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Do the maths: An analysis of the gender gap in mathematics in Africa

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ABSTRACT

This paper uses microdata for 19 African countries to examine the gender difference in maths test scores amongst primary school children. There is a significant difference in maths test scores in favour of boys, similar to that previously observed in developed countries. This difference cannot be explained by gender differences in school quality, home environment, or within-school gender discrimination in access to schooling inputs. However, the gender gap varies widely with characteristics of the regions in which the pupils live, and these regional characteristics are more predictive of the gender gap than parental education and school characteristics, including teacher gender. At the cross-country level, differences in fertility rates account for nearly half the variation in the gender gap, and this relationship is not due to the correlation between fertility and GDP.

1. Introduction

There is widespread evidence of the existence of a female disadvantage in performance in mathematics tests in high- and middle-income countries (e.g., Fryer & Levitt, 2010; Guiso, Monte, Sapienza, & Zingales, 2008; Hedges & Nowell, 1995). The causes underlying these differences remain the subject of much debate. In the literature focussing on developing countries, an increasingly important theme has been the study of female discrimination in human capital accumulation. However, few studies have investigated gender differences in test scores, and instead the focus has been on school enrolment and, to a lesser extent, grade completion. Skills acquired matter more for individual labour market outcomes and growth than mere attendance (Hanushek & Woessman, 2008), and so evidence on the former is needed. Estimates of the impact of cognitive skills on earnings are scarce outside developed countries. However, returns to cognitive skills are generally estimated to be large, and where maths and reading skills are considered separately, maths skills appear to matter more for income (Glewwe, 1996; Jolliffe, 1998 for Ghana; Moll, 1998 for South Africa), thus justifying our focus here on maths scores.

Two main types of arguments have been suggested to explain the gender gap in mathematics test scores documented in developed countries. A first potential explanation is the biological one that boys are genetically more able mathematically. In a recent critical review in which she refutes each claim in turn, Spelke (2005) summarises the three most prominent genetic arguments: (i) male infants' inherent larger interest in objects *versus* people; (ii) gender-specific profiles in spatial and numerical abilities leading to a greater aptitude for mathematics; and (iii) higher dispersion of male than female performance in quantitative and spatial ability,

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so that larger numbers of men have unusually high scores. For example, Machin and Pekkarinen (2008) clearly show that maths tests scores at age 15 are more dispersed among males than females in most OECD countries. Similarly, Ellison and Swanson (2010) document the universal over-representation of males in International Mathematical Olympiads, in which participants are under 20 years old. However, neither finding necessarily implies higher dispersion in intrinsic ability since societal factors can influence these outcomes.

Lack of suitable data prevents us from casting direct light on the importance of genetic factors. One way in which our findings speak to the biological argument, however, is that we find that the size of the gender gap varies widely across individuals with different characteristics, both within and between countries, and indeed becomes insignificant in some strata of the population. Thus, any explanation based on biology would have to be able to account for these differences i.e., by invoking an interaction of nature and nurture rather than nature alone.

Instead, we focus on the second group of explanations which have been suggested, namely cultural or societal explanations for the gender gap. Here we test for two possibilities. First, it could be that observable factors that influence mathematics tests scores vary systematically across the genders, with boys having observable characteristics that lead to higher test scores. It could, for instance, be the case that parents send their sons to better schools than their daughters, or that teachers discriminate against girls in the allocation of schooling inputs. If girls indeed face poorer observable schooling experiences than boys, then after controlling for such characteristics, the gender gap should disappear. The second possibility is that, although girls do not have observable characteristics that are less conducive to performing well in maths tests than boys, family, school and societal influences affect boys and girls differently in ways that we do not directly observe. For instance, some of these influences could result in genuine or perceived gender-specific returns to maths skills or in stereotype threats (i.e. “situation[s] where one faces judgement on societal stereotypes about one’s group” (Spencer et al., 1999, p.5)), that are not captured by our individual regressors. We investigate this second possibility by studying the interaction between female gender and various indicators of societal influences measured at the household-, school-, and (sub-national) region level, to determine whether the size of the gender gap varies with such influences.

We use data from two surveys of primary school pupils in Africa, namely the ‘Southern and Eastern African Consortium for Monitoring Educational Quality’ (SACMEQ) and the ‘Program for the Analysis of Education Systems’ (PASEC), which together cover 19 countries and nearly 50,000 pupils in Sub-Saharan Africa. We merge these data with relevant characteristics of 139 sub-national regions in which the pupils live based on microdata taken from available Demographic and Health Surveys (DHS).

We contribute to the maths gender gap literature in several ways. First, we are the first to document the ubiquity of a gender gap in mathematics in Sub-Saharan African countries. We find that the size of the gap (0.1 standard deviations (sd) or 4–5% of the male mean grade towards the end of primary school) is of the same order of magnitude as that observed in developed countries.[1] Second, we are able to rule out a number of potential explanations for the existence of this gap, including gender differences in school quality, within-school discrimination in access to schooling inputs and lower parental investments in female schooling conditional on enrolment. Third, we show that girls only perform substantially less well than boys in maths in some societal environments, and that characteristics of the societies children grow up in are more predictive of the gender gap than parental education and school characteristics, including teacher gender. Fourth, we show that, in Sub-Saharan Africa, differences in fertility rates account for nearly half the cross-country variation in the gender gap, and this relationship is not due to the correlation between fertility and GDP per capita or between fertility and gender (in)equality in the labour market and political sphere. Our findings therefore suggest that a gender gap in maths performance is observed in Africa too, but that it is not due simply to inherent, genetic differences between genders *per se*; specific environmental factors are required in order for any genetic difference to translate into substantially lower average female performance in maths.

Given the non-experimental nature of the data, we do not give a causal interpretation to the estimated effect of the variables entering the standardised maths score production function. Instead, we aim to shed light on the broad nature of the gender gap by answering the following questions: Can the gap be accounted for by differences in school quality, within-school discrimination in access to schooling inputs, differences in parental socio-economic status, or differential investments in schooling, such as help with maths school work and child labour? Under what circumstances does the gap arise? To what extent can biology account for the observed gap(s)? Are the same societal explanations valid uniformly across developed and developing countries?

Given the lower enrolment rates of girls compared to boys in developing countries, and especially so in Sub-Saharan Africa, we expect the girls we observe in our in-school samples to be more positively selected than the boys (Glick, 2008). We are not aware of a survey of African children that applied an internationally comparable test to all, irrespective of school enrolment status. By controlling for a wide range of observable characteristics, we expect to reduce much of the differential selection into enrolment between boys and girls. The remaining selection bias should work against finding a female disadvantage and so our estimates should be seen as lower bounds of the true gender gap in maths in Sub-Saharan Africa. Similarly, any selection bias should work against finding a lower gender gap in the circumstances under which we observe a lower gender gap.

The remainder of the paper is structured as follows. The next section summarises the most relevant literature. Section 3 describes the data sources employed. Section 4 documents the gender gap in the raw data and motivates the regression analysis, Section 5 presents the regression results and discussion, and, finally, Section 6 concludes.

[1] For example, 2% of the male mean in PISA countries at age 15 (Guiso et al., 2008), and 0.2 sd in the US in fifth grade (Fryer and Levitt, 2010).

2. Literature review

Previous research by social scientists and economists has explored potential explanations of the maths gender gap based on societal factors. Typically, the approach taken has been to test whether cross-country or cross-US state differences in gender differentials can be accounted for by differences in female status. In 39 middle- to high-income countries taking part in the 2003 Programme for International Student Assessment (PISA), Guiso et al. (2008) show that up to a third of the cross-country variation in the female maths gap can be accounted for by differences in GDP per capita and in indicators of gender inequality as measured by the 'Gender Gap Index' (GGI). The GGI comprises four sub-indexes: (i) economic participation and opportunity as measured by a weighted mean of 5 ratios, namely the ratio of female-to-male: labour force participation; wages; earned income; legislators, senior officials and managers; professional and technical workers; (ii) educational attainment as measured by the weighted mean of four ratios: literacy rate; net enrolment in: primary; secondary; and tertiary schooling; (iii) health and survival calculated as the weighted mean of female-to-male healthy life expectancy and female-to-male sex ratio at birth; (iv) political empowerment computed as the weighted average of the women-to-men ratio of seats in parliament; ministers; and female-to-male years as head of state during the last 50 years (see Hausmann, Tyson, & Zahidi, 2007 for further details). However, Fryer and Levitt (2010) show that the correlation between the gender gap and the GGI index does not hold in all the countries from the 2003 Trends in International Mathematics and Science Study (TIMMS) evaluation exercise, and point to a potential explanation based on the presence of a few predominantly Muslim outliers characterised by the dominance of single-sex schooling, and which exhibit both high female performance in maths and low levels of female empowerment.

The evidence considering the relationship between the GGI index and cross-country variation in gender differences outside the mean is equally mixed. Hyde and Mertz (2009) find a positive correlation between a country's 2007 GGI and the country's female representation at the International Mathematical Olympiad, but Ellison and Swanson (2010) do not observe such correlation when considering a different cut of the same data. Machin and Pekkarinen (2008) find no correlation between a country's GGI index and the relative dispersion of male and female maths scores. In the United States, Pope and Sydnor (2010) find that 40% of the variation across states in stereotypical gender differences in 8th-Grade test scores are accounted for by differences in survey responses to a question about gender roles.

In a similar approach to ours, Fryer and Levitt (2010) undertake a number of micro-analyses to try to explain the gender gap in the US in the early years of schooling, but ultimately can find no explanation within their data set. Their results suggest that the gap is not attributable to less investment in maths by girls, nor by low parental expectations of girls in maths, nor by testing mechanisms that are biased towards girls. Interestingly, they also show that the gap is observed in all strata of US society, contrary to what we find for Africa.

Our paper is also related to that of Bedard and Cho (2010), who use data from the Trends in International Mathematics and Science Study (TIMSS) surveys to investigate the gender gap in maths and science scores in OECD countries. Including class fixed effects in their estimated equations increases the size of the gender gap in most of the countries they analyse, suggesting that girls are, on average, placed in better performing classes than boys. In trying to explain the difference in the size of the gender gap across countries, Bedard and Cho (2010) focus on the issue of streaming, and find that the more exclusive the academic stream, and the earlier the streaming takes place, the larger is the gender gap in maths and science scores.

In this paper, we carry out micro-analyses in which we (i) control for observable differences between boys and girls and then (ii) interact characteristics of interest with female gender. Our approach in the first step of our analysis is similar to that in Fryer and Levitt (2010), and rules out a number of observable pathways through which girls may obtain lower scores than boys in the African context. The second step of our analysis is related to the cross-country studies reviewed above in that we test whether the gender gap in maths varies with characteristics of the pupil's environment. But contrary to these studies, we explore interactions of gender with parental, school and regional influences, while controlling for observable characteristics of the pupils. This allows us to shed light on a range of correlates of the gender gap, as well as compare the relative importance of different levels of socialisation.

Given the difference in economic and cultural background between Sub-Saharan Africa and countries covered by the previous literature on maths gender gaps, some discussion is warranted. In Sub-Saharan Africa, the main concern of researchers and policy makers with respect to the education of girls has been to find ways to allow them to get one at all. Even at primary schooling age, African enrolment rates have been far from unity in many countries, and especially so for girls. This has led to the United Nations setting as a Millennium Development Goal the elimination of gender inequality in enrolment in primary and secondary education, and female education enrolment rates have indeed been rising steadily, so that the gross enrolment parity index (GER) (i.e., the ratio of female-to-male gross enrolment) has reached 0.91 in Sub-Saharan Africa in 2009 (UNESCO Institute of Statistics, 2011). In the countries included in this study, this ratio varies from 0.64 to 1.08 (see Table A1).

Both demand-side and supply-side arguments have been put forward to explain why girls have lower enrolment or educational achievement in developing countries. We give an overview of these arguments and then discuss their relevance to performance in tests, conditional on enrolment.

On the demand side, different schooling investments may arise for boys and girls if costs, benefits, or preferences are gender-specific. Differences in direct costs should be minimal in co-educational settings such as those found in most of Sub-Saharan Africa, but may be important where single-sex schooling is the norm. Opportunity costs are likely to vary with gender in many developing countries, e.g., if a daughter is of greater use than a son in performing domestic and caring duties around the home. Benefits may be lower if girls expect lower earnings in adulthood due to gender-biased opportunities in the labour market. Furthermore, there may be gender-specific parental benefits from a given level of earnings if tradition dictates that only offspring of a certain gender are expected to look after their parents in their old age. Alternatively, cultural norms may lead to a gender-specific, subjective valuation of educational attainment.

On the supply side, education provision may vary by gender both in terms of quantity and quality. In the Sub-Saharan African countries studied here, almost all schools are co-educational, so that widespread differences in school quality would only arise from the supply-side if girls were rationed out of schools which in theory were open to both genders.[2] However, gender differences in schooling quality can arise within school. Colclough, Rose, and Tembon (2000), for instance, relate case studies in Ethiopia and Guinea in which girls were found to carry out more non-school activities during school hours, such as cleaning the classroom, offices and latrines, and fetching water.

A large number of studies have estimated the role of demand-side factors on gender differences in enrolment in poor countries, and consistently found that the enrolment of girls is generally more sensitive to changes in household income and schooling costs than that of boys. Glick and Sahn (2000) for Guinea; Björkman (2006) for Uganda; and Sackey (2007) for Ghana all find that girls' enrolment is more responsive to changes in household income than that of boys. Conditional transfers also tend to have larger enrolment effects for girls in contexts in which they start with lower enrolment (Glick, 2008). Fewer studies have considered the role of supply-side factors, but the review in Glick (2008) highlights the observation that female enrolment – and sometimes test scores (as in Chin, 2005) – appears to be more responsive to improvements in school quality, although it is not clear why this is the case.

How can these potential explanations for gender gaps in enrolment in developing countries translate into differences in test scores conditional on enrolment? Demand-side influences could result in differences in attendance or in investment in education both in terms of effort and in financial terms, by pupils and/or parents. For example, Aslam and Kingdon (2008) find evidence of lower educational expenditures for sons than daughters in Pakistan *conditional* on enrolment in middle- and secondary-school ages, but not at primary schooling ages. Supply-side factors could lead to systematically poorer access to schooling inputs within-school. We test for each of these possibilities in our data.

As gender gaps in school enrolment decrease, it becomes particularly important to consider inequality in the acquisition of cognitive skills during the time spent at school. The literature explicitly considering gender differences in test scores in developing countries is sporadic. Appleton (1995) studies gender differences in pass rates in the examination at the end of primary schooling in Côte d'Ivoire and shows that the female pass rate is lower and much more sensitive to household expenditure than that of boys. At very high levels of household consumption, girls actually outperform boys. Alderman, Behrman, Ross, and Sabot (1996) explore correlates of the gender gap in cognitive skills amongst individuals aged 10–25 in Pakistan. They find that the dominant explanation lies in differences in the demand, by parents, for primary education between the genders. Behrman and Knowles (1999) find that the exam score obtained in the last completed grade of schooling is more elastic to parental income for girls compared to boys in Vietnam. Chin (2005) finds that an exogenous increase in the number of teachers in schools in India increased female, but not male, enrolment and test scores. The recent randomized controlled experiment literature in developing countries has been successful in identifying interventions which are particularly beneficial to female enrolment, but has less to say about interventions which improve female relative performance at school tests. For example, the interventions analysed in Kazianga, Levy, Linden, and Sloan (2012), and Burde and Linden (2012) both led to large improvements in the enrolment of girls relative to boys, but they did not improve relative female test scores for those in school. However, exploiting a randomized natural experiment in West Bengal, Beaman, Duflo, Pande, and Topalova (2012) find that the gender gap in aspirations and educational outcomes decreases in villages where seats at the local council have been randomly reserved for women, thus suggesting a role for socialisation in shaping gender differences in educational attainment.

3. Data

Our education data come from two pan-African surveys of educational quality, the Southern and Eastern African Consortium for Monitoring Educational Quality (SACMEQ), and the Program for the Analysis of Education Systems (PASEC) which, taken together, cover 19 Western, Southern and Eastern African nations. We merge these microdata with (sub-national) region indicators which we construct based on Demographic and Health Surveys, where they are available.

3.1. SACMEQ

SACMEQ is a consortium of 15 Ministries of Education in Southern and Eastern Africa. We utilise data from the second survey (SACMEQ II) which gathered data from 14 countries in Southern and Eastern Africa between 2000 and 2002.[3] For the 12 countries considered in this study, almost 38,000 pupils were surveyed in over 5000 classes spread between 2125 schools.

In addition to testing the numeracy and literacy skills of Standard Grade 6 pupils, the survey collected data from pupils, teachers and the school headteacher. The mathematics test was based partly on TIMMS items and partly on other items newly written by the SACMEQ National Research Coordinators. The same questionnaire and tests were administered across all countries. Most of the data used here come from the pupil questionnaire, since we focus on the gender gap within-school. We also use information on teachers'

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[2] Systematic gender differences in school quality could also arise from the demand side, if parents sent their sons to better schools than their daughters.

[3] We use version 6.0 of the SACMEQ II data (dated October 2009): see Ross, Saito, Dolata, Ikeda, and Zuze (2004) for details. The countries are: Botswana, Kenya, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania (Mainland), Uganda, Zambia and Zanzibar. We exclude Zanzibar to focus on Mainland Tanzania only, and also the Seychelles because of the much higher standard of living there as compared to the other countries under consideration.

gender and classroom equipment from the teacher questionnaire.

3.2. PASEC

PASEC is the evaluation tool used by CONFEMEN, a network of Education Ministers from 41 Francophone countries. The programme consists of a number of national surveys using a combination of headteacher, teacher, and pupil questionnaires, as well as unified maths and (French) literacy tests. The questionnaires used cover the same themes as in SACMEQ, albeit in less detail. They are adapted to each country by a national team (e.g., for some of the household items which the pupils are asked to say whether they have in their homes), but most questions are the same across countries.

PASEC test items are based on common aspects of the curricula across the PASEC countries. Compared to SACMEQ, the PASEC surveys have the advantage of testing children who are in Grade 2 as well as those in Grade 5 at the time of the survey, and of administering two tests at each level, one at the beginning of the year, and a different one at the end of the year. This allows for an analysis of ‘value-added’. PASEC surveys have been carried out since 1995, but data quality is only considered high for surveys from 2003 onwards (see http://www.confemen.org/508/acces-aux-donnees-du-pasec/). We therefore focus on these data. More specifically, we use data from seven countries surveyed between 2003 and 2006, leading to a sample of 13,754 (14,413) Grade 5 (Grade 2) pupils in 956 (985) schools and as many classes. Cronbach’s alpha, which measures internal consistency across items and therefore the extent to which the test items measure underlying ability, is high, varying between 0.76 and 0.87 across the surveys used in this study.[4]

Both the SACMEQ and PASEC surveys have previously been used in research estimating the effectiveness of inputs in primary education, in a hierarchical model framework (Fehrler, Michaelowa, & Wechtler, 2009; Michaelowa, 2001). Contrary to these studies, however, we do not attach a causal interpretation to the correlations between pupil, school, and country characteristics, on the one hand, and test scores on the other. Instead, we use these correlations to shed light on gender differences in mathematics achievement.

Mathematics test results are comparable across countries within PASEC, and across countries within SACMEQ, but are not comparable between the two surveys. The mathematics test scores used as the dependent variable in our analyses are therefore standardised to have mean zero and a standard deviation of one within each survey (SACMEQ or PASEC) and the analysis is carried out separately for each survey.

3.3. Demographic and health surveys

In order to examine the variation in the gender gap across areas characterised by different levels of development and different cultural values, we construct regional indicators based on data from Demographic and Health Surveys (DHS). DHS surveys are national surveys of households, and women and men of reproductive age, which are carried out in many developing countries, including most of Africa. The main aim of these surveys is to provide internationally comparable, reliable data on fertility and maternal and child health where administrative data is lacking. Samples are designed to allow analysis at the regional level, and so we use these surveys, where available, to construct regional variables based on the individual responses. In particular, we calculate regional total fertility rates (TFR, which is defined as the number of children a woman would have by age 50 if she were subject to the age-specific fertility rate currently observed in the population) based on fertility histories for the 5 years preceding the survey, regional shares of women who defined themselves as Muslim, and the regional share of women who have no education. These data are available in all DHS surveys, including for Mauritania in 2003 (Isselmou, 2004), for which the DHS microdata are not in the public domain. Unfortunately, the DHS do not contain income or expenditure data.

Most countries can be matched with a DHS carried out within 2 years of the country’s SACMEQ or PASEC survey (see Appendix A, Table A4). Exceptions are: Mozambique (3 years), Lesotho (4 years), Gabon (5 years), and Swaziland (6 years). The second (Mauritius) and third (Botswana) wealthiest countries in our sample could not be matched as Mauritius has no DHS and Botswana’s last DHS took place in 1988.

3.4. Other data sources

In the cross-country analysis, we use a number of sources in order to obtain data on: GDP per capita (IMF World Economic Outlook Database); national total fertility rate (US Census Bureau International Database)[5]; genetic distance, which proxies for the “time elapsed since two populations’ last common ancestors” (Spolaore & Wacziarg, 2009); share Muslim in the population (CIA Factbook, 2010a, except for Botswana and Zambia, for which we use data in Kettani, 2009); maternal mortality (CIA Factbook, 2010b); and the gross enrolment rate in primary schools (UNESCO, 2006). See Table A4 for more details.

4. Descriptive statistics

4.1. Average test scores and control variables, by gender

Tables 1a and 1b contain descriptive statistics on all the variables used in the micro-analysis for the SACMEQ and PASEC (Grade 5) samples respectively, and in both cases separately for girls and boys. The top of the tables show the number of girls and boys and their scores on the maths tests. Since the tests are comparable only within survey, we standardise the test scores by the survey-specific (i.e., SACMEQ or PASEC) mean and standard deviation.[6] In SACMEQ countries, boys

[4] PASEC country reports (http://www.confemen.org/le-pasec/rapports-et-documents-pasec/les-rapports-du-pasec/) and personal communications with CONFEMEN technical advisors. The seven countries in question are: Benin, Cameroon, Chad, Gabon, Guinea, Madagascar, and Mauritania.

[5] DHS surveys are not available for all countries in our sample. Therefore, in the cross-country regressions, we use national TFR data from the US Census Bureau International Database rather than fertility rates based on DHS data.

[6] It is interesting to note, however, that the percentage of correct answers in the SACMEQ and PASEC (final) tests are very similar, at around 40% on average, with an only slightly higher dispersion of scores in the PASEC post-test (18.43 [18.54] for girls [boys]) as compared to the SACMEQ test (15.23 [15.72] for girls [boys]).

Table 1a
SACMEQ – descriptive statistics.

Variable	Girl mean	Boy mean	Difference (girl–boy)	(*t*-stat)
No. of children	18,302	18,860		
Maths score – percent (standard error)	38.88 (15.23)	40.25 (15.72)	−1.372***	(−8.54)
Maths score – standardised (standard error)	−0.046 (0.98)	0.043 (1.02)	−0.089***	(−8.54)
Age	13.06	13.65	−0.591***	(−28.73)
Individual pupil access to schooling inputs				
=1 if no maths text books	0.116	0.117	−0.001	(−0.27)
=1 if has own math text book	0.485	0.479	0.006	(1.20)
=1 if no maths homework	0.048	0.055	−0.007***	(−2.94)
=1 if teacher corrects maths some times	0.221	0.220	0.001	(0.16)
=1 if teacher corrects maths most times	0.206	0.207	−0.001	(−0.33)
=1 if teacher corrects maths always	0.492	0.478	0.014***	(2.70)
Pupil equipment index	5.569	5.469	0.100***	(5.15)
=1 if write on chair/bench	0.941	0.923	0.018***	(6.81)
=1 if write on desk/table	0.913	0.896	0.018***	(5.83)
=1 if can borrow library books	0.452	0.456	−0.003	(−0.64)
School/classroom characteristics				
=1 if single-sex school	0.005	0.012	−0.006***	(−6.61)
=1 if public school	0.895	0.909	−0.014***	(−4.39)
=1 if female teacher	0.440	0.399	0.041***	(7.85)
Class equipment index	5.221	5.101	0.120***	(5.69)
Home environment				
=1 if middle wealth tercile	0.340	0.327	0.013***	(2.69)
=1 if top wealth tercile	0.339	0.327	0.012**	(2.42)
=1 if stay with relatives during week	0.119	0.113	0.006*	(1.68)
=1 if stay boarding school during week	0.044	0.052	−0.008***	(−3.72)
=1 if stay on own during week	0.026	0.031	−0.005***	(−3.06)
Number of meals everyday	2.379	2.344	0.035***	(3.87)
=1 if someone does math with you some times	0.551	0.545	0.005	(1.05)
=1 if someone does math with you most times	0.255	0.243	0.012***	(2.73)
=1 if questions about maths some times	0.549	0.549	0.000	(0.02)
=1 if questions about maths most times	0.271	0.263	0.008*	(1.70)
=1 if extra maths tuition	0.359	0.363	−0.004	(−0.83)
Number of books in home	24.97	22.96	2.008***	(3.61)
Father education index	7.057	7.128	−0.072	(−1.30)
=1 if Father education index missing	0.239	0.205	0.033***	(7.75)
Mother education index	7.174	6.791	0.384***	(7.76)
=1 if Mother education index missing	0.160	0.155	0.005	(1.41)
=1 if gets no homework	0.011	0.012	−0.001	(−1.13)
=1 if check homework some times	0.469	0.489	−0.020***	(−3.84)
=1 if check homework most times	0.418	0.381	0.037***	(7.28)
=1 if help with homework some times	0.540	0.544	−0.004	(−0.71)
=1 if help with homework most times	0.295	0.262	0.033***	(7.08)
=1 if check schoolwork sometimes	0.501	0.508	−0.007	(−1.37)
=1 if check schoolwork most times	0.350	0.328	0.022***	(4.52)
Number days absent per month	1.511	1.759	−0.249***	(−9.43)
=1 if absent for work reason	0.039	0.055	−0.016***	(−7.23)
=1 if absent for family reason	0.085	0.089	−0.004	(−1.39)
=1 if absent for unpaid fees	0.044	0.044	0.000	(0.14)
Regional characteristics				
Regional share of uneducated adult women	0.149	0.175	−0.026***	(−16.16)
Regional total fertility rate (TFR)	4.748	4.916	−0.167***	(−10.15)
Regional share Muslim	0.059	0.072	−0.013***	(−7.89)

Source: Authors' calculations based on SACMEQ II data except for regional characteristics, which are calculated from DHS data, as described in Section 3.
Notes:
(1) Summary statistics based on the 37,162 children for whom all of the above variables are defined (as in Table 4a, Column (5)).
(2) Base category for maths text book is 'shares maths text book'; pupil equipment index ranges from 0 to 8 based on access to items such as exercise books, pencils and rulers; class equipment index ranges from 0 to 8 based on whether the classroom is equipped with a writing board, chalk, wall chart, cupboard, bookshelves, library, and a chair and table for the teacher.
(3) Wealth terciles are based on within-country PCA of ownership of a range of assets including housing and housing quality, household goods, and livestock; number of books at home is a continuous variable based on the mid-points of a 5 level categorical scale; father/mother education index is the estimated number of years of education completed based on the reported highest level of education attained and country-specific information on different education systems.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table 1b
PASEC – descriptive statistics.

Variable	Girl mean	Boy mean	Difference (girl–boy)	(*t*-stat)
No. of children	5139	6005		
Maths pre-test score Grade 5 – percent (standard error)	44.52 (20.93)	46.57 (20.91)	−2.052***	(−5.16)
Maths pre-test score Grade 5 – standardised (standard error)	−0.045 (1.00)	0.053 (1.00)	−0.098***	(−5.16)
Maths post-test score Grade 5 – percent (standard error)	38.37 (18.43)	38.98 (18.54)	−0.609*	(−1.73)
Maths post-test score Grade 5 – standardised (standard error)	−0.021 (1.00)	0.012 (1.00)	−0.033*	(−1.73)
Age	11.92	12.09	−0.178***	(−5.29)
Individual pupil access to schooling inputs				
=1 if has maths book	0.474	0.470	0.005	(0.49)
=1 if teacher help with homework	0.031	0.030	0.000	(0.13)
School/classroom characteristics				
=1 if single-sex school	0.020	0.017	0.003	(1.12)
=1 if public school	0.845	0.873	−0.028***	(−4.17)
=1 if female teacher	0.312	0.263	0.049***	(5.67)
Class equipment index	5.428	5.450	−0.021	(−0.49)
Home environment				
=1 if middle wealth tercile	0.409	0.424	−0.015	(−1.59)
=1 if top wealth tercile	0.350	0.303	0.047***	(5.31)
=1 if does not live with parents	0.133	0.121	0.012*	(1.94)
=1 if single parent	0.235	0.241	−0.006	(−0.77)
Regular daily meals (0–3)	2.751	2.675	0.076***	(6.57)
=1 if father is literate	0.779	0.688	0.092***	(10.93)
=1 if mother is literate	0.598	0.494	0.104***	(11.05)
=1 if parental help	0.278	0.236	0.042***	(5.06)
=1 if sibling help	0.423	0.441	−0.017*	(−1.85)
=1 if tutor help	0.043	0.037	0.007*	(1.77)
=1 if other help	0.050	0.047	0.003	(0.71)
=1 if domestic work	0.912	0.750	0.162***	(22.89)
=1 if works in agriculture or trade	0.580	0.647	−0.067***	(−7.29)
=1 if work affects study at home	0.184	0.179	0.005	(0.72)
=1 if work affects school attendance	0.123	0.133	−0.010	(−1.64)
=1 if work affects schooling ‘cos too tired	0.124	0.133	−0.009	(−1.43)
Regional characteristics				
Regional share of uneducated adult women	0.393	0.456	−0.062***	(−10.79)
Regional total fertility rate (TFR)	5.500	5.703	−0.203***	(−11.43)
Regional share Muslim	0.370	0.389	−0.019**	(−2.45)

Source: Authors' calculations based on PASEC data except for regional characteristics, which are calculated from DHS data, as described in Section 3.
Notes:
(1) Summary statistics based on the 11,144 children for whom all the above variables are defined (including imputed values where there are less than 15% missing values within school, as in Table 4b, Column (5)).
(2) Variables are imputed where an individual value is missing, but where the share of missing values within the school is less than 15%. Continuous variables are replaced by the school mean, and categorical variables by the school mode. Where more than 15% of values are missing within the school, values are not imputed.
(3) Wealth terciles are based on within-country PCA of ownership of a range of assets including housing and housing quality, household goods, and livestock, except for Chad and Guinea. For these countries, the PASEC data files do not provide information on ownership of individual items, but instead contain a country-specific wealth indicator based on ownership of these items, classifying households as poor, middle, or rich, but these categories do not correspond to terciles.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

score 0.09 standard deviations (sd) higher, on average, than girls. In the PASEC data, boys score more highly than girls at both the beginning and the end of Grade 5, by 0.10 and 0.03 sd respectively. All of these differences are statistically significant.

The remaining rows in Tables 1a and 1b contain information on the explanatory variables used in the analysis, and show how they differ between girls and boys. The SACMEQ data in Table 1a reveal that, on average, the boys in the sample are slightly, but statistically significantly, older than the girls. One plausible explanation for this difference is that girls are more likely to come from higher socio-economic status households in which children's school enrolment suffers fewer delays. Indeed, consistent with the lower enrolment rates of girls compared to boys, the girls that we observe in schools come from wealthier families, have more books at home, have a higher average number of meals per day, have better educated mothers, and are found in better-equipped classrooms.[7] Thus, the lower female performance in maths observed in the raw data is likely to underestimate the true extent of the gender gap, and should tend to increase as we

[7] We calculated the enrolment ratios (i.e. the number of girls/the number of boys) in our PASEC and SACMEQ samples and compared these to the gender parity index in primary education in the country published in UNESCO (2006) – see Table A1. The coefficient of correlation between the enrolment ratio in our sample (taken in a single year towards the end of primary schooling) and the enrolment ratios from this external source is 0.91.

control for school fixed-effects and family background characteristics.

We also see that girls are more likely to be enrolled in private schools and to have a female teacher. They are less likely to be absent from school for work reasons, and no more likely to be absent for family reasons. They are significantly more likely to receive help with their homework, and have their homework and schoolwork checked.

The main advantage of SACMEQ compared to PASEC is its wealth of variables on the quality of the pupil's learning environment, both at home and at school. In particular, the availability of multiple pupil-specific measures of access to learning resources within the school allows us to control for potential discrimination in access to school inputs, be it in terms of access to physical inputs (chair, desk, teaching materials etc.) or in terms of attention received from the teacher. At school, girls are significantly more likely to report that their teacher always checks their work, and more likely to have access to individual equipment such as a chair and desk. Despite being enrolled in schools with better equipped classrooms, they are no more likely than boys to have single use of a math text book during class. It is unclear from the raw data whether the female advantage in access to individual school inputs such as chairs and desks is driven by school heterogeneity or by better access to these inputs within a given school. Our school fixed-effects estimates shed more light on this. Finally, the girls observed in the sample live in areas with a smaller share of uneducated adult women, a lower fertility rate, and a lower share of the population defining themselves as Muslim.

The PASEC data in Table 1b paint a similar picture. Girls who we observe in schools come from wealthier households, and are more likely to have a literate father, a literate mother, to eat regular daily meals, to receive parental help and help from a tutor with school work. Table 1b also reveals gender-specific patterns of work outside the school among PASEC countries: girls are much more likely to be involved in domestic work at home, while boys are more often employed in agriculture or trade. However, there is no statistically significant difference in self-reported schooling issues due to work, be it in terms of ability to study at home or at school, or with respect to attendance. Girls are more likely to be enrolled in private schools and to have a female teacher. However, there is no gender difference in the average level of class equipment or in the individual pupil access to a maths book in class or in whether the individual pupil receives homework help from the school teacher.

The area characteristics matched into the PASEC data reveal a similar pattern to that discussed above for SACMEQ. In brief, as a result of variation in female-to-male school enrolment in Sub-Saharan Africa, girls who are enrolled in school come from richer areas, and areas with significantly different cultural traits than boys.

It is also interesting to note that areas covered by the two surveys are quite different in terms both of economic development and cultural characteristics. SACMEQ countries are much richer on average (with an average GDP per capita in 2000 of US$1427 compared to US$936 for PASEC), have a much lower proportion of uneducated female adults, lower fertility, and less than 10% of the population is Muslim compared to nearly 40% among PASEC countries, reflecting differences between Francophone and Anglophone Africa, and providing a very varied sample of countries with which to analyse gender differences in maths achievement.

So far we have seen that boys outperform girls in maths in the raw data in both surveys taken as a whole. As a consequence of the lower enrolment rates among girls than boys in Sub-Saharan Africa, the girls in our in-school samples have higher socio-economic status, and tend to have a better educational environment at home and in school. We anticipate, therefore, that as we control for characteristics of their parents, support with homework, school fixed-effects, and pupil-specific access to educational inputs within schools, the gender gap should *increase* unless anti-girl discrimination is sufficiently strong to reverse the SES gradient working in favour of girls. In the next section, we investigate whether, in the raw data, girls perform consistently badly relative to boys, or whether the gender gap only appears under certain circumstances.

4.2. Gender gap by characteristics

Tables 2a and 2b present the gender differential (girls-boys) in different strata of the population for the SACMEQ and PASEC datasets respectively. We report the raw gap by characteristics of particular interest, namely socio-economic status, parental literacy, school type and level of equipment, teacher gender and, where DHS data are available, socioeconomic characteristics of the region. For example, the first row of Table 2a reports that amongst the SACMEQ families categorised as 'poor' (bottom tercile), the gender gap is −0.128 sd, whilst amongst families not categorised as poor, it is −0.081 sd. The difference in the gender gap between these two types of families is −0.047 sd which is statistically significant, with the gap being greater in poor families. For continuous variables, we define categories as above/below the sample-specific median of the variable. For SACMEQ countries, we collapse the number of years of education of mothers and fathers into two categories (no education/at least some education) for comparability with the literate/illiterate information available in the PASEC datasets. Here we focus on strata defined by individual, school-level, or regional characteristics. Since the proportion of the population in each of these strata differs across countries, differences in the gender gap between these strata would imply differences in the gender gap between countries, as confirmed by results reported in Section 5.5.

For the SACMEQ data, we find that the gender gap does not vary systematically with household wealth, but there are striking differences when cutting the data by maternal education, teacher gender, level of class equipment, and regional characteristics. The female disadvantage is more than doubled amongst children of mothers with no schooling and nearly twice as large amongst girls with a male teacher. In single-sex schools, girls perform considerably worse than boys in single-sex schools, and much worse than in mixed schools.[8] Differences are particularly striking when dividing the sample along societal characteristics, such that the

[8] Note however that the number of children observed in single-sex schools is extremely small in the countries being studied. For this reason we do not pursue the analysis of single-sex schools in our main results in Section 5.

Table 2a
SACMEQ – gender difference in maths score by selected characteristics.

Characteristic Status:	(1) 'YES' Gender gap	N	(2) 'NO' Gender gap	N	(3) = (1) – (2) Difference in gender gap	N
Wealth						
Poorest tercile	−0.128***	12,388	−0.081***	24,774	−0.047**	37,162
Middle tercile	−0.060***	12,392	−0.100***	24,770	0.040*	37,162
Richest tercile	−0.101***	12,382	−0.090***	24,780	−0.011	37,162
Educated father	−0.081***	26,087	−0.114***	2,839	0.064	28,926
Educated mother	−0.083**	27,802	−0.179***	3,503	0.097***	31,305
Rural school	−0.098***	21,420	−0.081***	15,742	−0.017	37,162
Public school	−0.088***	33,517	−0.102***	3,645	0.014	37,162
Single-sex school	−0.470***	318	−0.084***	36,844	−0.386***	37,162
Female maths teacher	−0.055***	15,250	−0.105***	21,138	0.049**	36,388
Above-median class equipment	−0.046***	24,035	−0.179***	12,475	0.134***	36,510
Above-median regional TFR	−0.200***	15,471	−0.035**	15,224	−0.164***	30,695
Above-median regional share Muslim	−0.166***	15,408	−0.018	15,287	−0.148***	30,695
Above-median regional share uneducated women	−0.167***	15,565	−0.052***	15,130	−0.114***	30,695

Source: Authors' calculations based on SACMEQ II and DHS data, as described in Section 3.
Notes:
The *t*-tests reported in columns (1) and (2) are for the size and significance of the gender gap (girls–boys) for those with the characteristic listed in the first column (status: 'YES') and for those without the characteristic (status: 'NO') respectively. In Column (3) we report the size and significance for the difference in the gender gap between those with and without the characteristic.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table 2b
PASEC – gender difference in maths score by selected characteristics.

Characteristic Status:	(1) 'YES' Gender gap	N	(2) 'NO' Gender gap	N	(3) = (1) – (2) Difference in gender gap	N
Wealth						
Poorest tercile	−0.052	2870	−0.030	8,274	−0.023	11,144
Middle tercile	−0.048*	4652	−0.027	6,492	−0.021	11,144
Richest tercile	−0.035	3618	−0.050**	7,526	0.015	11,144
Literate father	−0.033	8134	−0.129***	3,010	0.097**	11,144
Literate mother	−0.009	6041	−0.151***	5,103	0.142***	11,144
Rural school	−0.034	5299	−0.046*	5,845	0.012	11,144
Public school	−0.064***	9583	0.052	1,561	−0.116**	11,144
Single-sex school	0.417***	202	−0.040**	10,942	0.457***	11,144
Female maths teacher	−0.003	3184	−0.061***	7,960	0.058	11,144
Above-median class equipment	0.009	5973	−0.082***	5,171	0.091**	11,144
Above-median regional TFR	−0.070***	5874	0.001	5,218	−0.071*	11,092
Above-median regional share Muslim	−0.160***	5546	0.024	5,546	−0.184***	11,092
Above-median regional share uneducated women	−0.148***	5792	0.017	5,300	−0.165***	11,092

Source: Authors' calculations based on PASEC and DHS data, as described in Section 3.
Notes:
The *t*-tests reported in columns (1) and (2) are for the size and significance of the gender gap (girls–boys) for those with the characteristic listed in the first column (status: 'YES') and for those without the characteristic (status: 'NO') respectively. In Column (3) we report the size and significance for the difference in the gender gap between those with and without the characteristic.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

gap disappears in areas with a below-median share of Muslims in the regional population, and is much lower in regions with below-median shares of uneducated adult women and below-median total fertility rates.

The sensitivity of the gender gap is particularly marked in the PASEC sample (Table 2b). For instance, a gap is only observed among children of illiterate parents, when the maths teacher is male, or where regional fertility or the share of the Muslim population or the regional share of uneducated adult women is above-median. Contrary to SACMEQ countries, girls do much better than boys in single sex schools, and better than in mixed schools (although the number of children in single-sex schools is again small, and are mostly concentrated in Mauritania). From the raw data, it is thus clear that the size of the gender gap varies across characteristics, such that girls do not do worse than boys in maths in all subgroups of the population. Of course, in Tables 2a and 2b, the characteristics of interest (e.g., maternal education

Table 3a
SACMEQ – distribution of scores.

Distribution percentile or moment	Ratio of #girls/#boys
1%	1.035
5%	1.077
10%	1.047
Below median (bottom 50%)	1.055
Below mean	1.042
Above mean	0.881
Above median (top 50%)	0.882
90%	0.834
95%	0.798
99%	0.808

Source: Authors' calculations based on SACMEQ II data, as described in Section 3.
Note: The ratio of girls to boys in the entire SACMEQ distribution is 0.968.

Table 3b
PASEC – distribution of scores.

Distribution percentile or moment	Ratio of #girls/#boys
1%	0.687
5%	0.947
10%	0.942
Below median (bottom 50%)	0.851
Below mean	0.851
Above mean	0.840
Above median (top 50%)	0.840
90%	0.819
95%	0.779
99%	0.661

Source: Authors' calculations based on PASEC, as described in Section 3.
Note: The ratio of girls to boys in the entire PASEC distribution is 0.846.

or literacy) may simply be acting as a proxy for a correlated characteristic, be it one(s) which we cannot observe, or one(s) which we do observe (e.g., teacher gender), but which we do not control for in these 'univariate' comparisons. In Section 5, we shed more light on the robustness of the interactions between gender and parental-, school-, and regional characteristics by including these interactions in a stepwise fashion in our main regressions.

4.3. Distribution of scores

We have concentrated so far on *average* test scores by gender, but a number of previous studies on gender gaps in mathematics have focused on the over-representation of males at the top of the *distribution* of scores. Indeed, in the US, where females have recently caught up with males in terms of the number of science and maths courses taken in high-school and in terms of enrolment at the undergraduate level in science and engineering (Goldin, Katz, & Kuziemko, 2006), attention has turned to the top of the distribution both in high-school and in the upper echelons of professionals, where a substantial gap persists (Pope and Sydnor, 2010).

Following Fryer and Levitt (2009) and Pope and Sydnor (2010), we calculate the gender ratio (number of girls to number of boys) at various percentiles of the test score distribution. These are reported in Tables 3a and 3b for SACMEQ and PASEC, respectively. For SACMEQ, the overall gender ratio is 0.968. If boys and girls are equally distributed across the maths ability distribution, we would expect to see this ratio replicated at all percentiles of the distribution of scores. Table 3a shows that this is not the case, but also that the gender gap observed in the means is not being simply driven by the extreme tails of the distribution. Instead, girls are equally over-represented below the mean (1.042) or median (1.055) as in the extreme lower tail (1.035), and fairly equally under-represented above the mean (0.881) or median (0.882) as at the very upper tail (0.808). Among the smaller set of PASEC countries, where the overall gender ratio is 0.846, there is a more marked degree of underrepresentation of females both at the very bottom and at the very top of the distribution. However, taken together, the distributional patterns for the 12 SACMEQ countries and 7 PASEC countries justify our interest in the average gender gap.

5. Regression results

5.1. Pooled regressions

Tables 4a and 4b report the results from a multivariate analysis of maths test scores, for the pooled SACMEQ and PASEC (Grade 5 final) samples respectively. Moving from left to right in the table, the estimated equations are gradually built up in terms of the explanatory variables that they include, the aim being to investigate whether any of the correlations between our explanatory variables and gender can account for the observed gender difference in maths test scores. Given our analysis of the characteristics of boys and girls in the raw data (Tables 1a and 1b, as discussed in Section 4.1), our hypothesis is that controlling for these various factors will not reduce the gender gap unless discrimination against girls is strong enough to reverse the socio-economic status gradient.

Column (1) in each table reports the simplest specification, which includes only the female dummy variable and country fixed-effects. Looking within countries, therefore, girls score on average, 0.06 (0.09) sd lower than boys in SACMEQ (PASEC) countries, both differences being statistically significant at the 1% level. The subsequent columns in each table add explanatory variables in order to investigate whether the correlation between gender and those variables affects the gender coefficient, so allowing us to test a range of hypotheses about the proximate causes of the gender gap.

5.2. Do boys go to better schools?

So far, we have considered average performance across schools. In the context of Sub-Saharan Africa, it could be the case that parents send their sons to better schools than their daughters, for the same reason as the enrolment statistics show that they are more likely to send their sons to school than their daughters. Column (2) tests this hypothesis by introducing school fixed-effects. In both data sets, however, this actually increases the size of the female disadvantage in maths test scores, thus indicating that, on the contrary, girls tend to be enrolled in schools where pupils perform better at maths tests. The same result is obtained in the majority of OECD countries considered by Bedard and Cho (2010).

Table 4a
SACMEQ – pooled regressions.

Column: Fixed effects:	(1) Country FE	(2) School FE	(3) School FE	(4) School FE
Female	−0.063*** (0.009)	−0.076*** (0.007)	−0.107*** (0.007)	−0.109*** (0.007)
Botswana	0.216*** (0.016)			
Kenya	0.770*** (0.016)			
Lesotho	−0.463*** (0.016)			
Malawi	−0.607*** (0.019)			
Mauritius	0.880*** (0.017)			
Mozambique	0.321*** (0.016)			
Namibia	−0.528*** (0.013)			
South Africa	−0.138*** (0.016)			
Swaziland	0.256*** (0.016)			
Tanzania	0.268*** (0.017)			
Uganda	0.119*** (0.017)			
Zambia	−0.604*** (0.018)			
Individual pupil access to schooling inputs + age	×	×	√	√
Home environment	×	×	×	√
No. of children	37,407	37,407	37,162	37,162
No. of schools	2125	2125	2110	2110
R^2 (within-school from Column (3))	0.242	0.003	0.029	0.052

Source: Authors' calculations based on SACMEQ II data, as described in Section 3.
Notes:
(1) Standard errors in parentheses.
(2) Regressors corresponding to the categories "individual pupil access to schooling inputs" and "home environment" are listed in Table 1a.
*** $p < 0.01$.

5.3. Are boys and girls treated differently within schools?

One potential explanation for observing a gender gap *within* schools is that girls and boys are treated differently within schools, as suggested, e.g., in Colclough, Rose and Tembon (2000). In Column (3) we test this hypothesis by adding controls for pupil-specific access to school inputs. For the SACMEQ survey, the added variables are: whether the pupil has access to a maths textbook in class, whether the pupil has access to an individual maths text book in class (omitted category: the pupil does not have access to a maths textbook in class), one binary indicator for each of the following four cases: the teacher corrects their maths homework sometimes, most times, always, or they do not get maths homework (omitted category: the teacher never corrects their maths homework), whether the pupil sits on a chair in class, whether the pupil writes on a desk in class, a variable equal to the number of stationery items the individual pupil has access to in class (from 0 to 8: exercise book, note book, pencil, sharpener, eraser, ruler, pen, folder), and whether the pupil can borrow books from the school library. For the PASEC survey, pupil-specific information is only available on whether they have access to a maths book in class which they can take home with them, and whether they receive help with homework from their teacher. In both data sets, however, the addition of these variables does not close the gender gap in maths scores, with the gap actually widening significantly in the SACMEQ countries. It is not the case, therefore, that discrimination against girls in the form of lower access to help or resources within schools is hindering girls.

5.4. Do girls come from poorer and/or less supportive households?

Column (4) in each table additionally includes controls for the home environment. These variables vary somewhat between the two surveys, with more information being available in the SACMEQ survey. In both surveys, controls for family background and educational environment at home include measures of family income, parental education, living arrangements, availability of regular meals, what type of help, if any, is available for school work at home (specifically for maths in the SACMEQ regressions), and variables capturing reasons for missing school days (SACMEQ) or aspects of child labour (PASEC). The full list of variables can be

Table 4b
PASEC – pooled regressions across countries.

Column: Fixed effects:	(1) Country FE	(2) School FE	(3) School FE	(4) School FE	(5) School FE	(6) School FE
Female	−0.089*** (0.016)	−0.113*** (0.012)	−0.116*** (0.012)	−0.114*** (0.013)	−0.123*** (0.014)	−0.045*** (0.012)
Benin	−0.310*** (0.021)					
Cameroon	0.440*** (0.022)					
Chad	−0.317*** (0.025)					
Gabon	0.323*** (0.024)					
Guinea	−0.053*** (0.020)					
Madagascar	0.771*** (0.022)					
Mauritania	−0.809*** (0.024)					
Initial score						0.401*** (0.009)
Individual pupil access to schooling inputs + age:	×	×	√	√	√	√
Home environment:	×	×	×	√	√	√
No. of children	11,904	11,904	11,761	11,144	10,055	11,144
No. of schools	933	933	933	930	929	930
R^2 (within-school from Column (3))	0.244	0.008	0.010	0.013	0.015	0.183

Source: Authors' calculations based on PASEC data, as described in Section 3.
Notes: (1) Standard errors in parentheses. (2) Regressors corresponding to the categories "individual pupil access to schooling inputs" and "home environment" are listed in Table 1b. (3) Column (5) is the same specification as Column (4) but excludes the imputed values. (4) Column (6) is the same specification as Column (4) but includes the score at the beginning of the year and hence reflects value-added during grade.
*** $p < 0.01$.

found in Tables 1a and 1b. However, in both data sets, the gender gap is virtually identical to that observed in the previous column. Controlling for a long list of household characteristics and the educational environment at home does not help to explain the gender gap at all, and so the reason for girls' poorer performance is not that they come from households where conditions are less favourable to the production of mathematical cognitive skills.

The PASEC results in Table 4b contain two more columns. As a robustness check, Column (5) restricts the sample to observations with no imputed values for any variable.[9] As can be seen, the coefficients are robust to this change, suggesting that imputed values are not affecting the results. Finally, Column (6) adds a control for performance at a pre-test (distinct from the end-of-year test) at the beginning of the academic year, and thus considers progress during Grade 5 from a given initial level. The results show that over the course of Grade 5, girls progress by 0.045 sd less than boys. Thus, amongst pupils who are observed at both the start and the end of Grade 5, the gap in performance on maths tests between boys and girls is widening; from a given starting point, girls make less progress than boys during the course of Grade 5.[10]

For PASEC, we are also able to conduct regression analyses at the beginning of Grade 5 and at the beginning and end of Grade 2. The results reveal that the girls lag boys in maths test scores at each of these points, and the magnitude of the gap is about the same in Grade 2 as in Grade 5 (observed at the same point in time for the two different cohorts). The gender gap in maths scores is therefore present at all points of the school system surveyed in SACMEQ and PASEC, and cannot be accounted for by gender differences in school quality, within-school gender discrimination in access to schooling inputs, or gender differences in family socio-economics status or the schooling environment at home. This is consistent with the findings for developed countries obtained by

[9] In both surveys, variables are imputed where an individual value is missing, but where the share of missing values within the school is less than 15%. Continuous variables are replaced by the school mean, and categorical variables by the school mode. Where more than 15% of values are missing within the school, values are not imputed. Contrary to the PASEC survey, the SACMEQ dataset does not contain the raw data, only imputed values, so that this robustness check can only be performed for PASEC.

[10] The raw data in Table 1b showed that the raw gender gap appears to be smaller at the end of Grade 5 than at the beginning. This is due to the fact that the raw average scores are calculated separately for those present at the start of Grade 5, and for the lower number present at the end of Grade 5. The value-added specification in Table 4b is estimated only on those observed at *both* the beginning and end of Grade 5. The difference between the two is therefore those who drop out during the year. Analysis of the data shows that such drop-outs are more likely to be low-achieving, and also more likely to be girls. Thus in the raw data in Table 1b, there are more low-achieving girls in the sample at the start of Grade 5 than at the end, explaining the apparent relative improvement by girls on average, whilst Table 4b is based only on those pupils observed both at the beginning and end of Grade 5, for whom the gap between boys and girls is shown to grow.

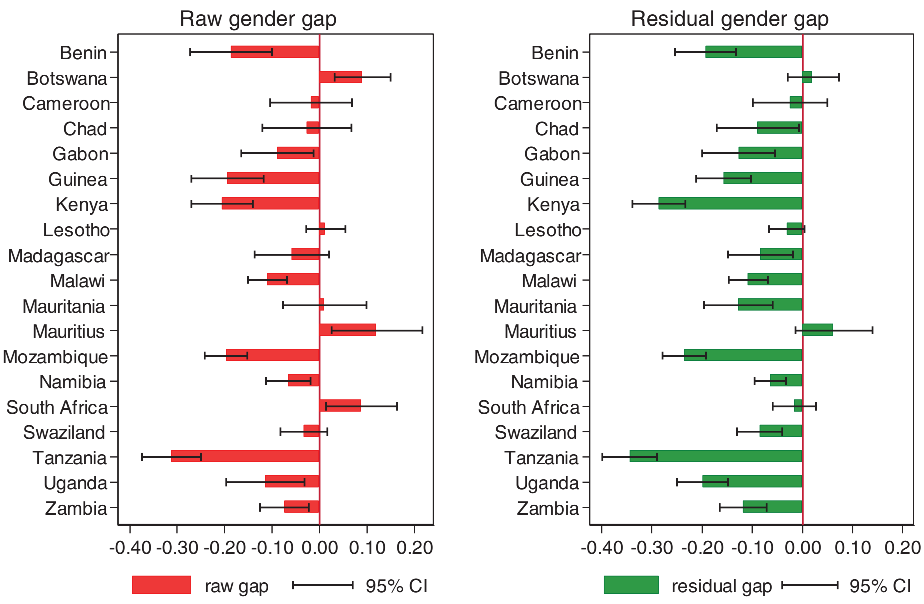

Fig. 1. Raw and residual gender gaps. *Source*: Authors' calculations using data from Southern and Eastern African Consortium for Monitoring Educational Quality (SACMEQ II) (Botswana, Kenya, Lesotho, Malawi, Mauritius, Mozambique, Namibia, South Africa, Swaziland, Tanzania (Mainland), Uganda, Zambia) and Program for the Analysis of Education Systems (PASEC) (Benin, Cameroon, Chad, Gabon, Guinea, Madagascar, Mauritania).

Fryer and Levitt (2010). Indeed, in their analysis as well as ours, the gender gap increases as more controls for environmental factors are included in the regression.

5.5. *Do girls have worse characteristics (individual country analysis)?*

As well as the pooled analyses discussed in the previous sub-sections, we also ran the same set of specifications for each country individually. The results are reported in Appendix A, Tables A2 and A3 for SACMEQ and PASEC countries respectively. The specifications mirror those estimated in the previous sub-sections, with the obvious exception that country level fixed-effects analyses are no longer estimated. For the sake of brevity, here we focus on the gender gaps obtained in the raw data (Column (1)) and in the specification including the full set of controls (Column (4)), as illustrated in Fig. 1.

Fig. 1 plots the size of the gender gap in maths in each country, both in the raw data (left-hand side) and after accounting comprehensively for differences in family background, the schooling environment at home and at school (right-hand side). Similar to the pooled regressions reported in Tables 4a and 4b, the gap tends to widen further as we include more covariates. In the raw data, girls have (significantly) lower scores in (10) 14 countries and (significantly) higher scores in (3) 5 countries. When comparing boys and girls with similar characteristics, girls obtain (significantly) lower scores in (14) 17 out of the 19 countries, and neither of the two gender gaps in favour of girls is statistically significant. However, the magnitude of the gap varies widely, from a non-significant 0.06 sd advantage in Mauritius to as much as a 0.34 sd disadvantage in Tanzania.

For PASEC countries, Column (6) of Table A3 reports the results from the value added specification. In all countries except Cameroon, the female coefficient is also negative in this specification, suggesting that the gap between boys and girls widens during Grade 5, and by a statistically significant amount in four of the countries.

In conclusion, a consistent gender gap in maths scores has been observed in both the pooled SACMEQ and PASEC data sets, and in almost all countries when analysed separately. The fact that the gender gap differs in size across countries suggests the absence of a common genetic explanation for why boys do better on average. Neither does the gap stem from gender differences in school quality, or from within-school gender discrimination in access to schooling inputs, or from gender differences in family SES or from the schooling environment at home.

However, in Tables 2a and 2b, we showed that the gender gap varies considerably across population sub-groups. Similarly, the results in Fig. 1 showed that the size of the gender gap varies across countries (and is negligible or absent in some countries). Thus it appears that girls only do worse when gender is compounded by other characteristics. In the next section, we analyse the sources of variation in the gender gap in a more systematic manner, and in the process shed light on the nature of the gap.

5.6. *Under what conditions does the gap arise?*

The regression analysis discussed above investigated whether boys and girls differed in terms of their observed characteristics, in ways which affected their relative maths performance. The conclusion is they do not. The analysis in this section asks whether boys and girls, exposed to the

Table 5a
SACMEQ – pooled regressions with interactions.

Column: Interactions:	(1) Baseline	(2) Parent ed.	(3) School	(4) Regional	(5) All
Female	−0.109***	−0.120***	−0.010	−0.037***	−0.042
	(0.007)	(0.009)	(0.024)	(0.013)	(0.030)
Female × uneducated father		0.033			0.019
		(0.025)			(0.023)
Female × father education missing		0.050***			0.021
		(0.019)			(0.019)
Female × uneducated mother		−0.052**			−0.023
		(0.023)			(0.025)
Female × mother education missing		0.009			0.012
		(0.021)			(0.019)
Female × public school			−0.050**		−0.004
			(0.024)		(0.029)
Female × male teacher			−0.030**		0.001
			(0.014)		(0.015)
Female × below-median class equipment			−0.102***		−0.009
			(0.015)		(0.015)
Female × above-median regional share uneducated women				−0.050*	−0.047*
				(0.026)	(0.026)
Female × above-median regional TFR				−0.051*	−0.048*
				(0.026)	(0.026)
Female × above-median regional share Muslim				−0.106***	−0.099***
				(0.024)	(0.025)
Individual pupil access to schooling inputs + age	√	√	√	√	√
Home environment	√	√	√	√	√
No. of children	37,162	37,162	36,388	30,695	29,921

Source: Authors' calculations based on SACMEQ II and DHS data, as described in Section 3.
Notes:
(1) Standard errors in parentheses.
(2) School fixed-effects estimates. The baseline specification in Column (1) is repeated from Table 4a, Column (4).
(3) Regressors corresponding to the categories "individual pupil access to schooling inputs" and "home environment" are listed in Table 1a.
(4) School/classroom environment and regional characteristics are not included in levels because they are subsumed in the school fixed effects.
(5) Standard errors for Columns (4) and (5) are clustered at the regional level.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

same societal and cultural factors, are affected by those factors differently (e.g., because these influences lead to genuine or perceived gender-specific returns to maths skills or to stereotype threats, in ways that are not captured by individual regressors). If so, then variation in those factors across groups or space can help explain variation in the size of the gap. Our approach is to interact the gender indicator with various parental, school, and regional characteristics, which appear to be unfavourable to female performance in maths in the raw data (Section 4). Namely, we have seen that the gap is much reduced among children whose parents are educated, who have a female (maths) teacher, attend a well-equipped school, and live in regions where regional fertility, or the share of the Muslim population, or the regional share of uneducated adult women is below-median. We now include interaction terms between female gender and these characteristics in our full school fixed-effects specification in order to: (i) measure the extent to which the residual gap is reduced in these favourable circumstances after controlling for gender differences in observable characteristics; and (ii) shed light on possible causes for the gender gap. Note that both school and regional variables in levels are subsumed in the school fixed-effects. Therefore, we need not, and indeed cannot, include these variables in levels. Parental characteristics are included in levels along with all the other covariates included in Column (4) of Table 4a (SACMEQ) or 4b (PASEC). The results are presented in Tables 5a and 5b for SACMEQ and PASEC respectively. Column (1) repeats the full specification from Tables 4a and 4b Column (4) (i.e. without interactions), to provide the comparison. We then add interactions between the gender variable and parental education in Column (2). In both groups of countries, after controlling comprehensively for observable gender differences, the gender gap remains substantial among children of educated/literate mothers, although it is significantly worse among children of uneducated mothers in SACMEQ countries and among children of illiterate fathers in PASEC countries. It should be noted that in SACMEQ, children were asked to report the highest educational level obtained by each parent, whereas in PASEC they were simply asked whether each parent was literate or not. The SACMEQ question on parental education is thus substantially harder for the child to answer, and as a consequence, parental education is often missing in this survey (see Table 1a). We therefore keep the

Table 5b
PASEC – pooled regressions with interactions.

Column: Interactions:	(1) Baseline	(2) Parent ed.	(3) School	(4) Regional	(5) All
Female	−0.114***	−0.087***	−0.054	−0.067**	−0.034
	(0.013)	(0.017)	(0.040)	(0.030)	(0.053)
Female × illiterate father		−0.053*			−0.037
		(0.032)			(0.030)
Female × illiterate mother		−0.032			0.008
		(0.028)			(0.030)
Female × public school			−0.058		−0.033
			(0.036)		(0.030)
Female × male teacher			−0.006		0.008
			(0.028)		(0.046)
Female × below-median class equipment			−0.013		−0.023
			(0.025)		(0.023)
Female × above-median regional share uneducated women				−0.092**	−0.089**
				(0.034)	(0.036)
Female × above-median regional TFR				−0.005	−0.001
				(0.033)	(0.032)
Female × above-median regional share Muslim				0.004	0.010
				(0.031)	(0.031)
Individual pupil access to schooling inputs + age	√	√	√	√	√
Home environment	√	√	√	√	√
No. of children	11,144	11,144	11,144	11,092	11,092

Source: Authors' calculations based on PASEC and DHS data, as described in Section 3.
Notes:
(1) Standard errors in parentheses.
(2) School fixed-effects estimates. The baseline specification in Column (1) is repeated from Table 4b, Column (5).
(3) Regressors corresponding to the categories "individual pupil access to schooling inputs" and "home environment" are listed in Table 1b.
(4) School/classroom environment and regional characteristics are not included in levels because they are subsumed in the school fixed effects.
(5) Standard errors for Columns (4) and (5) are clustered at the regional level.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

missing paternal/maternal education categories separate in the analysis.[11]

Next we add to the baseline specification interaction terms between female gender and school characteristics which we have seen are correlated with a greater female disadvantage in the raw data. Results in Column (3) of Table 5a show that, in the SACMEQ sample, the residual gender gap disappears among children enrolled in well-equipped private schools who have a female math teacher, and each of these three characteristics (above-median equipment, private schooling, female teacher) significantly contribute to improving female relative performance. In PASEC countries, the gap also becomes statistically insignificant in this more favourable school environment, but the point estimate is still 0.054 sd and none of these school characteristics significantly contributes to reducing the gap (Column (3) of Table 5b).

We then add to the baseline specification interaction terms between female gender and regional characteristics as presented in Column (4) of Tables 5a and 5b, and we now cluster standard errors at the regional level to prevent artificial inflation of the *t*-statistics on regional interactions due to positively correlated standard errors within regions. In both surveys, the residual gender gap is statistically significant but much reduced among children living in regions where the gap appears smaller in the raw data, i.e., in regions with fewer uneducated adult women, lower fertility rates, and a smaller share of the population being Muslim. In SACMEQ countries, each of these characteristics significantly contributes to reducing the gap (i.e., the individual coefficient on interactions between female gender and *above*-median regional characteristics are negative and statistically significant). In PASEC countries, however, only the interaction with the share of uneducated adult women is statistically significant, and conditioning on this interaction, the interactions with above-median fertility rates and above-median share of Muslims are essentially zero.

Finally, in the last column of each table we include all interaction terms simultaneously in order to test whether some interactions are proxying for others (e.g., because maternal education, teacher gender, and the regional share of uneducated women are correlated).

The results show that the coefficients on the interaction terms with parental education and, more dramatically so, the coefficients on the interaction terms with school characteristics, decrease (by an order of magnitude for school characteristics) and become statistically insignificant, whereas the coefficients on the interaction terms between female gender and regional characteristics are almost unchanged. It thus

[11] When allowing all parameters to differ between boys and girls (including school fixed effects), the negative effect on math scores of having an uneducated mother is more pronounced for girls than boys for SACMEQ countries, but there is no gender difference in the effect of parental literacy in PASEC countries.

appears that the gender gap arises in some types of schools, and, to a lesser extent, for some types of parents, only because these school- and parental characteristics are capturing some characteristic of the broader societies in which the children live. Note that not all regions of every country are covered by the DHS, and so we lose some observations when including these interaction terms (see Section 3.3). In particular, SACMEQ countries are richer, so that some of them are not covered by DHS surveys. In addition, we lose over a third of Ugandan schools due to missing teacher gender and class equipment data. In contrast, all PASEC countries are covered by DHS surveys, and so the loss of observations due to some regions not being covered is only minimal. Restricting the samples used in Tables 5a and 5b to observations with complete data does not change our conclusions (results are available upon request).[12] These results for the gender gap in average scores are consistent with those obtained by Pope and Sydnor (2010) for gender gaps at the top of the distribution among U.S. 8th graders. Indeed, they demonstrated the importance of differences in regional characteristics, in their case between states in the US, showing that the extent to which test scores adhere to gender stereotypes at the top end of the test score distribution is smaller in those states with more gender-neutral cultural attitudes.

Furthermore, relative female-to-male enrolment rates are lower where fertility is higher, where the share of Muslims in the population is higher, and where a larger share of the adult female population is uneducated as can be seen by comparing the mean values for these three variables by gender in Tables 1a and 1b. Girls observed in schools in regions characterised by higher fertility, higher Muslim share, and a greater proportion of uneducated women are thus likely to be more positively selected relative to boys in these regions. Therefore, we expect the worsening of the gender gap in these regions shown in Tables 5a and 5b to underestimate the true extent of the worsening.

In summary, we have shown that the gender gap is much reduced, and even disappears in some segments of the population, even after controlling comprehensively for gender differences in family background, school quality, and access to schooling inputs within the class and at home. Furthermore, societal factors appear to be more predictive of the gender gap than parental education or school-level factors including teacher gender, thus suggesting that a substantial portion of the gender gap in maths arises as a consequence of societal influences.[13] We do not give a causal interpretation to the coefficients estimated here, but our results suggest that the gap is much larger where the role of women in society is confined to the home (i.e., where fertility is high, the current generation of adult women has little schooling, and where Islam is more prevalent). This echoes previous findings by Guiso et al. (2008) for PISA countries, where the gap was found to decrease with higher levels of female empowerment as measured by a higher GGI. However, it may also be the case that our regional variables simply proxy for economic development. To further probe this hypothesis and for comparability with earlier literature, we complete our exploration of the data with cross-country regressions investigating the relationship between the gender maths gap and country characteristics.

5.7. Cross-country analysis

The results are reported in Tables 6 and 7. The dependent variable in these regressions is the difference between average female and male performance on maths tests, measured as the difference in mean standardised scores. Both SACMEQ and PASEC countries are included in these analyses so as to provide an overall picture.

The focus of our attention is on indicators of female empowerment. Similar to the regional characteristics considered earlier, we use the national total fertility rate (TFR) and the share of Muslims in the population, which are available for every country in our dataset (contrary to measures based on the World Value Survey, the Afrobarometer, or the GGI, which are only available for a subset of countries in our sample). The results in the first column of Table 6 first suggest that differences in GDP per capita are important, with the average gap being smaller in richer countries (Column (1)). However, the coefficient on GDP per capita is reduced by a factor of five and becomes statistically insignificant when including a control for the total fertility rate (Column (2)). The results in Table 6 thus reveal that higher fertility rates are associated with poorer performance of girls compared to boys on maths tests, even after controlling for levels of economic development. On the contrary, variation in the share Muslim in the country population does not account for cross-country variation in the gender gap (Column (4)). Interestingly, the R-squared obtained when regressing the gender gap on the fertility rate is 43%, which is very similar to the 40% obtained by Pope and Sydnor (2010) when regressing their US state-level stereotypical gender index on the proportion of individuals agreeing with the statement that “women are better suited for the home” in that state. Following Guiso et al. (2008), in Column (7) we check the sensitivity of the effect of the fertility rate to controlling for genetic factors that might be correlated both with our measure of female empowerment (fertility in our case) and gender differences in cognitive ability. In order to do so, we expand the dataset into a full set of country dyads and use the measure of genetic distance between the population of each pair of countries compiled by Spolaore and Wacziarg (2009). The estimate of the effect of the pair-wise difference in fertility rates on the pair-wise difference in relative female performance is virtually unchanged after controlling for genetic distance (cf. Columns (6) and (7)). A lower fertility rate may influence future expected returns to female schooling by lowering expected maternal mortality (Jayachandran & Lleras-Muney, 2009). However, in Column (5) in which we replace the total fertility rate as of 2000 with

[12] For the PASEC countries, we can also estimate a value-added specification controlling for maths scores at the beginning of Grade 5, as was done in Column 6 of Table 4b, although we lack statistical power to identify the contribution of interaction terms to the portion of the gender gap accumulated during Grade 5. While the coefficients on the interaction terms are statistically insignificant, the coefficient magnitude suggests that the contribution of the variable ‘above-median regional share of uneducated adult women’ to the gap accumulated during Grade 5 is proportional to its contribution to the overall gap.

[13] Given that Chad has a significantly lower female–male enrolment ratio than the other countries in the sample (see Fig. A1), we checked the robustness of the results to the exclusion of Chad from the PASEC sample, and found the conclusions to be unchanged.

Table 6
Cross-country regressions.

Variables	Difference in standardized scores (girl–boy)					Pairwise difference in scores (girl–boy)	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
GDP per capita/100	0.005**	0.001		0.005**	0.006**		
	(0.002)	(0.002)		(0.002)	(0.002)		
Total fertility rate (TFR)		−0.045*	−0.056***				
		(0.023)	(0.016)				
Share Muslim in population				0.010			
				(0.088)			
Maternal mortality rate					0.000		
					(0.000)		
Pairwise difference in TFR						−0.056***	−0.056***
						(0.007)	(0.007)
Genetic distance							0.000
							(0.000)
Constant	−0.126***	0.136	0.208**	−0.129***	−0.190**	0.012	0.012
	(0.029)	(0.139)	(0.080)	(0.040)	(0.072)	(0.023)	(0.026)
Countries (1)–(5); country dyads (6), (7)	19	19	19	19	19	171	171
R^2	0.321	0.449	0.434	0.321	0.360	0.438	0.438

Source: Authors' calculations based on SACMEQ and PASEC data (test scores) and diverse sources listed below (regressors).
Notes:
(1) Standard errors in parentheses.
(2) Data sources: GDP per capita in 2000 (IMF World Economic Outlook Database); national total fertility rate in 2000 (US Census Bureau International Database); Share Muslim in population from CIA Factbook (2010a) except for Botswana and Zambia, which are from Kettani (2009). Maternal mortality in 2010 from CIA Factbook (2010b). Genetic distance from Spolaore and Wacziarg (2009).
(3) Observations in Columns (6) and (7) are dyads. For these two regressions, standard errors are clustered at the country level.
* $p < 0.10$.
** $p < 0.05$.
*** $p < 0.01$.

Table 7
Cross-country regressions – restricted to countries with GGI data.

Variables	Difference in standardized scores (girl–boy)						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
GDP per capita/100	0.006***	0.007***	0.005***	0.006**	0.007***	0.007***	0.006***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Gender Gap Index (GGI)		−0.572					
		(0.461)					
Economic sub-index			−0.617**				
			(0.238)				
Educational sub-index				−0.027			
				(0.197)			
Health sub-index					2.623		
					(2.961)		
Political sub-index						−0.209	
						(0.313)	
Primary GER parity index							−0.007
							(0.225)
Constant	−0.130***	0.234	0.268	−0.108	−2.682	−0.105**	−0.124
	(0.029)	(0.294)	(0.156)	(0.162)	(2.881)	(0.047)	(0.202)
Countries	16	16	16	16	16	16	16
R^2	0.468	0.524	0.649	0.468	0.498	0.485	0.468

Source: Authors' calculations based on SACMEQ and PASEC data (test scores), Hausmann et al. (2007) (GGI index and subindexes) and UNESCO (2006) (Primary GER parity index).
Notes:
(1) Standard errors in parentheses.
(2) The GGI comprises the following four sub-indexes: (i) Economic participation and opportunity as measured by a weighted mean of 5 ratios, namely the ratio of female to male: labour force participation; wages; earned income; legislators, senior officials and managers; professional and technical workers; (ii) educational attainment as measured by the weighted mean of four ratios: literacy rate; net enrolment in: primary; in secondary; and in tertiary schooling; (iii) health and survival is calculated as the weighted mean of female to male healthy life expectancy and female to male sex ratio at birth; (iv) political empowerment is the weighted average of the women-to-men ratio of seats in parliament; ministers; and female-to-male years as head of state during the last 50 years. GGI data is not available for: Gabon, Guinea, Swaziland. For all indexes, gender parity implies a score of unity.
** $p < 0.05$.
*** $p < 0.01$.

the maternal mortality rate in 2010 from the CIA Factbook (2010b), the latter is statistically insignificant and the coefficient on GDP per capita is almost unchanged compared to Column (1). We also repeated the regressions in Tables 6 and 7 but excluding Chad, given its much lower school enrolment rate for girls, and found similar results both qualitatively and quantitatively.

In order to make comparisons with previous research, the regressions in Table 7 include the key national level variables that have been considered previously in the literature, for the sample of 16 countries for which these data are available (i.e., excluding Gabon, Guinea and Swaziland). The measure of female empowerment often used, the GGI, relates to the strength of female empowerment outside the home, rather than the more private sphere considered by the fertility measure in Table 6. The results in Column (1) show that the average gap is also smaller in richer countries among this sample of 16 countries. Higher values of the GGI, indicating more gender equality in the labour market, in terms of education (including relative enrolment rates and thus relative selection into schooling), health and survival, and political empowerment, cannot account for better female performance (Columns (2) to (6)), thus indicating that the relationship uncovered by Guiso et al. (2008) in PISA countries, but shown by Fryer and Levitt (2010) not to hold in TIMMS countries, does not appear to apply to Sub-Saharan Africa either. Indeed, the only statistically significant effect suggests that more equal economic participation is correlated with a larger *disadvantage* in maths for women (Column (3)). It is acknowledged, however, that the small number of observations mean that the GGI coefficients are not precisely estimated, and it is the case that the upper bound of the 95% confidence interval for the coefficient on the overall index is positive and sufficiently large enough to cancel out the gender maths gap.

Finally, we test whether the gender gap is larger where the female/male relative enrolment rate is closer to parity (i.e. where there is less selection into schooling for girls relative to boys). Fig. A1 in the appendix suggests that this is unlikely as it shows that the gender gap is *larger* in those countries that enrol a relatively smaller proportion of their girls. To confirm this, in the final column (Column (7)) of Table 7, we regressed the national gender gap on the primary gross enrolment ratio parity index (i.e., the ratio of female-to-male gross enrolment ratios as per UNESCO (2006)). The results show that differences in enrolment ratios had no influence on the gender gap.[14]

6. Conclusions

In this paper, we provide the first systematic assessment of the gender gap in maths tests in Sub-Saharan Africa. Controlling for a large set of observable characteristics measuring school quality, individual access to schooling inputs within schools, family background and schooling inputs at home does not reduce the gender gap. We can therefore rule out gender differences in school quality, within-school gender discrimination in access to schooling inputs, or gender differences in family SES and the schooling environment at home, as explanations for the observed gap. In both groups of countries under scrutiny, the residual gender gap is approximately 0.1 sd after controlling for a large set of observable characteristics. This order of magnitude is consistent with the gender gaps observed in developed countries.

At first glance, these findings may seem to suggest that girls indeed have some sizeable natural disadvantage in maths, since the gap is observed in Africa too, across most countries, and is relatively stable both between the two groups of countries included in our analysis and compared to estimates for developed countries. However, a closer look at the data shows that the overall gap hides considerable variation between groups, such that in the 'right' environment, girls do not do significantly worse than boys in maths.

When comparing boys and girls with similar characteristics, girls obtain significantly lower scores in 14 out of 19 countries. However, the magnitude of the gap varies widely, from a non-significant 0.06 sd advantage in Mauritius to as much as a 0.34 sd disadvantage in Tanzania. The raw gap also varies by characteristics of parents, schools and region. When controlling for our large set of observable characteristics, the gender gap is between 0.1 (PASEC) and 0.2 (SACMEQ) sd larger in regions with above-median rates of uneducated adult women, fertility, and share of Muslims in the population. When the interaction between gender and these regional characteristics is not controlled for, the gap appears larger among children of uneducated parents, and among pupils of poorly equipped public schools whose (maths) teacher is male. However, once the interaction between gender and the three above regional characteristics are included in the regressions, the correlation between female disadvantage, on the one hand, and parental education and school characteristics, on the other hand, disappears. This indicates that the broad societal environment not only dramatically influences female relative performance in maths, it also takes precedence over factors more directly influenced by policy such as teacher gender.

In cross-country regressions similar to those in Guiso et al. (2008) and Fryer and Levitt (2010) for medium- to high-income countries, we find confirmation that the gender gap in mathematics is strongly correlated with characteristics of the societies in which children grow up. Higher gender equality in terms of economic participation and opportunity, educational attainment, health and survival, and political empowerment, as measured by the Gender Gap Index is not correlated with better female performance in maths relative to boys in Sub-Saharan Africa, thus echoing the finding in Fryer and Levitt (2010) for TIMMS countries. However, about half the cross-country variation in the gender gap can be accounted for by variation in the total fertility rate, and when national differences in fertility are controlled for, cross-country variation in the gender gap is unrelated to differences in GDP per capita. We put less weight on our cross-country regressions than on our analysis of the micro data given that we have a sample of only 19 countries and that the PASEC and SACMEQ tests are different. But these estimates provide a useful point of comparison with previous literature, and suggest that the societal influences, which matter in determining the extent of

[14] The point estimates in Column (7) of Table 7 show that an increase of 36 percentage points in the parity ratio, which corresponds to fully bridging the gap between the lowest-parity country in the sample (Chad) and gender parity in primary enrolment would only account for a change (a decrease) in the gender gap by less than 0.003 of a standard deviation.

the gender gap in the individual data, and which are correlated with the regional share of adult women who have no education, the regional share Muslim in the population, and the regional total fertility rate, might have more to do with cultural values than economic opportunities.

This analysis gives support to the idea that a substantial share of the ubiquitous gender gap in maths performance is not due simply to inherent, genetic differences between genders *per se*, but that specific environmental factors are required in order for any genetic difference that there may be to translate into sizeably lower average female performance in maths. This gap therefore does not have to be accepted as unavoidable.

There are two possible interpretations for these findings. The first one is that girls perform less well in maths tests without having inferior mathematics knowledge due, e.g., to a stereotype threat, and that this stereotype threat is stronger in regions where traditional female roles are more pronounced. The second explanation is that girls acquire fewer mathematics skills in these regions. Lack of data prevents us from disentangling these two mechanisms. Either way, lower scores at mathematic cognitive tests are associated with lower income. Although the countries and tests referred to in the following studies are different to the ones considered here, estimates in Glewwe (1996) and Jolliffe (1998) for Ghana, and Moll (1998) for South Africa imply that an increase by 0.1 sd in maths test scores is correlated with a 2–6.5% increase in income. The magnitude of the gender gap observed in our data may therefore lead to non-negligible gender differences in income, especially in regions where the gap is particularly wide. Our cross-country comparisons as well as existing evidence of the gender gap in developed countries suggest that the gap is unlikely to disappear with economic growth alone.

Reduction in gender inequalities is not necessarily as powerful a tool for economic development as sometimes argued, but gender equality may be worth pursuing in its own right (Duflo, 2012). What can policy makers interested in promoting gender equality learn from our study? More research is needed in order to test the causal effect of specific interventions aimed at improving female performance in maths. But the evidence provided in this paper suggests that one intervention known to improve female *enrolment* in developing countries, namely the provision of female teachers, is unlikely to close the gap on its own, given that we show that girls do not perform any better with a female teacher conditional on living in regions with unfavourable characteristics. Furthermore, single-sex schooling is associated with a lower gender gap in maths only in a subset of countries in our sample, and the small numbers observed in such schools limit the generality of such an effect. Experimental evidence on the effect of single-sex schooling on the gender gap would be welcome in order to establish the extent to which this association can be interpreted as causal.

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Appendix A

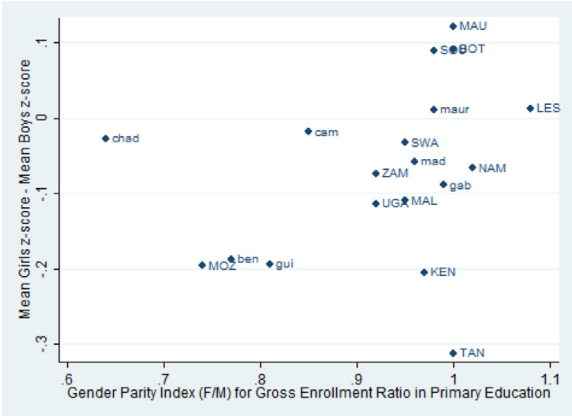

Fig. A1. Correlation between the gender gap in maths and the gross enrolment ratio. *Source*: Authors' calculations based on SACMEQ II, PASEC, and UNESCO (2006) as described in Section 3.

Table A1
Comparison of primary education gross parity index between UNESCO and SACMEQ/PASEC data sources.

Country	Primary education gross parity index from UNESCO (2006)	Grade 5 (PASEC) or Grade 6 (SACMEQ) enrolment ratio from surveys used in the analysis
SACMEQ		
Botswana	1.00	1.04
Kenya	0.97	0.95
Lesotho	1.08	1.29
Malawi	0.95	0.91
Mauritius	1.00	0.93
Mozambique	0.74	0.62
Namibia	1.02	1.05
South Africa	0.98	1.05
Swaziland	0.95	1.06
United Republic of Tanzania	1.00	1.07
Uganda	0.92	0.78
Zambia	0.92	0.93
PASEC		
Benin	0.77	0.65
Cameroon	0.85	0.77
Chad	0.64	0.55
Gabon	0.99	0.99
Guinea	0.81	0.79
Madagascar	0.96	1.20
Mauritania	0.98	1.02

Source: UNESCO (2006) and authors' calculations based on SACMEQ and PASEC data.
Note: The gross parity index from UNESCO (2006) is equal to the ratio of the female GER over the male GER for all primary school grades. The coefficient of correlation between the enrolment ratio in our sample (taken in a single year towards the end of primary schooling) and the enrolment ratios from this external source is 0.91.

Table A2
SACMEQ – individual country regressions: female coefficients.

Column: Specification	(1) No FE	(2) School FE	(3) (2) + age + individual pupil access to schooling inputs	(4) (3) + home environment
Botswana	0.091***	0.098***	0.029	0.021
	(0.030)	(0.027)	(0.027)	(0.026)
No. of children	3321	3321	3321	3321
R^2	0.003	0.004	0.058	0.121
Kenya	−0.205***	−0.227***	−0.280***	−0.286***
	(0.033)	(0.027)	(0.027)	(0.027)
No. of children	3296	3296	3279	3279
R^2	0.012	0.022	0.086	0.111
Lesotho	0.013	0.009	−0.029	−0.031
	(0.021)	(0.018)	(0.018)	(0.018)
No. of children	3144	3144	3144	3144
R^2	0.000	0.000	0.024	0.047
Malawi	−0.110***	−0.092***	−0.110***	−0.108***
	(0.021)	(0.020)	(0.020)	(0.020)
No. of Children	2,323	2,323	2,323	2,323
R^2	0.012	0.009	0.030	0.048
Mauritius	0.121*	0.096*	0.036	0.063
	(0.049)	(0.043)	(0.041)	(0.039)
No. of children	2870	2870	2870	2870
R^2	0.002	0.002	0.107	0.221
Mozambique	−0.197***	−0.244***	−0.244***	−0.236***
	(0.023)	(0.022)	(0.022)	(0.022)
No. of children	3136	3136	2999	2999
R^2	0.023	0.042	0.063	0.099
Namibia	−0.066**	−0.036*	−0.063***	−0.064***
	(0.024)	(0.016)	(0.016)	(0.016)
No. of children	4990	4990	4990	4990
R^2	0.002	0.001	0.025	0.047
South Africa	0.089*	0.019	−0.021	−0.016
	(0.038)	(0.022)	(0.023)	(0.022)
No. of children	3135	3135	3113	3113
R^2	0.002	0.000	0.029	0.075
Swaziland	−0.033	−0.032	−0.086***	−0.085***
	(0.025)	(0.023)	(0.023)	(0.023)
No. of children	3138	3138	3138	3138
R^2	0.001	0.001	0.036	0.051
Tanzania	−0.312***	−0.333***	−0.352***	−0.344***
	(0.032)	(0.029)	(0.029)	(0.028)
No. of children	2849	2849	2849	2849
R^2	0.031	0.048	0.090	0.149
Uganda	−0.114**	−0.188***	−0.203***	−0.199***
	(0.042)	(0.026)	(0.026)	(0.026)
No. of children	2619	2619	2619	2619
R^2	0.003	0.020	0.059	0.081
Zambia	−0.074**	−0.095***	−0.121***	−0.118***
	(0.026)	(0.024)	(0.024)	(0.024)
No. of children	2586	2586	2517	2517
R^2	0.003	0.007	0.044	0.080

Source: Authors' calculations based on PASEC data, as described in Section 3.
Notes: See notes under Table 4a.

Table A3
PASEC – individual country regressions: female coefficients.

Column: Specification	(1) No FE	(2) School FE	(3) (2) + age + individual pupil access to schooling inputs	(4) (3) + home environment	(5) (4) no imputed values	(6) (4) + initial score
Benin	−0.187***	−0.193***	−0.195***	−0.193***	−0.182***	−0.091***
	(0.044)	(0.030)	(0.030)	(0.031)	(0.033)	(0.028)
No. children	1822	1822	1820	1761	1606	1761
R^2	0.010	0.025	0.027	0.044	0.049	0.241

(*continued on next page*)

Table A3 (*continued*)

Column: Specification	(1) No FE	(2) School FE	(3) (2) + age + individual pupil access to schooling inputs	(4) (3) + home environment	(5) (4) no imputed values	(6) (4) + initial score
Cameroon	−0.018	−0.023	−0.025	−0.025	−0.029	0.032
	(0.044)	(0.036)	(0.036)	(0.038)	(0.040)	(0.037)
No. children	1735	1735	1723	1621	1480	1621
R^2	0.000	0.000	0.001	0.014	0.018	0.080
Chad	−0.027	−0.109***	−0.112***	−0.089**	−0.098**	−0.019
	(0.048)	(0.035)	(0.035)	(0.042)	(0.046)	(0.039)
No. children	1237	1237	1205	1046	915	1046
R^2	0.000	0.009	0.012	0.033	0.038	0.173
Gabon	−0.089**	−0.123***	−0.123***	−0.127***	−0.167***	−0.046
	(0.039)	(0.035)	(0.035)	(0.037)	(0.041)	(0.033)
No. children	1491	1491	1465	1393	1191	1393
R^2	0.004	0.009	0.017	0.032	0.046	0.248
Guinea	−0.194***	−0.151***	−0.155***	−0.157***	−0.157***	−0.081***
	(0.039)	(0.025)	(0.026)	(0.028)	(0.029)	(0.026)
No. children	2173	2173	2148	2036	1863	2036
R^2	0.012	0.017	0.019	0.026	0.030	0.193
Madagascar	−0.058	−0.071**	−0.086***	−0.083**	−0.100***	−0.068**
	(0.040)	(0.032)	(0.032)	(0.033)	(0.034)	(0.029)
No. children	1964	1964	1930	1857	1721	1857
R^2	0.001	0.003	0.011	0.021	0.026	0.273
Mauritania	0.011	−0.117***	−0.116***	−0.128***	−0.132***	−0.059*
	(0.045)	(0.032)	(0.032)	(0.035)	(0.037)	(0.032)
No. children	1482	1482	1470	1430	1279	1430
R^2	0.000	0.010	0.019	0.029	0.031	0.217

Source: Authors' calculations based on PASEC data, as described in Section 3.
Notes: See notes under Table 4b.

Table A4
Details of data sources.

Survey/country	Variables used in cross-country regressions							Regional variables used in individual-level regressions
	School survey	GDP year	National TFR year	GGI year	Share Muslim – year varies	Maternal mortality year	Primary gross enrolment ratio year	DHS year
SACMEQ								
Botswana	2000	2000	2000	2007	Kettani (2009)	2010	1999	n/a
Kenya	2000	2000	2000	2007	CIA Factbook (2010a)	2010	1999	1998
Lesotho	2000	2000	2000	2007	CIA Factbook (2010a)	2010	1999	2004
Malawi	2002	2000	2000	2007	CIA Factbook (2010a)	2010	1999	2000
Mauritius	2001	2000	2000	2007	CIA Factbook (2010a)	2010	1999	n/a
Mozambique	2000	2000	2000	2007	CIA Factbook (2010a)	2010	1999	1997
Namibia	2000	2000	2000	2007	CIA Factbook (2010a)	2010	1999	2000
South Africa	2000	2000	2000	2007	CIA Factbook (2010a)	2010	1999	1998
Swaziland	2000	2000	2000	n/a	CIA Factbook (2010a)	2010	1999	2006/2007
Tanzania	2000	2000	2000	2007	CIA Factbook (2010a)	2010	1999	1999
Uganda	2000	2000	2000	2007	CIA Factbook (2010a)	2010	1999	2000/2001
Zambia	2000	2000	2000	2007	Kettani (2009)	2010	1999	2001/2002
PASEC								
Benin	2004/2005	2000	2000	2007	CIA Factbook (2010a)	2010	2004	2006
Cameroon	2004/2005	2000	2000	2007	CIA Factbook (2010a)	2010	2004	2004
Chad	2003/2004	2000	2000	2007	CIA Factbook (2010a)	2010	2004	2004
Gabon	2005/2006	2000	2000	n/a	CIA Factbook (2010a)	2010	2004	2000
Guinea	2003/2004	2000	2000	n/a	CIA Factbook (2010a)	2010	2004	2005
Madagascar	2004/2005	2000	2000	2007	CIA Factbook (2010a)	2010	2004	2003/2004
Mauritania	2003/2004	2000	2000	2007	CIA Factbook (2010a)	2010	2004	2003

Notes:
(1) GGI: National Gender Gap Indexes data are only available from 2006 onwards (Haussmann et al., 2007).We use the 2007 data as it includes one additional country (Mozambique).
(2) The 2003 Mauritania DHS is not in the public domain. For this country, the variables used in the analysis are therefore taken from the corresponding DHS report (Isselmou, 2004) rather than calculated from the microdata.

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