the subject and with more years of teacher training in Swaziland, and teacher math knowledge, teacher experience, and more textbooks in Kenya). On the other hand, several teacher and classroom resources are correlated with the achievement of South African middle and higher social class students, as in Swaziland and Kenya. This could be the result of more variation in such teacher and other classroom resources in South Africa's middle and higher SES classrooms, and the probable greater self-sorting of middle and higher SES students into schools with, for example, more textbooks and teachers with higher math scores. Yet, it is also possible that these additional resources in higher SES schools are more likely to translate into more challenging course work.

5.4. Estimates of teacher/classroom resources on student achievement using student fixed effects

As described in our empirical strategy, estimating teacher and classroom resource effects for the same student across teachers with different characteristics teaching different subjects (with varying textbook availability, different relations with school principals, and different access to reference books and teacher guides) should yield unbiased estimates of these effects, assuming that students with a proclivity to do well is a particular subject are not assigned to teachers with particular characteristics, such as greater knowledge in that subject. Since we cannot control for students' previous ability (test scores or grades) in each subject, we cannot test for this possible bias. Nevertheless, we have evidence from our OLS estimates that female students generally score the same (Kenya) or higher (South Africa and Swaziland) in reading, but in Swaziland and Kenya, significantly lower in math. We can control for this possible source of bias from teacher non-random assignment to classes with female and male students by estimating achievement using student fixed effects separately for boys and girls. Similarly, we found that the coefficient of student SES (SACMEQ index) is much greater in estimates of reading achievement than of math, indicating that higher SES students tend to do relatively better in reading than in math (have a smaller difference in the two scores) compared to lower SES students. If, for example, lower SES students are more likely to face teachers with smaller differences in teacher subject matter knowledge, this would bias the effect of teacher knowledge downward We correct for this possible source of bias by estimating the effect of teacher characteristics and school resources on student achievement for three levels of student SES.

Table 6 shows the results of student achievement fixed effects estimates for boys and girls together and separately in South Africa, Swaziland, and Kenya. They are restricted to those students that have different teachers for reading and mathematics.[10] The results suggest that the effect of teacher test score is not significant either for male or female students in any of the three countries. But in all three countries, when female students have a female teacher, it has a significant impact on girls' academic achievement. The effect of a female teacher on girls' performance is especially large in Swaziland. Textbook availability is generally not an important factor in students' achievement except, again, for girls, and only in South Africa. Teacher pre-service education can have a significant effect on student performance, but the "optimum" level of education varies from country to country. Having a teacher with a university degree in South Africa has a positive effect on student achievement, but has a negative effect in Swaziland.[11] Most students in Kenya have teachers with senior secondary degrees, but for girls, having a teacher with that level of education has a negative effect on their academic performance. Teacher experience does not appear as significant in OLS estimates; yet, at least in South Africa, with its high percentage of more experienced teachers, greater teacher experience has a negative effect on student performance in the fixed effect results. Also, in South Africa a teacher trained in the subject matter has a negative effect on student achievement and in- service days has a positive effect (for girls). It is also noteworthy that in contrast to the OLS estimates, the fixed effect results show that teacher absence does have a significant effect in South Africa (for boys).

Two other variables that effect student performance are extra lessons outside of school hours (positive in Swaziland and Kenya, but negative in South Africa, especially for girls) and classmates' average test score in the subject (negative overall in Kenya and for boys in South Africa). Since only a small percentage of students take extra lessons in Swaziland and South Africa, the results could mean that students who take extra lessons in South Africa are doing so because they are doing poorly in the subject, whereas in Swaziland the gain is the result of students who are particularly good in one of the subjects trying to get even better. The most reliable estimate is for Kenya, where a high percentage of students take extra lessons. The negative result for classmates' average score suggests that students in Kenya (especially girls) and boys in South Africa do not do as well academically, the better other students are in the subject compared to them.

Table 7 shows the fixed effects for low, middle, and high SES groups. The results suggest, for example, that the positive effect of female teacher on girls' achievement we found in Table 6 is likely limited to middle and higher SES students in Swaziland, to higher SES students in Kenya, and in South Africa, may be biased upward, although is most likely to have an effect on higher SES girls. In Table 6 we found no effect of teacher subject knowledge on student achievement, but Table 7 shows that it has a positive effect on student performance in Swaziland for middle SES students, and in South Africa for higher SES students. This teacher subject knowledge effect suggests either that there is more variation in the test scores of math and reading teachers students face in middle and higher SES schools or that teacher subject knowledge is more likely to have an effect on students only when they are more academically able or have more support at home.

[10] In South Africa, 7688 of 9071 students in the sample (85%) have different teachers for math and reading. In Swaziland, 3298 of 4030 students (82%)have different teachers, and in Kenya, this is the case for 4316 of 4436 students (97%).

[11] Table 3 shows that 45% of South African and 33% of Swaziland 6th grade teachers reported having a university degree.

Table 7
South Africa, Swaziland, and Kenya: Student Cross-Subject Fixed Effect Estimates of Teacher Quality on Student Achievement, Classes with Different Teachers for Mathematics and Reading, by Socioeconomic Background, 2007.

Variable	Lower SES			Middle SES			Higher SES		
	South Africa	Swaziland	Kenya	South Africa	Swaziland	Kenya	South Africa	Swaziland	Kenya
Teacher test score (z-score)	−0.00	−0.07	−0.03	0.00	0.09***	−0.03	0.06***	0.04	0.00
	(0.03)	(0.04)	(0.02)	(0.03)	(0.03)	(0.02)	(0.02)	(0.03)	(0.02)
Female teacher (y/n)	−0.02	−0.04	0.01	0.04	0.16**	0.03	0.05	0.24***	0.08*
	(0.04)	(0.08)	(0.05)	(0.03)	(0.06)	(0.04)	(0.03)	(0.08)	(0.05)
Teacher trained to teach this subject (y/n)	−0.15***	−0.00	−0.04	−0.04	−0.07	0.01	−0.01	−0.09	0.02
	(0.05)	(0.07)	(0.08)	(0.04)	(0.07)	(0.06)	(0.05)	(0.10)	(0.10)
Teacher has primary education (y/n)	0.09	0.34*	0.10	0.01	0.05	0.23	0.10	0.24	−0.05
	(0.05)	(0.18)	(0.09)	(0.05)	(0.31)	(0.15)	(0.07)	(0.24)	(0.14)
Teacher has junior secondary education (y/n)	0.10	–	−0.00	−0.06	–	−0.01	0.08	–	−0.01
	(0.08)	–	(0.21)	(0.09)	–	(0.14)	(0.15)	–	(0.19)
Teacher has senior secondary education (y/n)	−0.03	0.10	−0.08	−0.01	−0.26**	−0.02	0.12	−0.37**	0.01
	(0.07)	(0.12)	(0.06)	(0.07)	(0.13)	(0.04)	(0.08)	(0.19)	(0.05)
Teacher has 1st degree of tertiary education or higher (y/n)	0.16***	−0.14	−0.05	0.02	−0.26***	0.01	0.10*	0.01	0.17
	(0.05)	(0.09)	(0.12)	(0.05)	(0.07)	(0.11)	(0.05)	(0.09)	(0.12)
6-10 years of teaching experience (y/n)	−0.18***	−0.03	−0.02	−0.12**	−0.02	−0.02	−0.06	0.01	−0.02
	(0.06)	(0.08)	(0.06)	(0.06)	(0.08)	(0.05)	(0.08)	(0.10)	(0.07)
11-15 years of teaching experience (y/n)	−0.05	−0.01	−0.09	−0.13***	−0.01	−0.03	−0.17**	−0.07	0.10
	(0.06)	(0.10)	(0.09)	(0.05)	(0.09)	(0.06)	(0.08)	(0.11)	(0.07)
16-20 years of teaching experience (y/n)	−0.13*	−0.27**	0.06	−0.15***	−0.19*	0.03	−0.18***	0.00	0.12*
	(0.07)	(0.11)	(0.07)	(0.05)	(0.11)	(0.06)	(0.06)	(0.12)	(0.06)
21-25 years of teaching experience (y/n)	−0.02	−0.01	−0.01	−0.09*	−0.02	0.09	−0.09	0.04	0.13
	(0.06)	(0.14)	(0.07)	(0.05)	(0.10)	(0.07)	(0.07)	(0.15)	(0.09)
More than 25 years of teaching experience (y/n)	−0.01	−0.35	−0.11	−0.09	0.18	−0.08	−0.06	0.47**	0.05
	(0.06)	(0.24)	(0.09)	(0.06)	(0.21)	(0.07)	(0.07)	(0.19)	(0.07)
Number of days spent on in-service courses during last 3 years	−0.00	0.00	0.00	0.00***	0.00	−0.00	0.00***	−0.00	−0.00
	(0.00)	(0.01)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Teacher's guide available (y/n)	0.15	0.08	0.31	−0.02	−0.35	0.07	0.07	−0.37**	0.54**
	(0.13)	(0.22)	(0.22)	(0.06)	(0.25)	(0.24)	(0.06)	(0.14)	(0.25)
Library/reference books for teachers available (y/n)	0.05	−0.01	−0.02	0.06	0.01	0.13**	0.02	−0.25**	0.04
	(0.06)	(0.09)	(0.08)	(0.03)	(0.09)	(0.06)	(0.05)	(0.13)	(0.07)
Principal never advise teacher on teaching (y/n)	0.15**	0.06	0.20*	−0.05	0.08	0.01	−0.15**	0.04	0.01
	(0.06)	(0.22)	(0.11)	(0.06)	(0.10)	(0.08)	(0.08)	(0.12)	(0.16)
Principal advise teacher on teaching once a year (y/n)	0.23**	−0.08	0.06	0.13	−0.10	−0.15	−0.12**	0.13	−0.04
	(0.09)	(0.15)	(0.13)	(0.09)	(0.10)	(0.12)	(0.06)	(0.16)	(0.15)
Principal advise teacher on teaching once a month (y/n)	0.07	0.03	−0.02	−0.02	0.02	−0.08	−0.06	0.10	−0.04
	(0.05)	(0.10)	(0.06)	(0.03)	(0.10)	(0.06)	(0.06)	(0.11)	(0.06)
Teacher is a principal (y/n)	−0.02	−0.32	−0.11	−0.06	0.14	0.01	−0.22**	0.02	−0.04
	(0.05)	(0.24)	(0.11)	(0.07)	(0.25)	(0.11)	(0.10)	(0.21)	(0.13)
Number of days teacher was absent during a school year	−0.00	−0.01**	−0.00	−0.00	−0.00**	0.00	−0.00***	−0.00	0.00**
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Textbook shared with two or more students (y/n)	0.06	–	0.07	0.01	–	0.01	−0.00	–	−0.00
	(0.05)	–	(0.07)	(0.04)	–	(0.07)	(0.07)	–	(0.08)
Textbook shared with 1 student (y/n)	0.07*	–	0.01	−0.01	–	0.08	−0.02	–	0.01
	(0.04)	–	(0.07)	(0.04)	–	(0.07)	(0.04)	–	(0.07)
Students had no textbooks in class (y/n)	0.08*	–	0.02	−0.04	–	0.14*	−0.07*	–	−0.15
	(0.05)	–	(0.11)	(0.04)	–	(0.08)	(0.04)	–	(0.18)
Extra lessons in subject outside school hours taken (y/n)	−0.00	0.18	0.15*	−0.16**	−0.22	0.13*	−0.04	0.34*	−0.01
	(0.06)	(0.13)	(0.09)	(0.07)	(0.41)	(0.06)	(0.06)	(0.20)	(0.06)
Classmates' average test score in a subject	−0.00	−0.01***	−0.00	−0.00***	−0.01***	−0.00	−0.00	−0.00***	−0.00***
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Observations	3962	1926	2028	4272	1970	2810	3288	2184	2384
R-squared	0.06	0.11	0.04	0.05	0.07	0.04	0.06	0.06	0.06
Number of individual pupils	1981	963	1014	2136	985	1405	1644	1092	1192

Robust standard errors in parentheses: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; Reference variables: student had personal textbook; teacher had A-level education; teacher has 0–5 years of experience; principal advises teacher once per term.Source: SACMEQ 2007 microdata, South Africa, Swaziland, and Kenya.

Notably, the positive effect of teachers with higher education in South Africa is largest for low SES students, and the largest negative effect of senior secondary teachers in Swaziland are for middle and higher SES students. This could be a “type of school” variation—in other words, adding university trained teachers in lower SES schools in South Africa could have a large effect on student achievement, but not in middle and higher SES schools.

Table 7 also shows that more teacher experience has a negative effect on South African student achievement across student SES groups, that the negative effect of teacher trained in the subject matter is significant (and large) only for South Africa’s lower SES students, and that the positive effect of teacher in-service training is limited to middle and higher SES students. Other interesting results are that in South Africa, lower SES students do better academically when the principal rarely advises their teacher, but higher SES students do better when teacher is advised more often (and when the teacher is not the principal). Further, the negative effect on a student’s achievement in Swaziland of being in a class with higher scoring students cuts across SES groups (as it did for both boys and girls); in South Africa, it affects only middle SES

Table 8
South Africa and Swaziland: Student Cross-Subject Fixed Effect & Teacher Fixed Effect Estimates of Teacher Quality on Student Achievement, Classes with the Same Teacher for Mathematics and Reading, by Gender and Socioeconomic Background, 2007.

	South Africa		Swaziland		South Africa			Swaziland		
	Boys	Girls	Boys	Girls	Low SES	Middle SES	High SES	Low SES	Middle SES	High SES
Teacher test score (z-score)	0.06	0.08	0.08	0.04	0.05	0.05	0.12*	0.07	0.09	0.05
	(0.07)	(0.07)	(0.06)	(0.06)	(0.07)	(0.08)	(0.06)	(0.08)	(0.07)	(0.06)
Textbook shared with two or more students (y/n)	−0.02	−0.19**			−0.26***	−0.11	0.16			
	(0.09)	(0.09)			(0.08)	(0.15)	(0.18)			
Textbook shared with 1 student (y/n)	−0.08	−0.31***			−0.28***	−0.27***	−0.01			
	(0.08)	(0.07)			(0.08)	(0.10)	(0.11)			
Students had no textbooks in class (y/n)	−0.25**	−0.20			−0.27***	−0.46**	−0.12			
	(0.10)	(0.13)			(0.10)	(0.18)	(0.15)			
Extra lessons in subject outside school hours taken (y/n)	0.06	−0.30***	0.53***	0.26	−0.15	−0.14	−0.18	1.13***	0.34**	0.39**
	(0.19)	(0.09)	(0.10)	(0.18)	(0.19)	(0.21)	(0.11)	(0.01)	(0.13)	(0.16)
Classmates' average test score in a subject	−0.00**	−0.00	−0.01***	−0.01*	−0.00***	−0.00	0.00	−0.01***	−0.01***	−0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Teacher trained to teach this subject (y/n)	−0.12	−0.05	0.10	0.11	−0.22	−0.26***	0.32***	0.32***	0.02	−0.00
	(0.11)	(0.09)	(0.12)	(0.13)	(0.14)	(0.10)	(0.08)	(0.11)	(0.12)	(0.18)
Teacher's guide available (y/n)	−1.32***	−1.07***	−0.65***	−0.09	−1.57***	−1.27***	−1.16***	−0.60***	−0.15**	−0.08
	(0.10)	(0.15)	(0.06)	(0.07)	(0.11)	(0.17)	(0.21)	(0.08)	(0.06)	(0.06)
Observations	874	862	660	672	726	498	512	358	424	550
Adjusted R-squared	0.10	0.14	0.08	0.02	0.12	0.18	0.17	0.15	0.06	0.02
Number of individual pupils	437	431	330	336	363	249	256	179	212	275

Note: We used a standardized version of the SACMEQ SES index to construct three approximately equally sized SES groups: low SES, middle SES, and high SES. Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; Reference variable: student had personal textbook.Source: SACMEQ 2007 microdata, South Africa and Botswana.

students, and in Kenya, only higher SES students. Extra lessons have a positive effect on lower and middle SES students' achievement in Kenya, and, in Swaziland, significantly impact only higher SES students. The finding for South Africa in Table 6 that extra lessons have a negative effect on girls' achievement is shown in Table 7 to be a middle SES phenomenon.

5.5. Estimates of teacher/classroom resources on student achievement using student fixed effects and teacher fixed effects

In South Africa and Swaziland, about 15% of the students in the SACMEQ samples were in classrooms where the same teacher taught both reading and mathematics. We estimated the effect of differences in teacher content knowledge of reading and math as measured by teacher tests in both subjects, whether the teacher was trained to teach the subject, whether the student took extra lessons (outside school) in the subject, the average test score in the student's class in that subject, the availability of a teacher guide, and, in South African, the effect of textbook availability (essentially all students in Swaziland had their own textbook). Such student fixed effect/teacher fixed effect estimates have the advantage of controlling for unobserved teacher characteristics such as teaching style and language ability. The disadvantage is that we can only estimate the effects of a few variables on student achievement, since variables such as teacher gender, experience, education, and training do not vary across the same teacher. In addition the 15% of students in such single teacher classes would tend not to be representative of students in the larger education system dominated by schools with teachers teaching single subjects. Since only 120 students in the Kenya sample had the same teacher (teacher data were available for only 105 of the 120), we do not report the results of those estimates.

The results in Table 8 have many consistencies with the results in Tables 6 and 7, but some major differences. As in Table 7, teacher subject knowledge (subject test score) has a positive effect on student achievement in South Africa only for higher SES students. The teacher subject knowledge effect is also significant for middle SES students in Swaziland (as in Table 7) when other variables are not included in the regression. The fact that the teacher is trained in the subject has a large and negative for South African lower SES students in Table 7, but rather for middle SES students in Table 8, and has a positive effect on achievement of higher SES students in South Africa and lower SES students in Swaziland. Classmates' average test score in the subject is significant in South Africa for boys and lower SES students in these same teacher estimates, and is generally consistent with Table 7 results for Swaziland. Extra lessons are much more important in these teacher fixed effects estimates for Swaziland and their impact on girls' performance in South Africa is larger. Two major differences in Table 8 results are that (a) the availability of textbooks for each student has a large effect on South African students' achievement, particularly for girls and lower and middle SES students, and (b) the availability of a teacher's guide has a consistently large negative effect on student achievement in both countries, whereas in Table 7, this negative effect is restricted to higher SES students in Swaziland. We speculate that this is a proxy for the teacher using such a guide to overcome difficulties in teaching the subject.

6. Conclusions

Our estimates of the relationship between teacher characteristics/teaching practices and student achievement in these three countries eliminate most selection bias and so approach causality. To deal with some remaining threats to validity of the student fixed effects analysis, we have presented estimates separately for male and female students and for students with different levels of family academic resources, taking into account the probability that boys tend to perform better in math and girls in reading, and that higher SES students tend to perform even better in reading relative to lower SES students than in math. However, the results are still subject to the assumption that a particular teacher characteristic or teaching process has a similar impact on student reading and student math achievement. This assumption should be kept in mind in considering the validity of our results showing that certain teacher and other variables would improve student outcomes in African schools.

- Assigning girls more consistently to female teachers may improve girls' academic achievement across three very different African contexts;

- Increasing teacher subject knowledge in some countries (Swaziland and South Africa) would probably contribute to higher student achievement, but more likely for middle and higher SES students (or perhaps in schools that cater to middle and higher SES students)—yet, the fact that teachers with university degrees have a positive effect on low SES student achievement in South Africa may also be an indicator of a subject knowledge impact in that group of students (or schools).
- Reducing teacher absence also seems to contribute to higher achievement for lower SES students in Swaziland, where teacher absenteeism is low—however, in South Africa, the country with the highest teacher absenteeism, reducing days absent only seems to be related positively to higher SES students' achievement;
- Extra lessons in reading and math outside school hours seem to help certain SES groups of students in Swaziland and Kenya improve their achievement scores, but for South African middle SES students, the effect is negative, suggesting that the extra lessons in South Africa may be remedial rather than for "advantage";
- In Swaziland and Kenya, being more careful to not place students in classes with students of much higher ability in math or reading could help students perform better;

Although we find some commonalities across our three countries in the fixed effects results, there are also major differences that seem consistent with the different contextual conditions in each country. For example, it is logical that in South Africa, higher teacher experience negatively impacts student achievement because of the Apartheid conditions in South Africa when older teachers were trained. Decades of Apartheid still impacts South African schooling. That logic does not obtain in Kenya and Swaziland, where more years of experience generally have a positive or neutral effect. Older teachers in Swaziland and Kenya were prepared in quite strong A-level or senior secondary teacher training colleges, and those with 0–5 years teaching experience or less in Swaziland, in post-secondary teacher training colleges and universities. Perhaps because teachers with that level of education have less experience, students who have such more highly trained teachers have lower levels of achievement.

Shepard (2015) estimated a positive but small effect of teacher subject knowledge test score on student achievement in South Africa. We find a somewhat larger effect, but only for higher SES students (or perhaps higher SES schools). This is also the case for the student fixed effects/teacher fixed effects model. We also find some evidence of a teacher subject knowledge effect on student performance in Swaziland for middle class students. It is worth noting, however, that both Shepard's and our estimates of the effect of higher teacher content knowledge are rather small: a one standard deviation increase in teacher test score (90–110 points in South Africa and 60–90 points in Swaziland) could result in less than 0.10 standard deviation increase in student achievement (about 6–10 points in South Africa and 4–6 points in Swaziland). In contrast, putting more girls with female teachers in both countries could result in a similar increase in (girls') test scores in South Africa and a much greater increase in Swaziland. That policy would also benefit girls in Kenya. Similarly, retiring older teachers to replace them with much younger, university educated hires could result in larger increases in student achievement than evidenced by increasing the subject knowledge of existing teachers, although younger, more educated teachers should also have greater subject matter knowledge.[12]

Our results therefore provide some evidence that it could be possible to raise student learning in all three countries through quite achievable educational interventions. It does appear, however, that the interventions would, in many instances, be different across countries, across student social class groups (this could mean across different types of schools) and between male and female students.

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Appendix.

See Table A1.

[12] We also have some evidence (from the student fixed effect/teacher fixed effect estimates) for South Africa that providing personal textbooks to students would have a very large impact on student achievement. Thus, students with the same teacher who have personal textbooks in one subject but not the other score about a 0.25 standard deviations higher in the course with the textbook (Table 8). However, because we find little evidence of a textbook effect in South Africa in our estimates when student have different teachers, the textbook teacher fixed effects results should be interpreted with care.

Table A1
South Africa, Swaziland, and Kenya: Mean Differences in Math and Reading Teacher Characteristics for Students With Different Teachers in Mathematics and Reading, SACMEQ 2007.

Variable	South Africa		Swaziland		Kenya	
	Mean Difference Between Teachers	Std. Dev.	Mean Difference Between Teachers	Std. Dev.	Mean Difference Between Teachers	Std. Dev.
Extra lessons in subject outside school hours taken (y/n)	−0.001	0.263	−0.001	0.115	−0.053	0.394
Students had no textbooks in class (y/n)	−0.171	0.526	−0.000	0.000	−0.005	0.197
Textbook shared with two or more students (y/n)	0.036	0.438	0.006	0.057	−0.015	0.394
Textbook shared with 1 student (y/n)	0.056	0.526	−0.001	0.057	−0.004	0.394
Personal textbook used (y/n)	0.079	0.526	−0.006	0.115	0.024	0.328
Teacher test score	−9.307	111.386	−46.247	107.333	−107.632	113.569
Teacher test score (z-score)	0.006	1.123	0.000	1.378	−0.001	1.495
Female teacher (y/n)	0.134	0.679	0.213	0.574	0.196	0.723
Teacher has primary education (y/n)	0.015	0.614	−0.014	0.172	−0.011	0.197
Teacher has junior secondary education (y/n)	−0.004	0.175	−0.007	0.057	−0.014	0.197
Teacher has senior secondary education (y/n)	0.031	0.438	0.021	0.345	0.035	0.657
Teacher has A-level education (y/n)	−0.012	0.526	−0.055	0.574	−0.011	0.657
Teacher has 1 st degree of tertiary education or higher (y/n)	−0.030	0.701	0.054	0.574	0.001	0.263
Teacher trained to teach this subject (y/n)	0.160	0.614	0.004	0.574	0.028	0.460
0-2 years of teacher training (y/n)	0.031	0.438	−0.008	0.632	0.018	0.460
3 years of teacher training (y/n)	0.036	0.701	−0.046	0.689	−0.012	0.197
More than 3 years of teacher training (y/n)	−0.067	0.701	0.054	0.517	−0.006	0.394
0-5 years of teaching experience (y/n)	−0.014	0.526	0.072	0.574	0.083	0.657
6-10 years of teaching experience (y/n)	0.008	0.438	−0.075	0.632	−0.073	0.526
11-15 years of teaching experience (y/n)	0.005	0.614	−0.032	0.574	−0.010	0.526
16-20 years of teaching experience (y/n)	−0.068	0.614	−0.028	0.459	0.043	0.591
21-25 years of teaching experience (y/n)	0.028	0.526	0.028	0.402	−0.028	0.460
More than 25 years of teaching experience (y/n)	0.041	0.526	0.035	0.230	−0.015	0.460
Number of days spent on in-service courses during last 3 years	6.429	77.423	−2.264	12.404	4.390	97.296
Teacher's guide available (y/n)	0.062	0.526	−0.007	0.172	0.018	0.263
Library/reference books for teachers available (y/n)	0.042	0.614	0.045	0.459	−0.035	0.460
Principal never advise teacher on teaching (y/n)	−0.008	0.438	−0.029	0.345	−0.008	0.197
Principal advise teacher on teaching once a year (y/n)	0.006	0.351	−0.008	0.345	−0.004	0.131
Principal advise teacher on teaching once a term (y/n)	0.013	0.614	0.036	0.517	−0.026	0.526
Principal advise teacher on teaching once a month (y/n)	−0.000	0.701	0.015	0.459	0.010	0.591
Teacher is a principal (y/n)	−0.011	0.263	−0.014	0.115	0.027	0.328
There is no education resource center (y/n)	−0.030	0.526	0.007	0.057	−0.032	0.328
Teacher visited resource center during school year (y/n)	0.043	0.526	−0.048	0.517	0.006	0.591
Teacher workload (h/week)	0.705	13.152	1.010	10.280	−0.329	9.920
Number of days teacher was absent during a school year	−0.028	25.077	0.674	16.941	2.955	17.869
Number of observations	7,688		3,298		4,316	

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