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Student Achievement in Primary School:
Evidence from a Randomized Experiment**

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ABSTRACT

The Effect of Teacher Gender on Student Achievement in Primary School: Evidence from a Randomized Experiment

This paper attempts to reconcile the contradictory results found in the economics literature and the educational psychology literature with respect to the academic impact of gender dynamics in the classroom. Specifically, using data from a randomized experiment, we look at the effects of having a female teacher on the math test scores of students in primary school. We find that female students who were assigned to a female teacher *without* a strong math background suffered from *lower* math test scores at the end of the academic year. This negative effect however not only seems to disappear but it becomes (marginally) positive for female students who were assigned to a female teacher *with* a strong math background. Finally, we do not find any effect of having a female teacher on male students' test scores (math or reading) or female students' reading test scores. Taken together, our results tentatively suggest that the findings in these two streams of the literature are in fact consistent if one takes into account a teacher's academic background in math.

JEL Classification: I21, J24

Keywords: teacher gender, student achievement, random assignment

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1. Introduction

Recent national media accounts have drawn attention to a growing concern that math anxiety among elementary school female teachers is leading to poorer math achievement among female students but not male students (see for example, Kaplan [2010], Mack [2010], and Molina [2010]). This stylized fact is based on a recent article in the educational psychology literature by Beilock et al. (2010). Not only do they document this negative effect, but they also show that it works through female students' beliefs about who is good at math.¹ Specifically, the more anxious female teachers are in math classes and the more likely female students are to endorse the stereotype "boys are good at math, and girls are good at reading," the lower the math achievement of female students relative to male students or female students without such a belief.²

These results are generally in sharp contrast to those found in the economics literature. Most of the existing research in economics has focused on the effect of having a female teacher on different academic outcomes, especially performance in math and the choice of a math and science major, of female students, either in middle school/high school (e.g., Ehrenberg et al. [1995], Nixon and Robinson [1999], Dee [2005], [2007]) or post-secondary education (e.g., Canes and Rosen [1995], Rothstein [1995], Neumark and Gardecki [1998], Bettinger and Long [2005], Hoffman and Oreopoulos [2009], Carrell et al. [2010]).³ These studies either find having a female teacher has a positive effect on

¹ Math anxiety among elementary school teachers, of which females constitute about 90 percent, is a commonplace phenomenon (Bursal and Pagnozas [2006], Gresham [2007]). Earlier studies also find a negative effect of math anxiety on teaching performance in math classes (Bush [1989], Tobias [1998]).

² This argument is in the tradition of the stereotype threat model introduced in Steele (1997) who argued that a person can experience anxiety or concern in a situation where s/he has the potential to confirm a negative stereotype about the social group the person belongs to.

³ Although the focus of this paper is gender interactions within classrooms, there are several studies in the economics literature investigating the effects of similarities in gender and ethnicity on the academic achievement of students. See for example, Ehrenberg et al. (1995), Dee (2007), and Fairlie et al. (2011).

female student achievement outcomes (e.g., Rothstein [1995], Nixon and Robinson [1999], Bettinger and Long [2005], Dee [2007], Hoffman and Oreopoulos [2009], Carrell et al. [2010]) or no effect on them (e.g., Canes and Rosen [1995], Ehrenberg et al. [1995], Neumark and Gardecki [1998]).⁴ Perhaps it is not surprising that they find this positive effect or no effect because female teachers in higher levels of education, particularly those from highly selective post-secondary institutions, are unlikely to suffer from math anxiety given they generally have stronger math backgrounds than their elementary school counterparts.

In this paper, we attempt to reconcile the results between these two streams of literature using data from a well-executed randomized experiment that was conducted to evaluate the effectiveness of the Teach for America (TFA) Program.⁵ Specifically, we look at the effects of having a female teacher on the math test scores of female students in primary school. We also analyze the effects of having a female teacher on the reading test scores of female students and the math and reading test scores for male students. Finally, conditional on finding a negative effect of having a female teacher on the math achievement of female students in primary school, we indirectly test whether math anxiety in conjunction with stereotype threat can help explain this finding by controlling for the math background of the teacher.

⁴ We are aware of only one study by Dee (2007) that finds that being assigned to a female teacher is associated with lower math test scores for female students in 8th grade. However, after conducting several robustness checks and given he also finds a similar effect for male students, he concludes this is largely due to the non-random assignment of female teachers to classrooms with low performing students in math. For the remainder of the analysis Dee (2007) does not focus on math achievement; he solely focuses on achievement in English, history, and science. Dee finds that a female teacher has a large positive effect on history outcomes for female students. He also finds smaller positive effects in English and science but these effects are not statistically significant at conventional levels.

⁵ TFA is a non-profit organization that recruits outstanding recent college graduates and mid-career professionals to teach in schools in highly disadvantaged neighborhoods for at least two-years throughout the United States. This program is explained in more detail in the next section.

We argue that our methodological approach helps us reconcile the educational psychology literature and the economics literature for the following reasons. First, the teacher-student gender dynamics in primary school might be different than they are for higher levels of education. In particular, the gender differences in children's self-perceptions about ability and their awareness of commonly held beliefs about gender stereotypes start emerging between the ages of 7 and 12 (Eccles et al. [1993], Steele [2003]). In addition, while math anxiety among elementary school teachers is found to be a commonplace phenomenon (Bursal and Pagnozas [2006], Gresham [2007]), we posit the same is unlikely to be true for teachers at higher levels of education, particularly highly selective post-secondary institutions, given the level of their academic training in math.

Second, the experimental nature of our data, which comes from 17 schools in 6 different states, allows us to avoid the issue of non-random assignment of teachers most of the previous research could not account for.⁶ Third, our data affords us a large sample of primary schools, students, teachers, and states. This is in sharp contrast to Biellock et al. (2010) whose analysis is based on a very small sample (17 teachers, 65 female students, and 52 male students) from one urban school district (1 school) in the Midwest. We must point out, however, that our data comes from a very disadvantaged part of the student population.⁷ While this allows us to take a closer look at the teacher-student interactions in a setting where the problems with the education system in the United

⁶ To our knowledge, in the existing economic literature, only Carrell et al. (2010) use experimental data from the U.S. Air Force Academy, which is a very selective post-secondary institution, to analyze the effect of teacher gender on grades in math and science courses, as well as the probability of taking a higher level math course and the probability of graduating with a degree in science, technology, engineering, and/or mathematics (STEM).

⁷ This is an artifact of the randomized experiment given members of the TFA program mostly teach in disadvantaged neighborhoods.

States are most evident and arguably more important from a policy perspective, our results may not be applicable to teacher-student interactions in U.S. primary schools more generally.

Finally, unlike Beilock et al. (2010) we are able to examine the relative effectiveness of male and female teachers on the achievement outcomes (math and reading) of male and female students. If the math anxiety hypothesis is the main factor behind the negative effect of female teachers on female student math achievement as these authors claim, then we should not see any impact of having a female teacher (relative to having a male teacher) on reading for female students or test scores (reading or math) for male students. Moreover, we should expect the negative effect to either disappear or in fact become positive, as in the economics literature, for female students taught by teachers who have a strong math background and are therefore less likely to suffer from math anxiety.

Using a unique data set where students are assigned to classrooms randomly at the beginning of the academic year, we find that female students who were assigned to a female teacher, as opposed to a male teacher, suffered from lower math test scores at the end of the academic year. Furthermore, using an indirect test of the math anxiety hypothesis, we find that this negative effect in math not only seems to disappear but becomes (marginally) positive in the classrooms where the female teacher had a math or a math-related major in college/post-college yet persisted in classrooms where the female teacher did not have a strong background in math. We also do not find any effect of having a female teacher on male students' test scores (math or reading) or female students' reading test scores. These robustness checks seem to rule out the explanations

pertaining to the unobserved quality differences between teachers with math or math-related majors relative to teachers *without* math or math-related majors.

Interestingly, our results extend the existing literature on primary schools students in a number of ways—we focus on disadvantaged neighborhoods, employ randomized data, include male teachers in the estimation sample, and utilize reading test scores as a robustness check—and yet they tentatively suggest that the findings in the educational psychology literature and economics literature are in fact consistent if one takes into account a teacher’s academic background in math.

The remainder of the paper is organized as follows. Section 2 describes the Teach for America Program and the data. Section 3 discusses threats to identification, as well as the estimation strategy and results. Conclusions are presented in Section 4.

2. Teach for America Program and Data

2.1 Teach for America

Teach for America (TFA) is a non-profit organization that recruits outstanding recent college graduates and mid-career professionals to teach in schools in highly disadvantaged neighborhoods throughout the United States for at least a two-year period. Since its inception in 1990, approximately 24,000 TFA Corps Members have taught more than 3 million students in 38 urban and rural areas. Between 2000 and 2009 the number of applications for TFA skyrocketed to 35,000 from 4,068 and the number of new corps members recruited each year grew from 868 to 4,100.⁸

TFA corps members are placed in schools that are in some of the most disadvantaged neighborhoods in the United States. The challenge of being an efficient

⁸ See <http://www.teachforamerica.org>.

teacher in these environments without any or with very little previous teaching experience raised questions about the effectiveness of the program. Although each TFA corps member goes through a very competitive selection process and receives a short but very intense training program including significant support following training, critics argue that TFA teachers are still ill-prepared to teach in the challenging environments due to the lack of specialized education, training, and experience (Lackzo-Kerr and Berliner [2002], Pilcher and Steele [2005], Darling-Hammond [2005]).⁹ Nevertheless, recent studies found that TFA teachers perform at least as well as, and in some cases better than, regular teachers (e.g., Decker et al. [2004], Kane et al. [2008], Antecol et al. [2012]).

2.2 Data

We use data from the *Mathematica Policy Research, Inc* (MPR) *National Evaluation of Teach for America* (NETFA) Public Use File. NETFA is a randomized study of elementary school students in six regions in the United States between 2001 and 2003. The pilot study was conducted in Baltimore in the 2001-2002 academic year followed by full-scale evaluations in Chicago, Los Angeles, Houston, New Orleans and the Mississippi Delta in the next academic year (2002-2003). Each region had one school district participating in the experiment with the exception of Mississippi Delta which had two school districts that participated in the experiment. Within each school district, schools that had both TFA teachers and “control” teachers in the same grade were randomly chosen. The final sample consisted of 17 schools, 100 teachers, and more than 1900 students in grades 1 through 5.

⁹ Other criticisms directed at the TFA program are the high attrition rate of TFA teachers and that more experienced and better trained teachers lose their jobs, in some cases to make room for TFA teachers (USA Today, 2009).

This data is ideal for our purposes because all students were randomly assigned to two types of classes, TFA and control group classrooms, before the start of the academic year. Therefore the randomization is done at the block level such that each block represents a grade level in any given school. Furthermore, throughout the year roster checks were performed to enforce the original assignment. These processes ensured not only those students in TFA and control group classrooms are comparable but also that the gender of the students and the gender of their teacher in each classroom are not correlated. After the random assignment and before the start of academic year, the students were given math and reading tests based on the grade they had completed in the previous academic year (which we call *pre-treatment* outcome variables); then at the end of the academic year in which the study was conducted the students re-took math and reading tests based in the grade they just completed (which we call *post-treatment* outcome variables).

As previously noted the schools in our analysis were chosen to be broadly representative of the schools where TFA teachers taught at the time of the evaluation. These schools are generally disadvantaged and face substantial teacher shortages, thus they are not a representative sample of average schools in the United States. For example, across the 17 schools in the TFA study, the average rate of student eligibility for a free or a reduced-priced lunch was about 97 percent as opposed to 41 percent nationwide.

Although sample attrition is relatively small, we lose around 16 (18) percent of our initial math (reading) test score sample because of missing test scores, missing teacher characteristics, and students moving out of the school districts. Fortunately, attrition does not vary between female and male students resulting in very similar mean

student characteristics in both groups (see detailed discussion below).¹⁰ After dropping these observations, our estimation sample consists of 1,646 (1,606) students for the math (reading) test score sample from classes taught by 94 teachers.¹¹

2.2.1 Student Characteristics

The data includes detailed information on student characteristics: type of class, gender, race and ethnicity, math test scores (pre- and post- treatment), reading test scores (pre- and post- treatment), and class size. There are two types of classes to which a student is randomly assigned: a class taught by a TFA teacher or a class taught by a control teacher. On average, 44 percent of the students (based on the math test score sample) were assigned to classrooms taught by a TFA teacher, and this assignment is not significantly different for male and female students (see Table 1).¹²

We consider three racial/ethnic groups for students: non-Hispanic black, Hispanic, and non-Hispanic white, henceforth referred to as black, Hispanic, and white, respectively.¹³ Given the schools in our sample are disadvantaged schools the student body is predominantly non-white. Specifically, 66.3 (27.6) percent of the student body is black (Hispanic), while 6.1 percent is white. Furthermore, the average number of students per class is 25.1, the mean pre-treatment (baseline) normal curve equivalent (NCE) math test score is 30.3 while the mean pre-treatment (baseline) NCE reading test

¹⁰ We also find that attrition does not vary between students in the TFA and control group classrooms. For the sake of brevity, we do not report these results in the paper but they are available upon request.

¹¹ Although our estimation samples (1,645 and 1,606 observations for the math and reading test score sample, respectively) are slightly different than the full sample Mathematica researchers use (1,715 observations), we are able to replicate their results with respect to the effect of TFA teachers on both math and reading test scores (with only slight differences in the coefficient estimates). These results are available upon request.

¹² Similar results are found based on the reading test score sample.

¹³ The white sample includes a small number of Asians and Pacific Islanders.

score is 25.6. Students in our sample are about one standard deviation below the national average (i.e., the NCE scale has a mean of 50 and standard deviation of 21 nationally). Furthermore, these characteristics are similar for male and female students, again illustrating that sample attrition did not differentially affect male and female students.

2.2.2 Teacher Characteristics

The data also includes detailed information on teacher characteristics. Specifically, we have information on their gender, race/ethnicity, certification status, teaching experience, their major in college, and their major in their graduate degree if they have one. About one quarter of the students in our sample are taught by male teachers irrespective of student gender (see Table 1).¹⁴ As previously noted, this allows us to examine the relative effectiveness of male and female teachers, and overcome a shortcoming of earlier research on teacher effectiveness in primary schools due to insufficient samples of male teachers.¹⁵ Roughly 47 percent of the students have black teachers, 10 percent have Hispanic teachers, and 40 percent have white teachers.¹⁶ For the remaining 3 percent, we do not have information on the race/ethnicity of the teacher.

Teachers were asked to describe what type of certification, license and credential they hold. We consider two broad certification types: regular certification (including

¹⁴ In our sample, about 33 percent of TFA teachers are male as opposed to slightly less than 15 percent of control teachers. Since the characteristics of TFA teachers are quite different than regular teachers in our sample (see Appendix Table A1), we control for whether a teacher is a TFA teacher or a control teacher in all our regressions to prevent any confounding effect this difference might generate. We also investigate whether a student's gender is correlated with the gender of their teacher. Specifically, we estimate the determinants of being assigned to a female teacher controlling for student characteristics (including an indicator variable equal to one if the student is female and zero if the student is male) and teacher characteristics, as well as block fixed effects. The female student indicator variable is never found to be large or statistically significant at conventional levels in any of the specifications (see Appendix Table A2).

¹⁵ Higher levels of education do not suffer from the same shortage of male teachers and thus is generally not a shortcoming of the economics literature on teacher effectiveness.

¹⁶ The white category again includes a small number of Asian/Pacific Islander teachers.

standard state certificate) and non-regular certification (including emergency, temporary, initial, and other types of certifications). About 55 (45) percent of the students (irrespective of gender) had teachers with regular (non-regular) certification. On average, male and female students had a teacher with slightly more than 6 years of experience.

Finally, in terms of college majors the teachers are very diverse. Since we are concerned with the potential impact of teacher math anxiety on student math performance, we construct an indicator for whether a teacher has a strong math background (see Section 3.3 for a detailed discussion). As such we focus our attention on one particular set of college (undergraduate or graduate) majors: math or math-related (i.e., computer science and system analysis, engineering systems, pre-med, economics, and accounting) majors. Teachers who have a math or a math-related college major taught roughly 11.5 percent of our students, and this does not differ by student gender.

3. Threats to Identification, Estimation Strategy and Results

3.1 Threats to Identification and Validity of Randomized Data

Any study analyzing the effect of teachers on student achievement has to deal with two important potential identification problems that might bias the conventional OLS estimates. First, schools assign students to teachers non-randomly, even within subjects and grade levels (e.g., Clotfelter et al. [2006], Kane et al. [2011]). In the current context, if high achieving and better motivated students are more likely to be assigned to male teachers, then the effect of having a male teacher on achievement will be overstated. The common practice in the literature to deal with non-random sorting is to control for students' prior achievement (e.g., Hanushek and Rivkin [2010]). In a recent paper,

however, Rothstein (2010) shows that the estimates of teachers' contribution on student achievement may still be biased even after conditioning on prior achievement. Second, even if students and teachers are randomly assigned to each other, there may be unobserved teacher traits that are correlated with student outcomes which again may bias the conventional OLS estimates; e.g., unobserved gender specific differences across teachers' quality.

Fortunately, the randomization of our data at the classroom level allows us to avoid the identification problems associated with non-random assignment of students and teachers. This is because, as we previously explained, students were randomly assigned to each teacher at the beginning of the academic year, and regular class roster checks throughout the year ensured that class compositions did not change. Therefore, non-random sorting of students to teachers of their parents' choice was avoided.¹⁷ The second problem, on the other hand, is harder to deal with directly. As we explain in detail below, however, we use different specifications and robustness checks to show that potential unobserved teacher traits do not appear to have a significant influence on our results.

There are also some drawbacks to using experimental data. One potential problem is if students and/or parents know that they are a part of an experiment, they may behave differently than they would do otherwise. In the current context, this should not

¹⁷ Of course it would be interesting to show how important the non-random selection is for our results if we had comparable non-experimental data on primary schools. While we do not have direct evidence, we can point to the analysis by Dee (2007) who argues that the non-random assignment of female teachers to classrooms with low performing students in math can explain why he finds that being assigned to a female teacher is associated with lower math test scores for female students in the 8th grade. Arguably, controlling for non-random assignment is important, however, as we outlined earlier our analysis extends the existing literature on primary schools in a number of other ways beyond employing randomized data (i.e., we focus on disadvantaged neighborhoods, include male teachers in the estimation sample, and utilize reading test scores as a robustness check) thus we cannot disentangle the relative importance of non-random selection from these other extensions.

be a problem since the main focus of the experiment was to assess the effect of TFA teachers (not female teachers) relative to control teachers (not male teachers). Hence, the effects associated with the participants' knowledge that they belong to a particular experimental assignment should not be relevant. Another potential drawback is the external validity of the experiment. As we mentioned in the preceding section, the data comes from very disadvantaged parts of the U.S. population such that almost 97 percent of the students are eligible for the free lunch program and that there are very few white students (slightly more than 6 percent). Therefore, we do not claim that our results can necessarily be generalized to the entire U.S. student population, but as previously noted they allow us to focus on a sample where problems with the education system in the U.S. are well documented.

3.2 Estimation Strategy and Results

In order to formally determine the effect of female teachers on student achievement in primary school we follow the existing economics literature and first estimate fully flexible regressions of the following form separately by student gender:

$$TS_{icb} = \beta_0 + \beta_1 FEMTEACH_{icb} + SC'_{icb} \delta + TC'_{icb} \gamma + \eta_b + \varepsilon_{icb} \quad (1)$$

where TS is subject-specific post-treatment student test scores for student i in class c and block b (i.e., classes in the same school and the same grade), and $FEMTEACH$ is equal to 1 if the student's teacher is female and zero otherwise. SC is a vector of student characteristics (i.e., race/ethnicity, pre-treatment NCE math or NCE reading test scores, and class size) and TC is a vector of teacher characteristics (i.e., treatment status, race/ethnicity, years of teaching experience and its square, and type of certification).

Finally, η represents block fixed effects, and ε is an error term with the standard properties.¹⁸

Table 2 presents our baseline results for post-treatment NCE math and NCE reading test scores by gender. Henceforth we refer to these as math and reading test scores. We find that having a female teacher as opposed to a male teacher decreases math test scores for female students by about 4.7 percentage points (i.e., roughly 25 percent of a sample standard deviation). While being taught by a female teacher does also lead to lower reading test scores for female students, the effect is much smaller and insignificant at conventional levels (column 3). The fact that female teachers appear to only lower the math achievement, but not the reading achievement, of female students suggests that the estimated effect of female teachers on math achievement is not biased by unobservable confounders. Furthermore, for male students, we do not observe any effect of having a female teacher either in math or reading test scores. Both coefficients are small, insignificant at conventional levels, and have opposite signs, i.e., the effect is positive (negative) for math (reading) scores. These results for male students further support the fact that the negative effect of female teachers on academic achievement is only limited to math scores of female students.¹⁹

Overall, the results are suggestive and consistent with Beilock et al. (2010) that female teachers differentially influence the math achievement of male and female

¹⁸ All regressions are clustered at the block-level.

¹⁹ We estimate a model that adds an interaction between TFA and teacher gender to ensure that our results are not driven by male TFA teachers. Our substantive conclusions remain the same; female teachers (relative to male teachers) negatively influence math achievement scores for female students (but not male students) irrespective of treatment (i.e., TFA or control teacher). Results are available upon request.

students in primary school and a similar effect is not found for reading.²⁰ In order to test whether the differential teacher gender effect we find in math for female and male students is statistically distinguishable, we estimate the following (more restricted) model:

$$TS_{icb} = \beta_0 + \beta_1 FEM_{icb} + \beta_2 FEMTEACH_{icb} + \beta_3 FEM_{icb} \times FEMTEACH_{icb} + SC'_{icb} \delta + TC'_{icb} \gamma + \eta_b + \varepsilon_{icb} \quad (2)$$

where FEM is an indicator variable equal to one if the student is female and zero otherwise, and all other variables are as previously defined.

Columns 1 and 3 of Table 3 present the results from equation (2) for our two achievement measures, respectively. There are several noteworthy patterns. First, female students relative to male students who were taught by a *female* teacher ($\beta_1 + \beta_3$) fare significantly worse (i.e., score 1.9 points lower, which is 10 percent of a sample standard deviation) on their math test. Second, female students relative to male students who were taught by a *male* teacher (β_1) have higher math test scores however the effect is insignificant at conventional levels (p-value of 0.38). Finally, the difference-in-differences coefficient (β_3), which gives the relative difference in math test scores between female students with female versus male teachers and male students with female versus male teachers, is large (-3.37, which is a little less than 20 percent of a sample standard deviation) and statistically significant at the 10 percent level. Not surprisingly given the results in Table 2, we continue to find no significant effects of teacher gender on reading achievement of male and female students.

²⁰We find similar results if we limit our analysis to female teachers only as in Beilock et al. (2010). See detailed discussion in Section 3.3.

At first glance, our findings for math test scores appear to be consistent with those found in the educational psychology literature and generally contradict the existing economics literature.²¹ This difference in findings may be driven in part by the difference in samples considered, as well as the type of data employed. Specifically, the existing economics literature focuses on middle/high school or post-secondary education. As previously noted one might expect the results to be different among primary school students because gender differences in children's self-perceptions about ability and their awareness of commonly held beliefs about gender stereotypes start emerging between the ages of 7 and 12 (Eccles et al. [1993], Steele [2003]). Moreover, math anxiety is likely more prevalent among elementary school teachers (Bursal and Pagnozas [2006], Gresham [2007]) than it is among teachers at higher levels of education, particularly highly selective post-secondary institutions, given the level of their academic training in math. Previous studies also focus on either nationally representative or very unique samples from a particular institution, while our analysis focuses on disadvantaged schools with large minority populations. Finally, unlike our analysis which is based on randomized data, the existing literature generally used non-randomized data.²²

Given that minority students from these disadvantaged schools may be particularly influenced by gender stereotypes, it may not be surprising that the magnitude

²¹ As previously mentioned, we are aware of only one study in economics by Dee (2007) that similarly finds that being assigned to a female teacher is associated with lower math test scores for female students in 8th grade. However, after conducting several robustness checks and given he also finds a similar effect for male students, he concludes this is largely due to the non-random assignment of female teachers to classrooms with low performing students in math.

²² One notable exception is Carrell et al. (2010) who used randomized data to examine the teacher gender effect in the post-secondary education. For the outcome measure that is most closely aligned to our test score measures, they find that female students receive grades that are roughly 5-10 percent of a standard deviation above their male counterparts if a female teacher as opposed to a male teacher taught them. They however focus on a very select sample of post-secondary students and professors from the U.S. Air Force Academy where the effect of a successful female role model on female student outcomes might be very pronounced.

of the negative effect of female teachers on female student math outcomes in primary school in these disadvantaged schools is non-trivial particularly if they are taught by female teachers who suffer from math anxiety. Nor is it surprising that the existing economics literature either finds a positive effect or no effect of being taught by a female teacher on female student math achievement outcomes because female teachers at higher levels of education (particularly those from highly selective post-secondary institutions) are less likely to suffer from math anxiety given their extensive training in math. The remainder of the paper examines the importance of accounting for the strength of a teacher's math background, and thus potentially their level of math anxiety, on the math achievement outcomes of female students.

3.3 Math Anxiety in Elementary School Teachers and Stereotype Threat

How can we explain our findings in light of the fact that we have randomized data and that our estimates are not likely to be biased by unobserved confounders? A tentative answer to this question is the math anxiety hypothesis. As previously mentioned, Beilock et al. (2010) found that higher math anxiety in female elementary school teachers hurts the math performances of the female students but not of the male students in the first and second grades.^{23,24} Moreover, they show that this negative effect works through female students' beliefs about who is good at math; the more anxious female teachers are in

²³ Beilock et al. (2010) measure teacher math anxiety through a questionnaire that was given to teachers at the beginning and the end of the academic year. Specifically, math anxiety was assessed using the short Mathematics Anxiety Rating Scale where teachers responded to 25 questions about how anxious different situations would make them feel (e.g., "reading a cash register receipt after you buy something," "studying for a math test", etc.). Responses were recorded on a Likert scale from 1 (low anxiety) to 5 (high anxiety). Beilock et al. 2010 construct an aggregate teacher math anxiety measure based on the average of the teacher responses from all 25 questions.

²⁴ Math anxiety among elementary school teachers, of which females constitute about 90 percent, is a commonplace phenomenon (Bursal and Pagnozas [2006], Gresham [2007]). Earlier studies also find a negative effect of math anxiety on teaching performance in math classes (Bush [1989], Tobias [1998]).

math classes and the more likely female students are to endorse the stereotype “boys are good at math, and girls are good at reading”, the lower the math achievement of female students relative to both male students and female students without such a belief.²⁵

Although the findings of Beilock et al. (2010) are not necessarily conclusive, it suggests some insights that may shed light on our results. Since we do not have either a measure of teacher’s math anxiety or student’s beliefs about stereotypical gender roles we cannot test the math anxiety hypothesis directly. We do however have information on teachers’ undergraduate and/or graduate major which will allow us to form an indirect test of this hypothesis. We conjecture that if the female teacher majored in a math or a math-related major, it is *less* likely that she suffers from math anxiety. This is not only as a result of better math knowledge and ability but, perhaps, also indicates that the female teacher is less likely to hold stereotypical gender beliefs about math if she chose to major in a math or a math-related field. Under this scenario, we should expect the negative effect on math achievement due to being assigned to a female teacher to disappear or become positive for the female students taught by female teachers with a strong math background.²⁶

²⁵ Students in the study were told two stories, one about a student who was good at math and another about a student who was good at reading at the beginning and end of the year. They were, then, asked to draw these students. To determine the extent to which students endorsed the traditional stereotype boys are good at math and girls are good at reading, Beilock et al. (2010) focused on the gender of the students in the drawings and formed a measure. The higher the score, the more children ascribed to stereotypical gender roles in school.

²⁶ Of course we cannot rule out alternative explanations pertaining to differences in math teaching styles between female teachers with and without a strong math background and how these differences might affect the math performance of male and female students. For example, it is possible to obtain the same results if female teachers without a strong math background choose to teach in a mechanical way that is fine for male students but harmful for female students. We argue however that this is not likely to be the case since, to the best of our knowledge, there is little evidence either on these potential differences in teaching styles or whether these differences in teaching styles differentially influence male and female students.

In order to test this hypothesis with our data, we run the following regression specification:

$$\begin{aligned}
TS_{icb} = & \beta_0 + \beta_1 FEM_{icb} + \beta_2 FEMTEACH_{icb} + \beta_3 FEMTEACH_{icb} \times FEM_{icb} + \beta_4 MATHREL_{icb} + \\
& \beta_5 FEMTEACH_{icb} \times MATHREL_{icb} + \beta_6 FEM_{icb} \times MATHREL_{icb} + \\
& \beta_7 FEMTEACH_{icb} \times FEM_{icb} \times MATHREL_{icb} + SC'_{icb} \delta + TC'_{icb} \gamma + \eta_b + \varepsilon_{icb}
\end{aligned} \tag{3}$$

where *MATHREL* is equal to one if the classroom was taught by a teacher with a math or a math-related (i.e., computer science and system analysis, engineering systems, pre-med, economics, and accounting) undergraduate or graduate major and zero otherwise, and all other variables are as previously defined. We must note that one should be cautious in interpreting the results based on these regressions since we only have 12 teachers with a math or a math-related major in our sample (9 female teachers with 143 students and 3 male teachers with 46 students).

The results are presented in Columns 2 and 4 of Table 3. For math test scores, the relative difference in the test scores between female students assigned to female versus male teachers and male students with female versus male teachers *with* a math or a math-related major ($\beta_3 + \beta_7$) is a very large positive number (4.745) and almost significant (with the p-value of 0.104) at conventional levels. Similarly, the relative difference in the test scores between female students assigned to female versus male teachers and male students with female versus male teachers *without* a math or a math-related major (β_3) is very large and negative (-4.393) and significant at the 5 percent level. Finally, the difference-in-difference-in-differences estimator (β_7) is very large and positive (9.138) and significant at the 1 percent level.

Although very large magnitudes for coefficient estimates raise some questions about their reliability, potentially because of the very small sample of male teachers who

have math or math-related backgrounds, these results tentatively suggest that the negative effect of being assigned to a female teacher on math test scores for female students results from female teachers *without* a math or a math-related major. When we look specifically at teachers with math and math-related majors, this negative effect not only seems to disappear but it becomes positive, although only marginally significant. This appears to be consistent with the results found in Carrell et al. (2010), who, using experimental data, find that highly selective female professors positively influence female student math achievement outcomes at the U.S. Air Force Academy.²⁷ When we run the same regression for reading test scores as a robustness check, none of the coefficients of interest are statistically significant at conventional levels.²⁸

In order to ensure that our results are not driven by the small number of male teachers with a math or a math-related major, following Beilock et al. (2010) we estimate the following two specifications using the female teachers only:

$$TS_{icb} = \lambda_0 + \lambda_1 FEM_{icb} + SC'_{icb} \varpi + TC'_{icb} \mathcal{G} + \kappa_b + u_{icb} \quad (4)$$

and

$$TS_{icb} = \lambda_0 + \lambda_1 FEM_{icb} + \lambda_2 MATHREL_{icb} + \lambda_3 FEM_{icb} \times MATHREL_{icb} + SC'_{icb} \varpi + TC'_{icb} \mathcal{G} + \kappa_b + u_{icb}. \quad (5)$$

where λ_1 captures the gender gap in test scores for those students taught by a female teacher, and λ_3 captures the gender gap for those students taught by female teachers with

²⁷ While Hoffman and Oreopoulos (2009) also find a small positive effect at a selective institution of higher education, their data is non-experimental.

²⁸ We cannot rule out the possibility that the reason we do not find any effect for reading test scores pertains to having less power due to small sample sizes, particularly small samples of male teachers. While the magnitudes on the coefficients of interest in the reading test score regressions are somewhat large, they are substantially smaller than the coefficients in the math test score regressions. Thus, even if power is an issue, our results present strong evidence in favor of the detrimental effect of having a female teacher without a strong math background on math test scores of female students in primary school. Moreover, the remainder of the analysis excludes male teachers and our results continue to support these findings.

a strong math background versus those taught by female teachers without a strong math background.

Table 4 presents the results from equations (4) and (5) with the first (last) two columns presenting the estimates for math (reading) test scores. Female students taught by female teachers have math test scores that are significantly lower (-1.798) than their male counterparts (Column 1), that is, lower by roughly 9 percent of a standard deviation. Moreover, the math test score gap remains similar (-2.161) if the classes are taught by female teachers with no math background (column 2). The gender gap, however, disappears and the coefficient estimate becomes positive (1.086), although statistically insignificant, for students taught by female teachers with a strong math background. Finally, the difference between these two effects is large (3.247) and statistically significant at 5 percent level. In other words, female students in classes taught by female teachers *with* a math or a math-related major score roughly 3 percentage points higher on their math test scores than female students taught by female teachers *without* a math background. In terms of reading test scores, we find that none of the coefficients of interest are statistically significant. These results are consistent with our previous findings and similar to Beilock et al. (2010) if we limit our analysis to female teachers, suggesting that the small number of male teachers with a math or a math-related major do not appear to be biasing our results.

Overall our findings show that female students fare worse on their math test scores if they were taught by a female teacher *without* a strong math background. This is true whether we compare female teachers to male teachers or we look at female teachers in isolation. Specifically, this negative effect is 9-10 percent of a standard deviation of

math test scores when our specification includes students taught by female teachers only and is roughly twice as large when our specification includes students taught by both female and male teachers. Taking the 2004 National Assessment of Educational Progress (NAEP) math test score averages at age 9 as our benchmark, our lower bound estimate is about the same size as the raw gender test score gap or the standardized gender gap in math test scores at age 13 on the 1999 NAEP (Dee [2007]). Our lower bound estimate is also in-line with Dee (2007) who finds the negative effect of female teachers on the math test scores of eighth grade students is roughly 6-8 percent of a standard deviation. However, as we pointed out before, he also finds this effect for male students and after conducting several robustness checks he concludes that his findings on math achievement are largely due to the non-random assignment of female teachers to classrooms with low performing students in math.

While our upper bound estimate at first glance may seem high relative to the existing literature, this may in part be due to the differences in the sample considered in our analysis, as well as the randomized nature of our data. Specifically, we not only focus on students in primary schools, more than 90 percent of the students in our sample are from very disadvantaged minority families. One might expect the results to be different among primary school students from disadvantaged families because gender stereotypes and their effects on student outcomes may be more pronounced in this population.²⁹ As such, not having a female role model with a strong math background, especially in primary school, is potentially more detrimental for female students from disadvantaged families. Furthermore, the magnitudes of the effect of teacher gender on

²⁹ As previously noted, gender differences in children's self-perceptions about ability and their awareness of commonly held beliefs about gender stereotypes start emerging between the ages of 7 and 12 (Eccles et al. [1993], Steele [2003]).

student achievement outcomes presented in the existing literature for higher levels of education may potentially be biased as they are generally based on non-randomized data.

Moreover, the effect of teacher gender on student achievement presented in the existing economics literature for higher levels of education (particularly post-secondary education) may indeed to be more closely aligned with the positive (although not always significant) effect we find for female students taught by female teachers *with* a strong math background as these studies tend to focus on select institutions of higher education with highly selective female teachers/professors who have extensive training in math. Thus it is unclear whether our upper bound estimates are indeed inconsistent with the existing literature.

Regardless of the magnitudes of our coefficient estimates, taken together our findings are highly suggestive that female students taught by female teachers *without* a strong math background have lower math achievement outcomes, and this does not appear to be driven by the small number of male teachers with a strong math background in our sample but by the nature of our sample and data.

4. Conclusion

Are female students adversely affected by having a female teacher? The evidence is mixed. Recent studies in economics either find having a female teacher has a positive effect on female student achievement outcomes (e.g., Rothstein [1995], Nixon and Robinson [1999], Bettinger and Long [2005], Dee [2007], Hoffman and Oreopoulos [2009], Carrell et al. [2010]) or no effect on female achievement outcomes (e.g., Canes and Rosen [1995], Ehrenberg et al. [1995], Neumark and Gardecki [1998]) in middle

school/high school or college/post-college. The educational psychology literature, on the other hand, finds that having a female teacher has a negative effect on female student math achievement in primary school (e.g., Beilock et al. [2010], Bush [1989], Tobias [1998]).

This paper attempts to reconcile the findings in these two strands of literature using evidence from a well-executed randomized experiment. In particular, our results show that having a female teacher has a negative impact on the math test scores of female students in primary school. Moreover, the negative impact of female teachers on the math achievement outcomes of female students does not appear to be an artifact of female and male teachers having differential unobserved characteristics because we do not find a similar negative effect on the reading test scores of female students, nor do we find a negative effect on the test scores (math or reading) of male students.

In an attempt to further understand the potential mechanism behind our results, we draw on the educational psychology literature and tentatively show that female students' internalization of female teachers' math anxiety can play a role under the assumption that having a math or a math-related college/post-college major reduces or eliminates math anxiety among female elementary school teachers. In other words, we posit math anxiety is reduced either because female teachers have more extensive training in math and/or they do not hold stereotypical beliefs about gender ability differences.

Specifically, the negative effect of having a female teacher on math test scores of female students not only seems to disappear but becomes (marginally) positive for students taught by female teachers *with* a strong math background. This finding is consistent with the findings in the economics literature based on a randomized

experiment from a highly selective institution of post-secondary education where female professors teaching math and/or science tend to have strong math backgrounds (see Carrell et al. [2010]). Thus, only female students taught by female teachers with *limited* math backgrounds appear to be adversely affected, which is consistent with the educational psychology literature (see Beilock et al. [2010]).

Therefore, our results extend the existing literature on primary school students in a number of ways—we focus on disadvantaged neighborhoods, employ randomized data, include male teachers in the estimation sample, and utilize reading test scores as a robustness check—and yet they tentatively suggest that the findings in the educational psychology literature and the economics literature are in fact consistent if one takes into account a teacher’s academic background in math.

Our findings also shed light on some policy prescriptions for elementary school education. Research in educational psychology suggests that a mathematics methods course could lessen mathematics anxiety in prospective primary school teachers and improve the quality of classroom instruction (Hembree [1990], Emenaker [1996], Vinson [2001] among many others). Therefore, training programs focusing on method courses in math might be useful to counteract this negative impact, particularly for female teachers who teach in schools located in disadvantaged neighborhoods. Moreover, since this negative effect seems to potentially work through female students’ beliefs about commonly held gender stereotypes, education policy geared at dispelling these beliefs (perhaps as early as preschool) would be a useful complementary policy that might have many other positive longer term effects for female students as well as the society in general.

We want to end by pointing out that we do not know whether our results would hold for the students at higher levels of education (i.e., middle school/high school or post-secondary). Moreover, our results apply to a very specific subset of the population, students in very disadvantaged neighborhoods. As such, it is unclear if our results can be generalized to the general population of primary school students. Having said this, however, this may be the subset of students we should be focusing on given that this is the setting where the problems with the education system in the United States are most evident and arguably more important from a policy perspective. Future research, with available randomized data, should address these important issues in further detail.

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Table I – Descriptive Statistics by Student Gender
(Means and Standard Errors)

	<u>All</u>	<u>Female</u>	<u>Male</u>	(2) - (3)
	(1)	(2)	(3)	
Student Characteristics				
Black	0.6628 (0.0117)	0.6814 (0.0163)	0.6447 (0.0166)	0.0367 (0.0233)
Hispanic	0.2758 (0.0110)	0.2595 (0.0154)	0.2917 (0.0157)	-0.0322 (0.0220)
Baseline Math (average NCE)	30.2716 (0.4607)	30.599 (0.6552)	29.951 (0.6480)	0.6480 (0.9216)
Baseline Reading (average NCE)	25.6008 (0.5194)	25.9548 (0.7592)	25.2531 (0.7100)	0.7017 (1.0390)
Class size (number of students)	25.1458 (0.1381)	25.1808 (0.1954)	25.1116 (0.1953)	0.0692 (0.2763)
Teacher Characteristics				
Female	0.7564 (0.0106)	0.7528 (0.0151)	0.7599 (0.0147)	-0.0071 (0.0212)
Treatment	0.4399 (0.0122)	0.449 (0.0174)	0.431 (0.0172)	0.018 (0.0245)
Certified	0.5462 (0.0123)	0.5571 (0.0174)	0.5354 (0.0172)	0.0217 (0.0246)
Teacher Experience (in years)	6.1343 (0.1959)	6.2902 (0.2836)	5.982 (0.2707)	0.3081 (0.3919)
Black	0.4739 (0.0123)	0.4846 (0.0175)	0.4634 (0.0173)	0.0212 (0.0246)
Hispanic	0.1021 (0.0075)	0.1009 (0.0106)	0.1032 (0.0105)	-0.0023 (0.0149)
Math or Math Related Major	0.1148 (0.0079)	0.1169 (0.0113)	0.1128 (0.0110)	-.0040 (0.0157)
Number of Observations	1646	813	833	-

Notes: Both white students and teachers constitute the left-out categories when controlling for race/ethnicity.

Table II – Determinants of Math and Reading Test Scores by Student Gender
(Coefficients and Standard Errors)

	Math		Reading	
	Female	Male	Female	Male
Female Teacher	-4.683*** (1.574)	0.381 (2.312)	-0.651 (1.418)	-0.612 (1.480)
Student Characteristics	Yes	Yes	Yes	Yes
Teacher Characteristics	Yes	Yes	Yes	Yes
Block Fixed Effects	Yes	Yes	Yes	Yes
Number of Observations	813	833	796	810
R-squared	0.589	0.550	0.749	0.666

Notes: Student characteristics include race/ethnicity, pre-treatment NCE math or NCE reading test scores, and class size. Teacher characteristics include an indicator for TFA teacher, race/ethnicity, years of teaching experience and its square, and type of certification. Standard errors are clustered at the block level. *** Significant at the 1 percent level; ** Significant at the 5 percent significance level; *Significant at the 10 percent significance level.

Table III – Determinants of Math and Reading Test Scores Pooled by Student Gender
(Coefficients and Standard Errors)

	<u>Math</u>		<u>Reading</u>	
	(1)	(2)	(3)	(4)
Female (β_1)	1.482 (1.653)	2.162 (1.604)	1.042 (1.516)	1.278 (1.635)
Female*Female Teacher (β_3)	-3.374* (1.871)	-4.393** (1.899)	-0.258 (1.493)	-0.614 (1.671)
Female*Female Teacher*Math Major (β_7)	-	9.138*** (3.210)	-	4.220 (4.706)
$\beta_1 + \beta_3$	-1.892** (0.740)	-	0.784 (0.801)	-
$\beta_3 + \beta_7$	-	4.745 (2.841)	-	3.606 (3.933)
Student Characteristics	Yes	Yes	Yes	Yes
Teacher Characteristics	Yes	Yes	Yes	Yes
Block Fixed Effects	Yes	Yes	Yes	Yes
Number of Observations	1646	1,646	1,606	1,606
R-squared	0.554	0.555	0.697	0.698

Notes: See notes to Table 2 for a detailed list of control variables. Columns 2 and 4 also include a math major dummy and its interaction with the dummies for female students and female teachers. *** Significant at the 1 percent level; ** Significant at the 5 percent significance level; *Significant at the 10 percent significance level.

Table IV – Determinants of Math and Reading Test Scores Pooled by Student Gender
for Female Teachers Only
(Coefficients and Standard Errors)

	Math		Reading	
	(1)	(2)	(3)	(4)
Female (λ_1)	-1.798**	-2.161**	0.814	0.667
	(0.787)	(0.860)	(0.824)	(0.803)
Female*Math Major (λ_3)	-	3.247**	-	1.297
		(1.512)		(2.938)
$\lambda_1 + \lambda_3$	-	1.086	-	1.964
		(1.330)		(2.908)
Student Characteristics	Yes	Yes	Yes	Yes
Teacher Characteristics	Yes	Yes	Yes	Yes
Block Fixed Effects	Yes	Yes	Yes	Yes
Number of Observations	1245	1245	1218	1218
R-squared	0.552	0.553	0.745	0.745

Notes: See notes to Table 2 for a detailed list of control variables. All the regressions also include a math major dummy. *** Significant at the 1 percent level; ** Significant at the 5 percent significance level; *Significant at the 10 percent significance level.

Appendix

Table AI Characteristics of TFA and Control Teachers

	<u>Total</u>	<u>TFA</u>	<u>Control</u>
Treatment			
Female	73 (77.7)	28 (68.3)	45 (84.9)
Male	21 (22.3)	13 (31.7)	8 (15.1)
Race/Ethnicity			
African American	45 (47.9)	8 (19.5)	37 (69.8)
Non-Hispanic White	36 (38.3)	30 (73.2)	6 (11.3)
Hispanic	10 (10.6)	2 (4.9)	8 (15.1)
Race Missing	3 (3.2)	1 (2.4)	2 (3.8)
Certification			
Regular	52 (55.3)	18 (43.9)	34 (64.1)
Non-Regular	42 (44.7)	23 (56.1)	19 (35.9)
Average Years of Teaching Experience	6.3	2	9.7
Number of Observations	94	41	53

Notes: Percentages are given in parentheses.

Table AII – Determinants of Being Assigned to a Female Teacher
(Coefficients and Standard Errors)

	Math Sample		Reading Sample	
	(1)	(2)	(3)	(4)
Female	-0.012	-0.011	-0.007	-0.008
	(0.011)	(0.012)	(0.011)	(0.012)
Student Characteristics	Yes	Yes	Yes	Yes
Teacher Characteristics	No	Yes	No	Yes
Block Fixed Effects	Yes	Yes	Yes	Yes
Number of Observations	1,646	1,646	1,606	1,606
R-squared	0.440	0.532	0.471	0.536

Notes: All regressions are estimated using linear probability models. Standard errors are clustered at the block level. *** Significant at the 1 percent level; ** Significant at the 5 percent significance level; *Significant at the 10 percent significance level.