Bridging Gender Gaps in Developing Country Education: The Role of Female Teachers

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Abstract: Recruiting female teachers is frequently suggested as a policy option for improving girls' education outcomes in developing countries, but there is very limited evidence on its impact in doing so. We study gender gaps in learning outcomes, and the effectiveness of female teachers in reducing these gaps using a large, representative, annual panel data set in the Indian state of Andhra Pradesh. We report six main results in this paper. (1) We find a small but significant negative trend in girls' test scores in both math (0.02σ/year) and language (0.01σ/year) as they progress through the primary school system; (2) Using five years of panel data and school-grade fixed effects, we find that both male and female teachers are more effective at teaching students of their own gender; (3) However, female teachers are more effective overall, resulting in girls' test scores improving by an additional 0.036σ in years when they are taught by a female teacher, with no adverse effects on boys when they are taught by female teachers; (4) Male teachers are significantly less effective at teaching math to girls (relative to language), and girls derive greater benefits from having a female teacher in math than in language; (5) We find no effect of having a same-gender teacher on attendance or school retention, suggesting that the mechanism of impact on learning outcomes is not on the extensive margin of school participation, but on the intensive margin of classroom leaning; (6) Finally, we estimate that 10-20% of the negative trend in girls' test scores as they progress through school can be accounted for by the increasing probability of having a male teacher in higher grades.

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1. Introduction

Reducing gender gaps in education attainment has been an important priority for international education policy, and is explicitly listed as one of the Millennium Development Goals (MDGs). This commitment has been reflected in the policies of many developing countries, and substantial progress has been made in the past decade in reducing gender barriers in primary school enrollment. One key policy that is credited with increasing girls' education is the increased recruitment of female teachers (UNESCO 2012, Herz and Sperling 2004, UN 2012). UNICEF has documented the practice in a variety of countries, including Bangladesh, India, Liberia, Nepal, and Yemen, and the United Nations Task Force for achieving the MDGs has advocated hiring more female teachers as an effective policy mechanism for reaching the goal of universal primary education of girls (UNDG 2010, Rehman 2008, Slavin 2006).

While the idea that hiring more female teachers can bridge gender gaps is widely prevalent among policy makers, there is very little empirical evidence on testing this hypothesis in developing countries. In this paper, we study the causal impact of having a female teacher on the learning gains of female students, using one of the richest datasets on primary education in a developing country. The dataset was collected as a part of the Andhra Pradesh Randomized Evaluation Studies (AP RESt), and features annual longitudinal data on student learning measured through independent assessments of learning conducted over five years across a representative sample of 500 rural schools and over 90,000 students in the Indian state of Andhra Pradesh. The data also includes detailed information on teacher characteristics and on their assignments to specific classrooms in each year.

The combination of panel data and variation in the gender of teachers that students are exposed to as they pass through grades over time allows us to estimate the causal impact of matching teacher and student gender in a *value-added* framework. Identification concerns are addressed by showing that our causal estimates of gender matching do not change under an increasingly restrictive set of specifications including school fixed effects, and school-grade fixed effects. We also show that there is no correlation between the probability of being assigned a female teacher and either the fraction of female students in the class or their test scores at the start of the year. Further, our estimation sample is restricted to schools that only have one section per grade, which precludes the possibility that students may be tracked across sections and that female teachers may be assigned to different sections based on unobservables.

We report six main findings in this paper. First, we find a small but significant negative trend in girls' test scores in both math (0.02σ/year) and language (0.01σ/year) over the five years of primary school. Girls have significantly higher test scores in language and equal test scores in math relative to boys at the end of grade one, but score almost on par with boys in language and significantly worse in math by the end of grade five. Thus, consistent gender gaps in achievement at later ages, such as those documented in the mathematics scores in the PISA test at age 15 (Bharadwaj et al. 2012), probably reflect a cumulative effect of a trend that starts as early as primary school.

Second, using five years of panel data and school-grade and student gender-grade fixed effects, we find that teachers are .034 standard deviations more effective in teaching students of their own gender *relative* to teachers of the opposite gender. This is a difference-in-difference estimate that compares the relative advantage of female teachers in teaching girls rather than boys with the relative disadvantage of male teachers in teaching girls rather than boys, and is *symmetric by construction*. However, the overall effectiveness of a teacher is also determined by his or her effectiveness at teaching students of the opposite gender, which varies across male and female teachers.

Our third result speaks to this issue and we find that female teachers in our setting are more effective overall than male teachers, resulting in a positive shared gender effect for girls, who perform .036σ better with female teachers rather than male teachers, but not for boys, who perform similarly regardless of the gender of their teachers. This implies that girls are likely to benefit from a policy of hiring more female teachers, and overall educational performance is likely to increase due to the lack of any offsetting effect on boys.

Fourth, these effects do differ by subject. In particular, male teachers are considerably less effective at teaching math to girls than to boys (relative to their effectiveness at teaching language). We also find that the value to a girl of having a female teacher is higher in math than in language and while girls continue to fare better with female teachers relative to male teachers in both language and math, the effect is greater in math (.04σ) relative to language (.02σ). Boys though fare a little worse with female teachers (relative to male teachers) in language (.02σ), and experience no differential effect of teacher gender in math. Together, these results suggests that the overall gains from hiring female teachers come mainly from improving mean math test scores relative to male teachers (positive for girls, no effect for boys) than from language (positive for girls, negative for boys, and no overall effect).

Fifth, since we also have data on student attendance and drop-out rates, we also examine the possible mechanisms of the above impact and find no effect of teachers being more effective at raising the attendance or school retention for students of the same gender. This suggests that the likely mechanism for the 'matching' effect is not on the extensive margin of increased contact time, but rather on the intensive margin of more effective classroom interactions.

Finally, we document that female teachers are more likely to teach in earlier grades. We show therefore that around 10-20% of the trend of increasing gender gaps in test scores over time can be attributed to the reduction in the probability of girls being taught by female teachers as they advance to higher grades. Since teachers in higher grades are more likely to be male across several countries (NAEP 2011; UNESCO 2010), our results suggest that an important channel for growing gender gaps in achievement (especially in math) could be the greater likelihood of having male teachers in higher grades.

While there have been several studies on the impact of shared gender between teachers and students on learning outcomes in developed country contexts, there is surprisingly little evidence on this question from developing countries. In the US and UK, studies have shown improved test scores, teacher perception, student performance, and engagement of girls when taught by a female teacher in schools, with magnitudes of test score impacts similar to those found in our paper (Dee 2007, Dee 2005, Nixon and Robinson 1999, Ehrenberg et al. 1995, Ouazad and Page 2012). However, other studies conducted in both US and European countries have failed to find such an effect (Holmund and Sund 2008, Carrington, Tymms and Merrell 2008, Lahelma 2006, Winters et al. 2013, Marsh et al. 2008, Driessen 2007, Neugebauer et al.). In higher education institutions in the US, female professors have been found to have small effects on female students' course selection, achievement, and major choice (Bettinger et al. 2004, Carrell et al. 2009, Hoffmann and Oreopoulos 2009).[2]

However, the question of the role of female teachers in reducing gender gaps is much more salient in developing country contexts, because recent evidence suggests that there is no longer a

[2]Analogous to gender, studies in the United States have also looked at the effect of sharing the ethnicity of a teacher and have generally found positive effects on such educational outcomes as drop outs, pass rates, and grades at the community college level, and teacher perceptions and student achievement in school going children (Dee 2004, Dee 2005, Farlie et al. 2011). We find no similar effect on other important dimensions in the India context, particularly disadvantaged castes and minority religions.

gender gap in mean test scores in most developing country contexts (PISA 2009, NAEP 2011). In contrast, there are still considerable gender gaps in school enrollment and attainment in developing countries (Muralidharan and Prakash 2013). The only related paper in a developing country setting is Rawal and Kingdon (2010), who use test score data on 2nd and 4th grade students in the Indian states of Bihar and Uttar Pradesh, and find a positive impact on educational achievement for girls taught by female teachers, but find no similar effect for boys.

In addition to providing well-identified estimates of the impact of matching teacher and student gender on learning outcomes in a developing country (where the literature is very sparse), our dataset allows us to make advances relative to both the developed and developing country literatures on this subject. First, while several existing papers in this literature (especially those looking at college-level outcomes) use grades or test scores assigned by the students' own teachers, the test scores used in this paper are based on independent assessments and grading. This limits the concern that the measured effects of gender matching may reflect more generous grading by teachers towards students who share their own gender and allows us to be confident that the effects we measure reflect genuine impacts on learning.

Second, the majority of papers in the global literature on this question (including Dee 2007 and Rawal and Kingon 2012) use student fixed effects and variation in the gender of teachers across different subjects to identify the impact of the gender match on learning, but they are based on comparing *levels* of test scores as opposed to value added. Thus, it can be difficult to interpret the magnitudes of the estimated effects without knowing the gender composition of the teachers in that subject in previous grades.[3] Our use of five years of annual panel data on test scores allows us to estimate the impact of a gender match on the *value-added in the year that the match occurred*, which has a much clearer interpretation. Finally, we observe students at a younger and more formative age than most of the literature, when the role of matching characteristics may be especially important. This is also the age that is most relevant to policy for reducing education gender gaps in developing countries since the majority of students do not complete more than eight years of school education.

[3] Thus, if this approach finds that a girl in eighth grade who has a female language teacher and a male math teacher does better in language, the interpretation of the point estimate is confounded by the possibility that the girl is also more likely to have had female language teachers in earlier grades (especially if teacher gender is correlated with subjects taught)

The remainder of this paper is organized as follows: Section 2 describes the dataset and presents summary statistics on students and teachers; Section 3 lays out the estimation and identification strategies; Section 4 presents the main results, and section 5 concludes.

2. Context and Dataset

India has the largest primary schooling system in the world, catering to over 200 million children. As in other developing countries, education policy in India has placed a priority on reducing gender disparities in education, and both the Five Year Plans and Sarva Shiksha Abhiyan (SSA), the flagship national program for universal primary education, have called for an increase in recruiting female teachers as a policy for increasing girls' education. SSA requires that 50% of new teachers recruited be women, and the 11^{th} Five Year Plan suggested that it be increased to 75% (Government of India 2008). These calls for increased female teachers reflect a belief that through such mechanisms as role model effects, increased safety, reduced prejudices, and greater identification and empathy, female teachers are arguably more effective in increasing girls' achievement in primary school relative to their male counterparts (Dee 2005, Steel 1997).

This paper uses data from the Indian state of Andhra Pradesh (AP), which is the 5^{th} most populous state in India, with a population of over 80 million (70% rural). The data was collected as part of the Andhra Pradesh Randomized Evaluation Studies (APRESt), a series of experimental studies designed to evaluate the impact of various input and incentive-based interventions on improving education outcomes in AP.[4] The project collected detailed panel data over five years (from 2005-2010) on students, teachers, and households in a representative sample of 500 government-run primary schools (grades 1 through 5) across 5 districts in Andhra Pradesh. The dataset includes annual student learning outcomes as measured by independently conducted and graded tests (conducted once at the start of the 2005-06 school year as a baseline, and subsequently at the end of each school year) in language (Telugu) and math, basic data on student and teacher demographics, and detailed household socio-economic data for a subset of households. The test scores are normalized within each year-grade-subject combination and all analysis is conducted in terms of normalized test scores, with magnitudes being reported in standard deviations.

[4] These interventions are described in Muralidharan and Sundararaman (2011). Note that while different schools in our sample were exposed to different treatments, our main specifications of interest use school-fixed effects and thereby use only *within* school variation to identify the effects of matching teacher and student gender.

Table 1, Panel A, presents descriptive statistics on students who have at least one recorded test score and data on gender in the dataset.[5] Girls comprise 51% of the sample of public-school students in our sample, but this does not imply that more girls are going to school than boys since it is likely that more boys are attending private schools (ASER 2012). However, it does illustrate that on average, girls are well represented in public primary schools and in our sample. The girls in the sample come from modestly better off socioeconomic backgrounds than the boys, and have parents who are slightly more educated and affluent. These differences probably reflect two dimensions of selection into the sample – better off households are more likely to send girls to school, and better off households are more likely to send boys to private schools. However, the magnitudes of these differences are quite small (often in the range of 0-2 percentage points), and the statistical significance reflects the very large sample size. Since the household surveys were completed for only 70% of the sample of students for whom we have test score data, our main specifications do not include household controls.[7]

Table 1, Panel B, presents summary statistics for the teachers in our analysis. Female teachers comprise 46% of the total teacher body, but are less experienced, less likely to have completed a college or masters degree, and less likely to hold a head-teacher position. Not surprisingly, their mean salaries are also lower. They also comprise a much greater share of the contract teacher work-force than that of regular civil-service teachers. Since teacher characteristics vary systematically by gender, we will report our key results on the impact of matching teacher and student gender, both with and without controls for these additional teacher characteristics.

Table 2 - Panel A presents summary statistics on gender differences in test scores by subject and grade. We see that girls score as well as boys in math and score 0.05σ *higher* on language in grade 1, and that this result holds both in the overall sample means as well as with school fixed effects. However, there is a steady decline in girls' test scores in both math and language as they advance through higher grades, and by the last two years of primary school (grades 4 and 5) we see that girls' initial advantage in language scores has declined and they do significantly worse

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[5] Less than 3 percent of students with test scores have no recorded gender.

[7] While there are a few observable differences between the boys and girls in the sample, including these in the estimation will only matter if there are differential interactions between these household characteristics and teacher gender across boys and girls. We verify that our results are robust to the inclusion of household characteristics, but prefer to not include household characteristics in our main estimating equations because doing so reduces the sample size by 30% and it is likely to cause non-random attrition. Results with household controls are available on request.

than boys on math (.1 standard deviations). Table 2 - Panel B quantifies the annual decline in girls' relative scores with a simple interaction specification and we see a mean decline of 0.02σ/year in math scores and 0.01σ/year decline in language scores for girls relative to boys.[8]

3. Estimation and Identification

Our main estimating equation takes the form:

$$(1) \quad E_{itjk} = \alpha + \delta_1 E_{it-1j-1k} + \beta_1 (F * g)_{itjk} + \beta_2 g_{itjk} + \beta_3 F_{itjk} + \boldsymbol{\gamma T_{itjk}} + \mu_{itjk}$$

where E_{itjk} are student educational outcomes (i.e., test scores, attendance, drop-out) for student i, in year t, grade j, and school k respectively. g_{itjk} is an indicator for whether the student is a girl, F_{itjk} is an indicator for whether the student's current teacher is female, and $F*g_{itjk}$ is the indicator for whether a girl student shares her teacher's gender in the current year. $\boldsymbol{T}_{itjk}$ is a vector of additional teacher characteristics, and μ_{itjk} is a stochastic error term. The inclusion of the lagged test score on the right-hand side of (1) allows us to estimate the impact of contemporaneous inputs in a standard *value-added* framework. Since all test scores are normalized by grade and subject, the estimated coefficients can be directly interpreted as the correlation between the covariate and annual gains in normalized test scores.[9] When studying attendance and whether a student drops out, we do not include the lagged attendance or enrollment of the previous year. The above estimating equation is a 'difference in difference' specification that allows us to calculate the marginal impact of changing each component of the feasible student-teacher gender combinations relative to boys taught by male teachers (the omitted category).

The first coefficient of interest in this paper is β_1, which indicates the extent to teachers are relatively more effective at teaching to their own gender compared to teachers of the opposite gender. Since the indicator variable is based on the interaction of dummies for teacher and student gender, the coefficient is a 'difference in difference' estimate of the impact of female teachers when teaching girls rather than boys *relative* to their male counterparts teaching girls rather than boys. The coefficient on the interaction term therefore reflects the sum of the relative advantage of female teachers when teaching girls (rather than boys) and the relative disadvantage

[8] It is worth noting that achievement differences could be due to educational quality and access being different across genders in schools or to environmental factors that affect education achievement outside of the school's control. Furthermore, lack of differences does not necessarily mean that gender gaps are nonexistent since this is a sample of public schools only – a closing of gender gaps within public schools could be illustrative of more academically superior boys being sent to private schools relative to girls.

[9] In the case of grade 1 where there is no lagged score (since there was no testing prior to enrolling in school), we set the normalized lagged score to zero.

of male teachers when teaching girls (rather than boys). (i.e., β_1 = *(female teachers teaching girls – female teachers teaching boys) – (male teacher teaching girls – male teachers teaching boys)*).

By construction, this is symmetric and equivalent to the relative effectiveness of male teachers teaching boys compared to girls *relative* to female teachers teaching boys compared to girls. It is important to highlight that a positive β_1 does not necessarily imply that both boys and girls have better outcomes when sharing their teacher's gender. For example, a positive β_1 could co-exist with a situation where all students are better off with female (or male) teachers because the general effectiveness of female (or male) is considerable higher (even for students of the opposite gender).

β_2 is the difference in test score gains of girls taught by male teachers relative to boys taught by male teachers (i.e., *male teachers teaching girls – male teachers teaching boys).* β_3 is the difference in test score gains of boys taught by female teachers relative to when taught by male teachers (i.e., *female teachers teaching boys – male teachers teaching boys)*. Thus, β_3 estimates to what extent, if any, are boys adversely affected when taught by a female teacher relative to a male teacher.

Starting with the omitted category (of male teachers teaching boys), adding combinations of $\beta_1, \beta_2$and β_3 allow us to measure other marginal effects of interest. Thus β_3 estimates whether boys learn more when taught by female teachers. Similarly, testing if $\beta_1 + \beta_3 > 0$ provides a formal test of whether girls gain by being paired with female teachers relative to male teachers. The derivation is below:

$$(2)\ female\ teachers\ teaching\ girls\ -\ male\ teachers\ teaching\ girls > 0$$

$$(\alpha + \beta_1 + \beta_2 + \beta_3) - (\alpha + \beta_2) > 0$$

$$\beta_1 + \beta_3 > 0$$

As highlighted earlier, it is possible that female teachers are relatively more effective at teaching girls than boys compared to male teachers (a positive β_1) , but that female teachers are overall less effective (a negative β_3), resulting in girls being better off with male teachers despite the loss in gains from not sharing their teacher's gender ($\beta_1 + \beta_3 < 0$) .

Additionally, if we value both boys' and girls' educational achievement equally, then we would be interested in knowing whether the positive gain for girls taught by female teachers outweighs any adverse effects from mismatching boys to being taught by female teachers (i.e., (*potential gain to girls + potential loss to boys).* The formal test for this (under the assumption of an equal proportion of boys and girls in the population) is $\beta_1 + 2 * \beta_3 > 0$, derived as follows:

$$(3)\ potential\ gain\ to\ girls + potential\ loss\ to\ boys > 0$$

$$(Female\ teachers\ teaching\ girls - Male\ teachers\ teaching\ girls) + (Female\ teacher\ teaching\ boys - Male\ teachers\ teaching\ boys\ -) > 0$$

$$[(\alpha + \beta_1 + \beta_2 + \beta_3) - (\alpha + \beta_2)] + [(\alpha + \beta_3) - (\alpha)] > 0$$
$$\beta_1 + 2 * \beta_3 > 0$$

The test outlined in Eq (3) can also be interpreted as a proxy for the overall effectiveness of female teachers relative to male teachers.

The main identification challenge in interpreting these coefficients causally are that teachers are not randomly assigned to schools, and it is possible that schools with more female teachers are in areas with greater female education levels to begin with and that girls would perform well in these schools regardless of their teacher's gender. In such a case, the estimate of β_1 could be confounded by omitted variables correlated with both the probability of having a female teacher and higher educational outcomes. We address this concern by augmenting (1) with school fixed effects, and thereby estimating the impact of a gender-match on value-added *relative* to the schools' average effectiveness at improving value-added for each gender.

A further concern could be that teachers are not assigned randomly to grades within schools, and a similar omitted variable concern would apply if female teachers are differentially assigned to grades in which girls are more likely to show greater test score gains (for instance, if female teachers are more likely to be assigned to younger grades and if girls outperform boys in earlier grades). To address this concern, we include school grade fixed effects, which controls for the average performance in a given *grade* in the school (instead of the overall performance of the school). Finally, to account for potentially differential trajectories of learning in different grades *by gender*, we also include grade fixed effects by student gender to estimate the parameters of interest by comparing educational outcomes relative to girls' and boys' average learning trajectories in each grade. Our preferred specification therefore includes both school-grade fixed effects and grade fixed effects by gender to addresses this concern.[11]

A final concern could be that if grades in a school have multiple sections, then the assignment of teachers to sections within grades could be based on omitted variables such as a greater probability of assigning female teachers to sections that have girls with a greater likelihood of improving test scores. However, this is not an important factor in our setting because schools typically have fewer teachers than grades, and the typical teaching arrangement is one of multi-grade teaching (where the same teacher simultaneously teaches multiple grades) and so there are only few cases where there are multiple sections per grade with different teachers assigned to different sections. We drop all such cases (6% of observations) where there are multiple teachers per grade.

3.1. Testing the Identifying Assumptions

Table 3 shows the correlation between various classroom characteristics and the probability of the classroom having a female teacher. We see that there is no significant correlation between having a female teacher and the fraction of girls in the classroom or with the average test scores of incoming cohorts for either gender. Female teachers *are* more likely to be assigned to younger grades though. But once school-grade fixed effects are included, this is no longer an issue for average female teacher effects, and it continues to be case that having a female teacher in the class has no significant correlation with either the fraction of female students or the test scores of the incoming cohort (columns 3 and 4).

However, we see in Table 4 that girls do have a slightly flatter learning trajectory than boys. We estimate a standard value-added model that controls for lagged test scores (as in Eqn. 1), but allow for an interaction between student gender and grade, and we see that female students have lower value-added in higher grades. Since female teachers are more likely to be assigned to lower grades, the inclusion of school*grade fixed effects (i.e., an average effect of the school grade for both student genders) does not address the possible spurious correlation of female students being assigned to female teachers in the grades in which they fall behind boys at a lower

[11] Since the data are drawn from schools that were exposed to various experimentally-assigned programs, all estimates include dummy variables indicating the treatments that the schools were assigned to. But, this turns out to not matter in practice because our main estimating equations already include school fixed effects, which makes the treatment status of the school irrelevant for identification purposes.

rate. Therefore, we also include grade fixed effects for each student gender in our main specifications to control for average value-added test scores in each grade *by student gender*.

We also verify that there is no significant difference between classrooms taught by male and female teachers on any of the household socio-economic variables listed in Table 1 (tables available on request), but we focus our attention on the test-scores of incoming cohorts as the most useful summary statistic of previous inputs into education to test balance on, because the sample size with the household survey is 30% smaller than that of just the test scores.

4. Results

The main results of the paper (from estimating equation 1) are presented in Table 5. Panel A pools the results across both subjects (math and language), while Panels B and C separate out the results by subject. The columns show increasingly restrictive identification assumptions with school fixed effects (Column 2), school*grade fixed effects (Column 3), and both with grade fixed effects by student gender (Column 4 and 5). Column 6 expands the preferred specification in Column 5 with the inclusion of teacher covariates to differentiate between a pure "gender effect" versus effects driven by teacher characteristics correlated with teacher gender. Thus, the estimates in column 5 are relevant to the policy question of "what will happen if we hire an additional female teacher from the typical pool of female teachers", whereas those in column 6 answer the question of "what will happen if we just switch a teacher's gender from male to female holding other observable characteristics constant". While our main results are remarkably stable and robust under the various specifications, our discussion below will use the estimates in column 5, unless mentioned otherwise.

Averaged across subjects, we see that teachers are .034 standard deviations more effective in teaching to their own gender relative to a student of the opposite gender compared to teachers of the other gender. In other words, female (male) teachers are .034 standard deviations more effective in teaching girls (boys) rather than boys (girls), relative to male (female) teachers. We find no negative effect on boys from being taught by female teachers relative to male teachers (β_3 is close to zero). We estimate that girls gain .036 standard deviations ($\beta_1 + \beta_3$)when taught by female teachers instead of male teachers, and the net welfare effect ($\beta_1 + 2 * \beta_3$) is nearly equivalent (.037) and statistically significant. However, once we control for teacher characteristics, this net welfare effect drops by .01 standard deviations, suggesting that characteristics correlated with female teachers[12] may partly contribute to female teachers being more effective overall, and that the "pure" gender effect is slightly smaller.

Panels B and C of Table 5 breaks down the results by subject, and a striking result is the extent to which (β_2) is much lower for math than for language. Thus, male teachers are particularly less effective at improving math test scores for female students (relative to their effectiveness in improving language test scores). Comparing ($\beta_1 + \beta_3$) across subjects also shows that the gains to girls from having a female teacher are higher in math. Finally, comparing the total social gains of shifting from a male to a female teacher ($\beta_1 + 2 * \beta_3$) across subjects, we see that all the gains in Panel A - Column 6 can be attributed to math (where female teachers do much better with girls and no worse with boys) with the net effects in language being close to zero (positive for girls and negative for boys).

We also study the impact of a teacher-student gender match on attendance and retention respectively. We find no significant effect of a gender-match on student attendance (Table 6). We do find that female teachers are slightly more effective at increasing attendance overall (by less than 1 percent), but there is no differential impact by student gender. Table 7 finds teachers are not relatively more effective in reducing drop-outs of students of the same gender, but that female teachers may slightly increase the likelihood of students dropping out. However, these results again are very small in magnitude (.68%) and are not robust to the inclusion of teacher covariates.

These results are interesting because the rhetoric of hiring female teachers is often based on the belief that a female teacher presence increases the safety and comfort of a school, and thus encourages girls' attendance of school. However, they suggest that the mechanism for our results on the impact of a gender match on test scores is less likely to be due to effects on the extensive margin of school participation, but more due to the increased effectiveness of classroom transactions between teachers and students.

5. Conclusion

We present empirical evidence on the impact of matches between teacher and student gender in bridging gender gaps in developing countries using one of the richest datasets in developing country education. We find that at the start of primary school, girls have a slight advantage in

[12] See Muralidharan and Sundararaman (2013) for further discussion of how contract teachers (who are typically more likely to be female and from the village) have better measures of performance.

the local language (approximately .05 standard deviations) and are at par in math. However, in higher grades girls tend to lose the advantage in language (by 0.01σ/year) and fall behind in math (by 0.02σ/year). These trends are in addition to any sorting into private schools, and thus are likely to be a lower bound estimate of learning gaps in primary schools.

Our results suggest that female (and male) teachers are relatively more effective when teaching to their own gender, that learning for girls increases when they are taught by female teachers relative to male teachers, and that boys do not suffer adverse effects when taught by female teachers relative to male teachers, even when controlling for teacher observables.

These results differ within subject, however, suggesting that boys suffer no adverse effect when taught math by female teachers, but do perform worse in language when taught by female teachers relative to male teachers (.02 standard deviations). Similarly, girls have higher gains in math compared to language when taught by female teachers instead of male teachers. One possible explanation for this pattern could be that boys and girls face different stereotypes in math and language and that in areas with negative stereotypes, shared teacher gender matters more. These differences by subject are similar to Dee's (2007) finding of strong shared effects for boys in reading and Rawal and Kingdon (2010) with greater gains to female teachers in math.

From a policy perspective, expanding the hiring of female teachers - both at the margin of the current patterns of hiring, and also when holding other characteristics constant would improve overall learning outcomes, and be especially useful as a tool for bridging gender gaps in learning trajectories over time. Though we find that achievement is boosted by sharing a teacher's gender, the mechanisms through which shared gender influences achievement remains unanswered. Deciphering the underlying reason behind the significance of gender matching would possibly allow for other policies to capture these positive gains without having adverse effects on either gender.

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Table 1: Summary Statistics by Gender

	Panel A: Students				
	No. Obs.	Mean	Male	Female	Female - Male
Female	94599	0.509			
Literate Father	66511	0.592	0.582	0.600	0.0185***
Literate Mother	66827	0.439	0.429	0.449	0.0199***
Proper House	66851	0.311	0.306	0.315	0.00981***
Has Toilet	66974	0.289	0.284	0.294	0.0106***
	Panel B: Teachers				
	No. Obs.	Mean	Male	Female	Female - Male
Female	2680	0.458			
Head Teacher	2680	0.288	0.377	0.182	-0.195***
Regular Teacher	2680	0.503	0.497	0.511	0.0141
Contract Teacher	2680	0.188	0.116	0.273	0.157***
Completed Education: 12th Pass	2680	0.931	0.962	0.893	-0.0696***
Completed Education: Masters	2680	0.226	0.270	0.174	-0.0964***
Has Teacher Training	2661	0.833	0.909	0.743	-0.166***
Native to Village	2679	0.234	0.175	0.304	0.128***
Married	2676	0.810	0.845	0.769	-0.0762***
Active in Union	2674	0.183	0.276	0.074	-0.202***
Salary (monthly)	2674	9560.21	10697.00	8209.46	-2487.5***
Age	2660	36.91	39.54	33.75	-5.791***
Years Experience	2285	12.95	14.47	11.08	-3.389***

Notes: (1) All variables are indicators, except for salary which ranges from 300 to 38400 (with a standard deviation of 5776), age which ranges from 12 to 58 (with a standard deviation of 9.76), and years experience which ranges from 1 to 42 (with a standard deviation of 7.94). (2) Significance levels are as follows: *10%, **5%, and ***1%.

Table 2 - Learning Gaps by Gender and Grade

Panel A: Gender Differentials in Test Scores by Grade

	Dependent Variables: Normalized Test Score (Within Grade)					
	Pooled Across Subjects		**Math**		**Telugu**	
	(1)	(2)	(3)	(4)	(5)	(6)
Female (Grade 1)	0.0279**	0.0206**	0.00238	-0.00376	0.0531***	0.0448***
	(0.0122)	(0.00925)	(0.0135)	(0.0101)	(0.0127)	(0.0100)
No. of observations	66660	66660	33187	33187	33473	33473
Female (Grade 2)	0.00526	0.00571	-0.0271**	-0.0242***	0.0376***	0.0354***
	(0.0114)	(0.00828)	(0.0117)	(0.00880)	(0.0122)	(0.00889)
No. of observations	70953	70953	35453	35453	35500	35500
Female (Grade 3)	-0.0217*	-0.0225***	-0.0569***	-0.0571***	0.0136	0.0121
	(0.0118)	(0.00813)	(0.0120)	(0.00863)	(0.0128)	(0.00894)
No. of observations	74715	74715	37349	37349	37366	37366
Female (Grade 4)	-0.0442***	-0.0379***	-0.0956***	-0.0879***	0.00709	0.0122
	(0.0120)	(0.00771)	(0.0122)	(0.00815)	(0.0130)	(0.00864)
No. of observations	79972	79972	39973	39973	39999	39999
Female (Grade 5)	-0.0262**	-0.0209***	-0.0749***	-0.0671***	0.0225*	0.0254***
	(0.0115)	(0.00738)	(0.0123)	(0.00771)	(0.0123)	(0.00846)
No. of observations	85572	85572	42777	42777	42795	42795

Panel B: Trends in Gender Differentials in Test Scores from Lower to Higher Grades

	(1)	(2)	(3)	(4)	(5)	(6)
Female	0.0311**	0.0271***	0.0115	0.00812	0.0506***	0.0457***
	(0.0132)	(0.00993)	(0.0142)	(0.0106)	(0.0139)	(0.0107)
Female*Grade	-0.0144***	-0.0127***	-0.0207***	-0.0189***	-0.00805*	-0.00635**
	(0.00383)	(0.00281)	(0.00410)	(0.00298)	(0.00410)	(0.00308)
No. of Observations	377872	377872	188739	188739	189133	189133
School Fixed Effects	No	Yes	No	Yes	No	Yes

Notes: (1) Standard errors (in parentheses) are clustered at the school level for OLS regressions not including school fixed effects, and are clustered at the student level for OLS regressions including school fixed effects . (2) Significance levels are as follows: *10%, **5%, and ***1%.

Table 3: Characteristics of Classrooms Assigned to Female Teachers

	Dependent Variable: Classroom Has a Female Teacher			
	(1)	(2)	(3)	(4)
Proportion of Female Students	**-0.000673**	**0.00109**	**0.00523**	**-0.0134**
	(0.0338)	**(0.0209)**	**(0.0205)**	**(0.0202)**
Grade 1	0.0156	0.0243**		
	(0.0163)	(0.0121)		
Grade 2	0.0228	0.0278**		
	(0.0150)	(0.0121)		
Grade 4	-0.0671***	-0.0676***		
	(0.0150)	(0.0123)		
Grade 5	-0.140***	-0.134***		
	(0.0170)	(0.0121)		
Test Score of Incoming Cohort of Boy Students	**-0.0142**	**-0.00149**	**-0.00906**	**-0.00282**
	(0.0228)	**(0.0134)**	**(0.0136)**	**(0.0133)**
Test Score of Incoming Cohort of Girl Students	**0.0189**	**-0.00698**	**0.00172**	**0.00758**
	(0.0191)	**(0.0119)**	**(0.0124)**	**(0.0118)**
Number of Observations	10974	10974	10974	9759
Teacher Characteristics	No	No	No	Yes
School Fixed Effects	No	Yes	No	No
School*Grade Fixed Effects	No	No	Yes	Yes
Boys' Test Score = Girls' Test Score (p-value)	0.3168	0.7932	0.6117	0.6156

Notes: (1) "Teacher Characteristics" are salary, age, experience, and indicators for caste, teacher status, education, training, native to school location, marital status, and union status. (2) Standard errors (in parentheses) are clustered at the school level for OLS regressions not including fixed effects, and are clustered at the student level for OLS regressions including fixed effects. (3) Significance levels are as follows: *10%, **5%, and ***1%.

Table 4: Trends in Gender Differentials in Learning Trajectories from Lower to Higher Grades

	(1)	(2)	(3)	(4)	(5)	(6)
Female	0.0251**	0.0255***	0.00464	0.00667	0.0464***	0.0453***
	(0.0120)	(0.00923)	(0.0132)	(0.0102)	(0.0125)	(0.00980)
Female*Grade	-0.00624*	-0.00725***	-0.00830**	-0.0106***	-0.00563*	-0.00562**
	(0.00322)	(0.00252)	(0.00368)	(0.00281)	(0.00339)	(0.00271)
No. of Observations	304410	304410	151785	151785	152625	152625
School Fixed Effects	No	Yes	No	Yes	No	Yes

Notes: (1) Regressions include student's previous year's test score as an independent variable. (2) Standard errors (in parentheses) are clustered at the school level for OLS regressions not including school fixed effects, and are clustered at the student level for OLS regressions including school fixed effects . (3) Significance levels are as follows: *10%, **5%, and ***1%.

Table 5: Impact of Female Teachers on the Learning Gains of Female Students

	Dependent Variable: Normalized Test Scores					
	Panel A: Across Subjects					
	(1)	(2)	(3)	(4)	(5)	(6)
(β1) Female Student * Female Teacher	0.0383***	0.0362***	0.0354***	0.0350***	0.0343***	0.0336***
	(0.00997)	(0.00788)	(0.00753)	(0.00792)	(0.00757)	(0.00801)
(β_2) Female Student	-0.0120*	-0.0140***	-0.0126**			
	(0.00676)	(0.00522)	(0.00498)			
(β_3) Female Teacher	-0.0154	-0.00344	0.000700	0.00212	0.00132	-0.00442
	(0.0188)	(0.00629)	(0.00697)	(0.00634)	(0.00699)	(0.00800)
$\beta_1 + \beta_3 = 0$	0.023	0.033	0.036	0.037	0.036	0.029
F-statistic	1.575	30.113***	29.585***	37.954***	28.615***	14.400***
$\beta_1+2*\beta_3 = 0$	0.008	0.029	0.037	0.039	0.037	0.025
F-statistic	0.045	9.743***	10.533***	17.068***	10.575***	3.365*
Number of Observations	268548	268548	268548	268548	268548	237832
	Panel B: Math					
(β_1) Female Student * Female Teacher	0.0338***	0.0335***	0.0336***	0.0312***	0.0315***	0.0294***
	(0.0111)	(0.00876)	(0.00843)	(0.00880)	(0.00847)	(0.00898)
(β_2) Female Student	-0.0374***	-0.0428***	-0.0408***			
	(0.00729)	(0.00575)	(0.00553)			
(β_3) Female Teacher	-0.0139	0.00240	0.00806	0.00916	0.00917	0.00949
	(0.0209)	(0.00701)	(0.00785)	(0.00706)	(0.00786)	(0.00903)
$\beta_1 + \beta_3 = 0$	0.020	0.036	0.042	0.040	0.041	0.039
F-statistic	0.928	28.781***	30.823***	35.745***	29.364***	20.171***
$\beta_1+2*\beta_3 = 0$	0.006	0.038	0.050	0.050	0.050	0.048
F-statistic	0.022	13.200***	15.009***	21.601***	15.102***	10.074***
Number of Observations	133907	133907	133907	133907	133907	118608
	Panel C: Language (Telugu)					
(β_1) Female Student * Female Teacher	0.0429***	0.0393***	0.0373***	0.0385***	0.0364***	0.0378***
	(0.0104)	(0.00851)	(0.00819)	(0.00856)	(0.00824)	(0.00871)
(β_2) Female Student	0.00971	0.0104*	0.0113**			
	(0.00724)	(0.00563)	(0.00539)			
(β_3) Female Teacher	-0.0174	-0.00858	-0.00531	-0.00389	-0.00485	-0.0169*
	(0.0182)	(0.00687)	(0.00762)	(0.00692)	(0.00764)	(0.00875)
$\beta_1 + \beta_3 = 0$	0.026	0.031	0.032	0.035	0.032	0.021
F-statistic	2.130	22.243***	19.361***	27.818***	18.819***	6.140**
$\beta_1+2*\beta_3 = 0$	0.008	0.022	0.027	0.031	0.027	0.004
F-statistic	0.058	4.589**	4.591**	8.689***	4.613**	0.073
Number of Observations	134641	134641	134641	134641	134641	119224
Teacher Characteristics	No	No	No	No	No	Yes
School Fixed Effects	No	Yes	No	Yes	No	No
School*Grade Fixed Effects	No	No	Yes	No	Yes	Yes
Grade Fixed Effects by Student Gender	No	No	No	Yes	Yes	Yes

Notes: (1) Regressions include student's previous year's test score as an independent variable. (2) "Teacher Characteristics" are salary, age, experience, and indicators for caste, teacher status, education, training, native to school location, martial status, and union status. (3) Standard errors (in parantheses) are clustered at the school level for OLS regressions not including fixed effects, and are clustered at the student level for OLS regressions including fixed effects. (4) Significance levels are as follows: *10%, **5%, and ***1%.

Table 6: Impact of Female Teachers on the Attendance of Female Students

	Dependent Variable: Student Attendance					
	(1)	(2)	(3)	(4)	(5)	(6)
(β_1) Female Student * Female Teacher	-0.00298	-0.00410	-0.00377	-0.00355	-0.00317	-0.00158
	(0.00349)	(0.00306)	(0.00307)	(0.00308)	(0.00310)	(0.00331)
(β_2) Female Student	0.00786***	0.00766***	0.00706***			
	(0.00265)	(0.00207)	(0.00207)			
(β_3) Female Teacher	0.000496	-0.00320	0.00786***	0.00411*	0.00753***	0.00550*
	(0.00463)	(0.00247)	(0.00287)	(0.00250)	(0.00288)	(0.00333)
Number of Observations	148798	148798	148798	148798	148798	131333
Male Student with Male Teacher Mean	0.777	0.777	0.777	0.777	0.777	0.779
$\beta_1 + \beta_3 = 0$	-0.002	-0.007	0.004	0.001	0.004	0.004
F-statistic	0.327	9.718***	2.201	0.056	2.480	1.493
$\beta_1 + 2*\beta_3 = 0$	-0.002	-0.011	0.012	0.005	0.012	0.009
F-statistic	0.058	7.981***	6.399**	1.542	6.325**	2.791*
Teacher Characteristics	No	No	No	No	No	Yes
School Fixed Effects	No	Yes	No	Yes	No	No
School*Grade Fixed Effects	No	No	Yes	No	Yes	Yes
Grade Fixed Effects by Student Gender	No	No	No	Yes	Yes	Yes

Notes: (1) Attendance is calculated as the average of the indicator of whether the student was present or not on the day of 2 to 6 visits per year. (2) "Teacher Characteristics" are salary, age, experience, and indicators for caste, teacher status, education, training, native to school location, marital status, and union status. (3) Standard errors (in parentheses) are clustered at the school level for OLS regressions not including fixed effects, and are clustered at the student level for OLS regressions including fixed effects. (4) Significance levels are as follows: *10%, **5%, and ***1%

Table 7: Impact of Female Teachers on Female Student Dropouts

	Dependent Variable: Indicator of Student Dropping Out					
	(1)	(2)	(3)	(4)	(5)	(6)
(β_1) Female Student * Female Teacher	-0.0036	-0.0039	-0.0056*	-0.0021	-0.0038	-0.0020
	(0.0036)	(0.0031)	(0.0031)	(0.0031)	(0.0031)	(0.0033)
(β_2) Female Student	-0.0206***	-0.0210***	-0.0196***			
	(0.0026)	(0.0020)	(0.0020)			
(β_3) Female Teacher	0.0025	0.0057**	0.0078***	-0.0027	0.0068**	0.0043
	(0.0046)	(0.0026)	(0.0029)	(0.0026)	(0.0029)	(0.0034)
Number of Observations	194548	194548	194548	194548	194548	172707
Male Student with Male Teacher Mean	0.153	0.153	0.153	0.153	0.153	0.156
$\beta_1 + \beta_3 = 0$	-0.001	0.002	0.002	-0.005	0.003	0.002
F-statistic	0.060	0.584	0.635	3.989**	1.190	0.532
$\beta_1+2*\beta_3 = 0$	0.001	0.007	0.010	-0.007	0.010	0.007
F-statistic	0.032	3.764*	4.410**	3.685*	4.285**	1.386
Teacher Characteristics	No	No	No	No	No	Yes
School Fixed Effects	No	Yes	No	Yes	No	No
School*Grade Fixed Effects	No	No	Yes	No	Yes	Yes
Grade Fixed Effects by Student Gender	No	No	No	Yes	Yes	Yes

Notes: (1) Student Dropping Out is calculated as not having taken the test at the end of the year, but being in attendance at the school the previous year for grades 2 - 5 or for being present in the start of the year for grade 1. (2) "Teacher Characteristics" are salary, age, experience, and indicators for caste, teacher status, education, training, native to school location, marital status, and union status. (3) Standard errors (in parentheses) are clustered at the school level for OLS regressions not including fixed effects, and are clustered at the student level for OLS regressions including fixed effects. (4) Significance levels are as follows: *10%, **5%, and ***1%.