Gender composition of science teachers at school: does it matter for later choice of science?*

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Abstract

Same-gender teachers may affect educational preferences by acting as role models for their students. Using family fixed effects in population-wide register data from Sweden I find that increasing the share of female science teachers in lower secondary school has no effects on girls' likelihood to choose a math-intensive track at upper secondary school nor to complete a math-intensive degree at university. There is a slight negative effect on boys' likelihood to choose such a track at upper secondary school, which at least partly stems from an effect on achievement. No long-run effects are found at university level.

Keywords: Role models, gender segregation, human capital, STEM
JEL codes: I21, I24, J16

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1 Introduction

Despite the fact that girls and boys perform equally well in mathematics from early school years to secondary education (see e.g. Kahn and Ginther 2017), boys are much more likely to pursue math-intensive degrees. If women with high abilities in mathematics do not enter math-intensive fields of study, societies are losing an important potential in human capital in some of the most productive jobs (Joensen and Nielsen 2016) which can lead to slower economic growth (Hsieh et al. 2019). Since these degrees often lead to higher wages, the gender segregation in these fields also enlarge the gender wage gap (Card and Payne 2017). A possible explanation for this educational segregation is gender-specific role models as girls are less exposed to same-gender role models from these fields than boys are.

In this paper, I study whether the gender composition of mathematics and science teachers at lower secondary school matters for later choice of math-intensive education. I measure the exposure to the female mathematics and science teachers at a time of schooling when everyone is still following the same national curriculum and have not yet made specific choices about a field of further studies. Importantly, in the Swedish schools no ability-based tracking is allowed. This institutional setting and the timing of exposure is ideal to study the effect of the gender composition of teachers on later choice of field of study. Understanding the factors behind these choices is important as the field of study matters greatly even for long-run labour market outcomes (Dahl et al. 2021, Kirkeboen et al. 2016).

Rather than focusing on one single education institute, as is the case with most of the previous literature, I make use of registry data for the full population of Sweden for the cohorts 1986–1995. The data allow me to study the importance of the gender composition both in the short and in the long run on the choice of field of study. In addition, I analyse the effect on students' achievement in mathematics and sciences to distinguish a potential effect on grades as an alternative mechanism besides the role model effect. To control for endogeneity of teacher sorting across schools, I use sibling fixed effects to compare the effects between girls and boys. This method controls also for the time invariant role models in the home environment.

I find that increasing the share of female mathematics and science teachers has no effect on the likelihood of girls completing a STEM[1] track at upper secondary school nor on graduating from a math-intensive field of study at university. While boys are slightly negatively affected with respect to the likelihood of applying to and graduating from a STEM track at upper secondary school, this negative effect loses its significance and magnitude in the long run as pursuing a math-intensive degree at university is not affected. My results indicate that increasing the share of female mathematics and science teachers from one standard deviation below the mean to one above decreases boys' likelihood to graduate from a STEM-track by almost three percent relative to the mean outcome of boys. This change in the share of female teachers in these subjects is equivalent of changing the share from a quarter to three quarters. This change in share of female science teachers decreases the gender gap in graduating from STEM by 8.2 percent—driven by the negative effect on boys. To analyse potential heterogeneity effects of being exposed to female science teachers, I follow Carrell et al. (2010) and estimate the effect for the top-performing students separately but find no difference to the main results. Further, I investigate whether having a parent or an older sibling with STEM degree affects the main results but find again no difference to the main results. In addition, I study the share of social science teachers as competing role models but I find them to have no effect on graduating from a STEM-track.

I also investigate whether these results are driven by the effect on achievement. I find that boys' average grade in STEM subjects decreases with a higher share of female mathematics and science teachers and this further has a very small effect on boys' grade point average. Hence, I do not find indication that the gender composition of these teachers in lower secondary school has an effect on girls' likelihood to choose science in

[1]STEM stands for Science, Technology, Engineering and Mathematics.

further levels of education. Nor do I find the same-gender teachers as role models to matter greatly in this respect for boys in these subjects.

Previous literature shows mixed evidence regarding the role model effect of a same-gender teacher on the likelihood of studying math-related fields. Carrell et al. (2010) find positive effect on continuation and graduation with a STEM degree among the best-performing female students in mathematics and no effects on male students if the share of female professors in introductory science and mathematics classes is increased at college. Bottia et al. (2015) conclude similar findings when studying the effect of the share of female STEM teachers in upper secondary school on the likelihood of majoring in STEM fields at university. They find effects on female students across the entire achievement distribution, not just among the top performers. Similar to Carrell et al. (2010), they find no effects on male students. Lim and Meer (2020) find that having a female math teacher in 7th grade increases the likelihood to choose math-science track in upper secondary school and aspiration to choose STEM even in post-secondary education among female students but find no effects on male students.[2] All of these studies investigate the effects at a stage when the students have already made choices of specialisation in terms of courses or have had selection to classes based on ability.

My results are more in line with a second set of papers which find no effect on choice of study field. Griffith (2014) finds no effects on opting for STEM among female students if they are having a female instructor and Bettinger and Long (2005) find mixed evidence depending on the STEM subject for the same treatment. Canes and Rosen (1995) find no association between the share of female faculty and the share of female students enrolling in science and engineering. In comparison to this set of papers I focus on a lower level of education and have the possibility to control for a larger set of outside factors as I focus on the difference between siblings.

Achievement in mathematics and science is a related outcome that has also been

[2] Recent literature has even found strong and long lasting effects for rather short interaction with a same-gender role model on the individual's choice for math-intensive field of study (e.g. Riise et al. 2019, Breda et al. 2020, Porter and Serra 2020).

studied extensively. Having a female teacher in mathematics and sciences could result in better achievements for girls in these subjects, which in turn could make it more likely that girls would choose STEM. However, most previous studies conclude that having a same-gender teacher has little or no effect on achievement (Antecol et al. 2015, Ehrenberg et al. 1995, Griffith 2014, Hoffmann and Oreopoulos 2009, Holmlund and Sund 2008 and Winters et al. 2013). An exception is a study by Lim and Meer (2020) in Korea where they find positive effect on female students but no effect on male students when exposed to female teacher in 7$^{\text{th}}$ grade. Dee (2007) finds that same-gender teachers raise the achievement level of both boys and girls in different subjects for 8$^{\text{th}}$ grade students in the US, although for mathematics he finds negative effects on girls. Carrell et al. (2010) find positive effects on female college students' test performance but negative effects on boys in introductory science and mathematics courses when having a higher share of female professors. In line with Carrell et al. (2010) and Dee (2007) I find negative effect on boys' performance but in contrast to them, I find no effect on girls.

In Section 2, I discuss the conceptual framework related to the potential effect of role models and why there may be heterogeneous effects across students. I subsequently explain the relevant components of the Swedish education system in Section 3. In Section 4, I explain the research design and describe the data and variables of interests in Section 5. In Section 6, I show the main results and conduct heterogeneity analyses as well as investigate the robustness of the results and shed light on potential alternative mechanisms behind the effects. Finally, in Section 7, I conclude and make some final remarks.

2 Conceptual framework

Role models of the same gender provide a potential channel for gender-specific preference formation. Bussey and Bandura (1999) explain that according to social cognitive theory, different role models that we are exposed to early on and throughout our lives, play an important role in shaping our ideas of what is typical for each gender. For a school-aged child, the three main sources of role models are typically members of the family, teachers at school and different characters in entertainment.[3] In this paper, the focus is on same-gender teachers at school, and the effect they have on choosing a math-intensive study track. Teachers at school can affect both the performance and the preferences of the students in different subjects, which both in turn might determine the further educational choices of the students.

Same-gender role models in mathematics and sciences at school may matter more for girls than for boys, as there are fewer same-gender role models in these fields for girls. Additionally, and potentially due to this difference in role models, boys have greater self-confidence in math-related subjects. According to Bussey and Bandura (1999) this difference arises from the gender-specific role models and incentives and disincentives we experience in our social environment. The assumption about boys having a stronger belief in their mathematical abilities than girls is supported by a study by Dahlbom et al. (2011) in Sweden and a study by Correll (2001) in US. Conditional on the level of skill, if having a same-gender teacher matters for your confidence, we would expect girls' preferences to be more affected than those of boys when they face an environment with same-gender STEM teachers as there are more men than women in STEM occupations in general (and thus also, for example, in films and books).[4] The effect is also likely to be stronger among girls with a high level of skill in mathematics as these skills are a prerequisite for entering a math-intensive field of study.

A teacher of the same gender might also affect the performance of a student more than a teacher of a different gender. It could be that a same-gender teacher conducts the teaching in a more suitable way and hence affects the future educational choices not only via preferences but also via the performance of the students. An additional concern might be gender-specific grade discrimination by teachers which might be linked

[3] Riise et al. (2019) show that even other same-gender role models, in their case a doctor, can matter as a role model that affects choice of STEM education.

[4] Correll (2001) develops a model along these lines by considering the importance of cultural beliefs about gender and self-assessment as determinants of the gendered occupational choices.

to biases and stereotypes the teachers have towards the achivement of girls and boys. Previous studies have found some evidence of female students getting better grades if a female teacher corrects their exams (Lindahl 2016, Lavy 2008) but lower if the teacher has strong gender stereotypes (Carlana 2019, Lavy and Sand 2018). However, a Swedish study where the same exam was corrected both blinded and non-blinded shows no grade discrimination (Hinnerich et al. 2011).

In Sweden, the performance of girls in mathematics is not a concern when considering the reasons for the lower share of women in math-intensive fields. Girls do on average as well as boys in mathematics at school (see e.g., Figure A.2) and outperformed boys in the latest PISA tests, including science and mathematics (Schleicher 2019). However, while girls are doing as well as boys in mathematics they on average perform notably better than boys across all other subjects (see Figure A.2). This comparative advantage in relation to other subjects is what Card and Payne (2017) conclude to be the main driver of the STEM gap in the choice of majors. As girls more often than boys perform well in a variety of subjects, when they also perform well in mathematics, girls enjoy a broader set of options for future studies than their male peers. The broader set of options makes it potentially harder to affect the preference for mathematics among girls compared to boys.

An additional source of influence could come from home if there already is someone with a degree in math-intensive field of study. These family members could on one hand have a stronger effect than teachers at school on the choice of field of study and hence make the potential influence of a teacher at school smaller. On the other hand, it could be that it is the joined effect that matters: that one needs a role model both at school and at home before the effect kicks in. To analyse this possibility, I study the effect of female science teachers separately on a sample of children who have such role models at home; either an older sibling or a parent.

In this paper, I use the share of female science and mathematics teachers at the school level as a proxy for female role models in science at school. This measure captures a combination of having a female teacher in class and the potential within-school spillover effects to other classes. Being in direct contact with a teacher of the same gender or having multiple same-gender teachers in science subjects at school will probably have different effects on students. The estimated effects will be a combination of direct and indirect exposure to the same-gender role models at school. As explained above, it is possible that the effect of a higher share of female science teachers could involve other channels for affecting the preference of future education than purely via the teachers acting as same-gender role models. I explore this possibility by studying the impact of same-gender teachers also on performance.

3 Swedish schools and STEM education

3.1 Compulsory school

The Swedish compulsory school system consists of nine years of schooling. Children start the first grade in the autumn of the year they turn seven, and complete their compulsory education the year they turn 16. The majority of compulsory schools are run by a municipality but there are also private voucher schools that are financed by public funding.[5] All compulsory schools are obliged to follow the national curriculum set by the Swedish National Agency for Education. Notably, no skill-based tracking is allowed in Swedish compulsory schools. Currently, about one fourth of the teaching hours in the curriculum for the final three years of compulsory school, the lower secondary level, is dedicated to different STEM subjects. The teachers in these classes are the ones that I focus on in my analysis.

The lower secondary school that a student attends is mainly determined by the alternatives available in the municipality that the student resides in. Schools run by a municipality give priority to the students who live closest to the school and the choice of lower secondary school is therefore usually determined by proximity rather than a desire

[5] During the research period the share of students in private schools has increased from 8 to 13 percent.

for a particular type of school.[6] Different schools may thus have students with different socioeconomic backgrounds mainly due to housing segregation. In my research design, I control for family fixed effects to remove this type of sorting. However, siblings may attend different schools if the family moves, a school closes or a new one opens.

Municipalities are responsible for organizing education but in practice it is the school principals who make decisions concerning teacher recruitments and who negotiate pay with the teachers. More women than men become teachers, and the lower the level of school, the higher the share of female teachers. The share differs across subjects: there are more female teachers of languages and fewer of science subjects.

3.2 Choice of study after compulsory school

Almost all students move on to upper secondary school after finishing compulsory school. The upper secondary school level consists of different types of programs. The choice of a program at upper secondary school is the first major educational choice the students face in the Swedish education system. All programs run for three years, some are vocational and some are preparatory for higher education. All programs give access to some higher education courses but the vocational ones only give the access to a restricted number of fields. Two programs are substantially more math-intensive than the others: the technical program and the natural science program. Throughout my analysis, I define these two programs as STEM tracks and refer to the natural science track as the science track. These two STEM tracks are both preparatory programs for higher education. The technical program is especially intended for those who aim to continue with engineering studies after completing their upper secondary education. The science track is the most flexible program in terms of further studies.

[6] Voucher schools may have additional queuing systems for the applications if there are more students applying than places available. However, the rules of acceptance have to be accepted by the Swedish Schools Inspectorate. In general, no compulsory school may have entrance tests or skill-based acceptance rules. A few exceptions exists for schools that specialize in the arts or sports.

4 Empirical strategy

The aim is to study the effect of the share of female mathematics and science teachers (hereinafter referred to interchangeably as STEM or science teachers) at lower secondary school on the probability of graduating from a STEM track at upper secondary school or to major in a math-intensive field at university. The same explanatory variable, share of female teachers, has previously been used, for example, by Lindahl (2016) and Bottia et al. (2015). By focusing on the average effect among students, I avoid problems caused by the sorting of students and teachers into specific classes as long as sorting into classes is exogenous to the share of female teachers.

Ideally, I would compare outcomes of two identical individuals who are exposed to different share of female science teachers and have otherwise similar set of role models. However, teachers and students are not randomly allocated to schools and role models we are surrounded by vary from person to person. Given that the data do not allow linking students to teachers directly, individual fixed effets are not an option. To overcome such endogeneity problems, I focus on between-siblings variation in the share of female STEM teachers, where the identifying variation comes from different siblings being differently exposed over time. With family fixed effects I control for any family-specific unobservables that are correlated with the share of female STEM teachers at a school and that may also affect the likelihood of the students choosing STEM. With family fixed effects, I also control for exposure to other types of role models at home such as parents and the family-specific consumption of culture (e.g. entertainment) that all siblings are exposed to.

The identification strategy relies on the assumption that the average exposure to female STEM teachers is randomly allocated across children conditional on family fixed effects. The effect is thus estimated net on other sibling-invariant role models. In the main specification (Equation 1),

$$Y_{ij} = \alpha_i + \beta_1 ShareFeSTEM_i + \beta_2 Girl_i + \beta_3 ShareFeSTEM_i \times Girl_i + \gamma_j + \delta_i \mathbf{X_i} + \mu_{is} \mathbf{Z_{is}} + \epsilon_{ij}, \tag{1}$$

my explanatory variables of interest are the share of female teachers in STEM subjects ($ShareFeSTEM_i$) in the school for student i of family j. As I am interested in the same-gender effect, I include a dummy for being a female student ($girl_i$) and an interaction of it with the share of female STEM teachers to analyze the gender difference in the effect. I control for the family-specific characteristics (γ_j), and I include year of birth and sibling order as student-specific controls ($\mathbf{X_i}$) and ($\mathbf{Z_{is}}$) is the vector for school-level controls discussed further in Section 4.1. The outcomes of interest (Y_{ij}) are applying to and graduating from a STEM track at upper secondary school and pursuing a degree in a math-intensive field at university as well as several outcomes on performance. The coefficient β_1 captures the direct effect of an increase in the share of female STEM teachers on boys whereas the combination of coefficients β_1 and β_3 shows the direct effect on girls. The coefficient on the female-student dummy (β_2) captures the regression difference between girls and boys regarding the likelihood of graduating in STEM at the next level of education, i.e. the gender gap in STEM. The coefficient β_3 tells us how much the likelihood of girls choosing STEM increases in percentage points, in comparison to boys, if the share of female STEM teachers increases from none to all.

Families with children of both genders or just either contribute to the identification of the estimated parameters differently. While families with same-gender children contribute to the identification of the main effect of the share of female STEM teachers (β_1), they do not contribute to the identification of the interaction coefficient (β_3) nor the main effect of gender (β_2). Families of children of both genders contribute to the identification of all of the parameters. The interaction (β_3) is identified from families where the children are of both genders, who can be exposed to either the same or a different share of female STEM teachers at the school.

To investigate the importance of adding family fixed effect to the model, I also run an OLS model without family fixed effects among all students (with or without siblings) and a model among all students with school fixed effects included. The simple OLS model does not account for the fact that students who are exposed to a high share of female STEM teachers may systematically have different outcomes than students who attend a low share school. One option to account for such a selection problem is to compare all the students who attended the same school by including school fixed effects. This method has the advantage that it is possible to apply to all the children—not only those who have a sibling. However, by studying all the students at the same school, we are not taking into account any family specific characteristics that may also play an important role in terms of the outcomes and the probability of ending up in a school with a low or high exposure to female STEM teachers. In particular, by including the family fixed effect we are able to control for both observable and unobservable characteristics that are the same across siblings, such as role models in the home environment. With the family fixed effects we can better net out the actual effect of the teachers as role models.

4.1 Potential threats to identification and interpretation

By including family fixed effects, I control for family characteristics that are shared between siblings. However, it is still possible that within a family, the parents enter their children into different schools based on gender in a manner that correlates with both the outcome variables and the explanatory variable of interest. Such gender specific school choices would bias the estimate for the importance of the share of female STEM teachers. To rule out such a channel I investigate whether the treatment, share of female science teachers, varies between brothers and sisters systematically by regressing the explanatory variable of interest on the same set of control variables as in the main model. On top of the main treatment variable, I also test for the qualification of the teachers, share of female teachers in social sciences and the average grade point in the schools to make sure that there is no selection in quality of schools between siblings of different gender.

Importantly, the share of female STEM teachers is not differing systematically between siblings of different gender as is shown in the first column of Table A.2. Nor is there a difference in the share of female teachers in social sciences (Column 3) in schools that the brothers and sisters attend. However, there are minor differences in terms of share of qualified STEM teachers (Column 2) and average GPA of compulsory school graduates (Column 5). These two characteristics are used as additional school level controls in the main specifications to make sure it is the effect of the share of female STEM teachers and not sorting to schools that we are measuring.

When interpreting the effect of female STEM teachers on female students as a role model effect we have to bear in mind that I capture everything that correlates strongly with female gender in the explanatory variable of interest. Female science teachers may differ in multiple ways from male science teachers that we are not able to distinguish. Women may teach in a way that decreases competition (Spencer et al. 1999) or they weaken stereotypes about science and mathematics being masculine fields (Carlana 2019). If female STEM teachers are, for example, better (or worse) teachers, the effect of the gender is not only via a role model effect but also due to the difference in the quality of teaching. Thus, same-gender teachers may also affect the performance of the students, not only the preferences via the role-model effect. If performance in science and mathematics is improved by having a same-gender teacher, this in itself might increase the likelihood of opting for a STEM education later on. I analyse the effect on performance by investigating the effect of the treatment on achievement in a set of different performance measures.

5 Data

The population of the study includes all individuals born between 1986 and 1995 who completed compulsory school in Sweden. The main sample consists of students who graduated from a compulsory school at the usual age of 16 give or take a year.[7] The

[7]For the cohort born 1986, I can only include age 16–17 at graduation while for the rest of the cohorts also age 15 is included. The restriction is due to availability of the STEM-teacher identifier: prior to

sample of siblings is constructed by using the Swedish Multi-Generational registry where I am able to select the sample by birth year and identify the persons with the same mother. These data also include information about the registered sex. The registry includes all persons who have been registered in Sweden at some point since 1961 and were born in 1932 or later. This registry, as well as the other registries used in this study, is collected and maintained by Statistics Sweden.

The data include a unique identifier for each individual which makes it possible to link information at the level of the individual from different registries. In order to define the population of compulsory school graduates, I make use of the graduation registry. This registry also includes information about the grade point average and final grades for each subject. This information is missing for a small number of schools in some years and hence I only include those years where I can observe the GPA.[8] During the final year of compulsory school, students sit national exams in mathematics, Swedish and English. The results of these exams are collected in a separate registry for subject exams. I utilize these data to examine the effect of same-gender teachers on the performance of the students. As I am only able to observe registered sex in the data, I proxy gender by this variable. The registry for lower secondary school graduates also includes a unique identifier for each school. The school identifier makes it possible to attach more detailed school-specific information to the research data such as the total number of students in the schools. Information at the school level comes from a separate compulsory school registry over all schools in Sweden. Additionally, I am able to link information about the teachers at these schools from the teacher registry with the help of the school identifier that exists in both registries.

The choices of further education are observed from variety of registries. The applications registry for upper secondary education includes information about a maximum of six choices for upper secondary school programs that a student has applied to as well

year 2002, this identifier is only partially available. However, even for cohort 1986 I have above 97% of the individuals included after the restriction.

[8]Schools where no GPA is reported in a year are mostly small special schools but year to year variation happens also with some larger schools in reporting.

as information on whether the student has been accepted to a specific program. The upper secondary school graduation registry includes information about the final grades of the students as well as the programs the students graduated from. The school and student related data are collected and maintained by Statistics Sweden but are under the responsibility of the National Agency for Education. The Agency uses the statistics to follow and evaluate the functioning of the school system both at the local and national levels.

I observe the field of study at university from the education registry which is updated annually and includes the highest level of education attained by persons aged 16 and above who are registered in Sweden. The highest level of education is based on a multitude of different registries, partly those that have already been mentioned above (graduation registries from compulsory and upper secondary schools) and also other registries such as the study credit registries of universities, population registries as well as registry of immigration forms. The information of the highest level of education includes both the level and the field of education.

I include those schools where I am able to identify at least one mathematics or science teacher and which have students in all the grades of lower secondary school (grades 7 to 9). There are about 2,000 lower secondary schools in my sample. My sample of graduates from upper secondary school, who have a sibling, consists of about 710,000 students from about 320,000 families. In the majority of the families (80 percent), all the siblings have attended the same lower secondary school.

5.1 Explanatory variable of interest

My explanatory variable of interest is the share of female STEM teachers at a school. The information about the share of female STEM teachers and the share of the teachers of other subjects are calculated from the teacher registry. The share is defined the year the children graduate from their schools.[9] The STEM teachers are defined as those who

[9]The graduation year is the only year when I can observe the school the students attended.

teach sciences, technical studies and mathematics in grades 7 to 9. There is no indication for each subject separately but there is a common subject identifier in the teacher registry for teachers who teach in one or more of these subjects.[10]

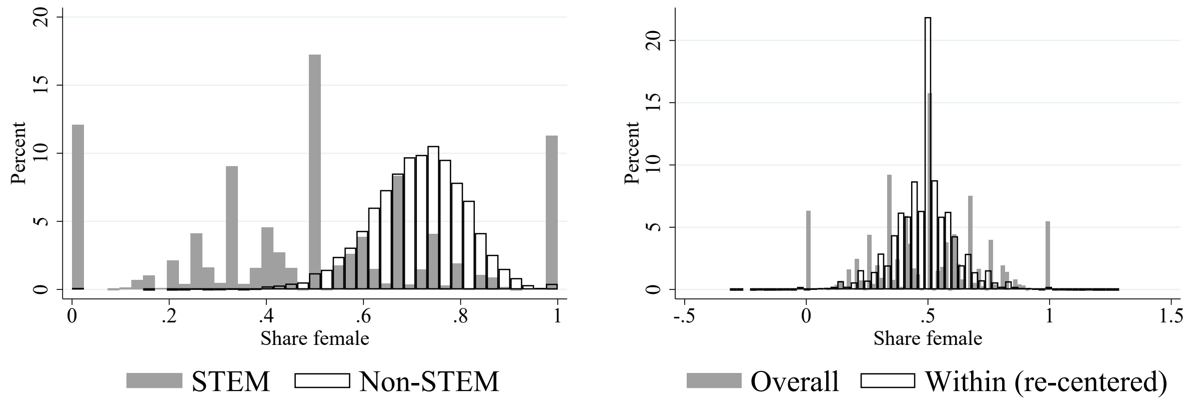
In Figure 1a, I show the distribution of the share of female STEM teachers and the share in other subjects across the years the individuals in the sample completed their lower secondary school. It is apparent from Figure 1a that most of the teachers in the schools are female but the variation is greater among the STEM teachers. In Figure A.3, we can also see that the share of female teachers in STEM subjects has been increasing steadily over the years whereas the increase in female teachers in other subjects has been modest. Figure 1b shows the same overall distribution of the treatment variable as in Figure 1a but also the distribution when we only focus on within family. This within family variation is re-centered in the figure at the overall mean share of female science teachers. Importantly, the variation in the explanatory variable is relatively large after restricting to within family variation. While the overall variation is 0.24 the within variation is 0.13, meaning that more than half of the overall variation remains after we control for family fixed effects.[11]

[10] The identifier is available since 2002 for the complete teacher registry. In the prior years this identifier is only partially registered. Due to this restriction, year 2002 is the first graduation year from compulsory school that I can include to the study.

[11] I have also investigated the variation by age difference between siblings (Table A.12) and by number of science teachers at a school (Table A.13). The variation in the share of female teachers is somewhat greater in families with greater age differences and in smaller schools with less science teachers.

Figure 1 – Variation in share of female teachers

(a) STEM and non-STEM (b) STEM, overall and within family



Notes: The within family variation is re-centered to the mean share of female STEM teachers. Graduation years 2002–2012 are included

5.2 Outcomes studied

I study the effect of same-gender teacher role models on further educational choices. Hence, I study whether a student applies for a STEM track at upper secondary school, graduates from a STEM track, or pursues a degree in a math-intensive field at university. I categorize the science and technical tracks in upper secondary school as the STEM tracks. I study both application to and graduation from upper secondary school as students may change their track during the course of upper secondary school.[12] About 80 percent of each cohort has completed upper secondary school by the year they turn 20. This age is when I measure the graduation from a STEM track. The share of boys and girls who graduate from the science track is fairly equal, but in contrast there are many more boys graduating from the technical track (see Figures A.1a and A.1b). During the study period the share completing a STEM track has increased slightly among both girls and boys (Figure A.1c).

I study the field of graduation in the year the students turn 25.[13] In line with Kahn

[12]I additionally check for acceptance to the first choice track but almost all who apply to a STEM track are also accepted. Hence, the results are essentially the same in both cases. The correlations between application, acceptance and graduation are shown in Figure A.11.

[13]The median graduation age is 28 for university degrees but as there is a limit to how many cohorts

and Ginther (2017), I define geosciences, engineering, economics, mathematics, computer sciences and physical sciences as math-intensive majors and refer to them as GEMP fields of study. These fields of study are separated from the life sciences where female participation is already high and which tend to be less math-intensive. The degrees in these GEMP fields are included in my main results for the outcome at university level. More women than men have completed a 3-year university degree by the age of 25, but notably more men than women major in GEMP (see Figure A.1d). Additionally, I conduct the analysis for various alternative definitions of STEM-majors: the results are not notably affected by the different definitions. Due to data limitations, I am able to observe graduation by the age of 25 only for the sub-population of my sample who were born between 1986 and 1993.

In order to investigate an alternative mechanism, I study the effect of the share of female STEM teachers on achievement in the national mathematics exam, the final grade in mathematics, the average final grade in all STEM subjects[14] and the grade point average (GPA, *meritvärde*). I test the effect on the GPA as the grades in other subjects also matter for further education. The exam results are available from the year 2004 for most of the population who has finished 9$^{\text{th}}$ grade. For across year comparison, I standardize all these measures by school year to obtain a mean zero and standard deviation of one. Girls and boys fare very similarly in their national mathematics exam (Figure A.2) but girls do notably better on average across all subjects when measured by their GPA (see Figure A.2).

5.3 Descriptive statistics by sample

Table 1 shows descriptive statistics of the different samples used in the analysis. The first column includes all the children in the sample with or without a sibling and the

I can follow to later in life, I study the university degree at age 25, which gives for most individuals in the sample six years to complete a three year university degree after graduation from upper secondary school. In this way I only lose two cohorts in comparison to the main research sample.

[14]STEM subjects are defined as those that are taught by STEM teachers: the sciences, technical studies and mathematics.

second column includes only those with at least one sibling. For the first two samples I am able to study whether a child applied to and graduated from a STEM track at upper secondary school. The last column shows the sample that is used to study the outcome at university level of pursuing a GEMP degree by the age of 25. The sibling samples, shown in the last two columns, include the individuals who have a sibling born within the same interval of years, i.e. 1986–1995 and 1986–1993 respectively. As expected, the number of siblings decreases the fewer the number of years included. However, the samples are fairly similar in all other aspects. About 40 percent of the individuals have at least one parent with a university degree at the time the child is 16 and about the same share of the children have at least one parent or older sibling with a STEM background. The number of STEM teachers has risen over time and the share of female STEM teachers has gone up whereas the share of female teachers in social sciences has remained stable. This pattern is also seen in Figure A.3. The number of students per school has decreased slightly over the years. The different samples seem very similar in terms of the outcome variables, which is reassuring in their representativeness for the whole population.

Table 1 – Descriptive statistics (mean and standard deviation) of the different samples by year of birth and existence of sibling(s).

	$\leq 1995, All$	$\leq 1995, Sibling$	$\leq 1993, Sibling$
Family background			
# of siblings	1.87	2.33	2.25
	(0.79)	(0.59)	(0.51)
Share parents, Uni degree	0.39	0.40	0.39
	(0.49)	(0.49)	(0.49)
STEM track/degree in family	0.14	0.17	0.16
	(0.34)	(0.38)	(0.37)
School characteristics			
# of STEM teachers	6.41	6.45	6.53
	(3.11)	(3.11)	(3.11)
Share female STEM teachers	0.49	0.49	0.47
	(0.24)	(0.24)	(0.23)
Share qualified STEM teachers	0.48	0.48	0.44
	(0.27)	(0.27)	(0.26)
# of Soc Sci teachers	4.31	4.33	4.37
	(2.44)	(2.44)	(2.45)
Share female Soc Sci teachers	0.56	0.55	0.55
	(0.29)	(0.29)	(0.29)
# of students	315	317	328
	(140)	(140)	(141)
Outcome variables			
STEM track, application	0.18	0.18	0.17
	(0.38)	(0.38)	(0.38)
Natural Science	0.12	0.12	0.12
	(0.32)	(0.32)	(0.32)
Technical	0.06	0.06	0.06
	(0.23)	(0.23)	(0.23)
STEM track, graduation	0.15	0.15	0.14
	(0.36)	(0.36)	(0.35)
Natural Science	0.10	0.10	0.10
	(0.30)	(0.30)	(0.30)
Technical	0.05	0.05	0.04
	(0.21)	(0.21)	(0.21)
GEMP major, graduation			0.08
			(0.28)
N	1,091,666	713,411	523,639

Notes: The columns indicate different samples used in the analysis. The first column includes all individuals born 1986–1995, the second column includes those born 1986–1995 who have a sibling and the third column includes individuals with a sibling who are born 1986–1993 and who we can observe at age 25 when we measure graduation in university.

6 Results

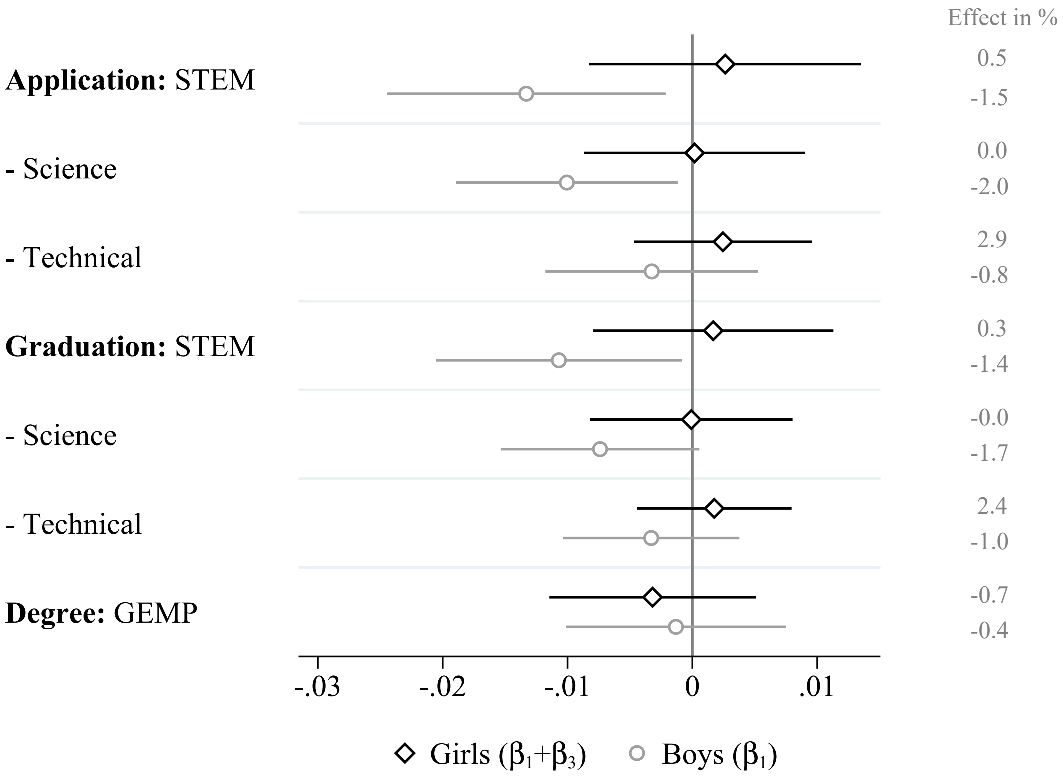
Figure 2 displays the main results on further choice of math-related field of study. The point estimates are also presented in Table A.3. If anything, there is a negative effect on the likelihood of boys choosing math-related education path if the share of female science teachers is increased in lower secondary school, while for girls the effect is close to zero. The effect on boys is very similar at the application and graduation stages: a one standard deviation increase in the share of female science teachers decreases the likelihood to apply by 1.5 percent and likelihood to graduate from a STEM track by 1.4 percent relative to the mean. This result means that increasing the share of female science teachers from a quarter to three quarters decreases the likelihood of boys to graduate from a STEM track by about three percent relative to the mean.[15] This effect is driven by the science track. However, at a later stage, there is no effect on the likelihood on pursuing a math-intensive degree at university. While the point estimates are negative for both boys and girls, they are highly insignificant at university level. Hence, girls' choice for math-related field of study seem not to be affected by a change in the share of female science teachers. However, due to the negative effect on boys, there is a decrease in the gender gap at upper secondary school level of 4.2 percent if the share of female science teachers is increased by one standard deviation.

In comparison to the previous literature, these effects on choice of further education in math-related fields of study are very modest and in line with most of the previous literature that has found little or no effect on boys' choice of math-related field of study, when exposed to female teachers or instructors (Bottia et al. 2015, Carrell et al. 2010, Hoffmann and Oreopoulos 2009, Lim and Meer 2020, Price 2010). The result regarding the effect on girls is in line with the findings of Canes and Rosen (1995) and Griffith (2014) at college level. However, in comparison to the results of Bottia et al. (2015) at upper secondary school or Lim and Meer (2020) at lower secondary school, it is striking

[15]Increasing the share from one quarter to three quarters is the same as increasing the share from one standard deviation below the mean to one above as the mean share of female science teachers is about half and the standard deviation lose to a quarter (0.236).

that no effects on girls are found. For example, according to the results by Lim and Meer (2020), there is a 40 percent increase in girls' interest to major in STEM if 7^{th} grade teacher has been a woman instead of a man, while Bottia et al. (2015) find that a change of the share of female science and math teachers from one standard deviation below mean to one above increases the likelihood of girls to graduate with a STEM degree by 19 percent.

Figure 2 – Effect of share of female STEM teachers on girls and boys on choice of math-related study path.



Notes: All specifications include family fixed effects, sibling order, year of birth, share of qualified STEM teachers and average school level GPA as controls. Robust standard errors are clustered at school level. Vertical lines show 95% confidence intervals for each point estimate. The point estimates are shown in Table A.3. The effect in % shows how much each outcome is affected by an increase of one standard deviation in share of female science teachers relative to the mean outcome.

6.1 Heterogeneity

Carrell et al. (2010) and Bottia et al. (2015) find the greatest effects of female role models for female students who performed particularly well in mathematics. As explained in Section 2, this result could be caused by female students having a low level of confidence in their skills in mathematics despite performing well. If same gender teacher role models matter for enhancing confidence in STEM skills, we would expect especially those with the required levels of skill to be affected the most. Additionally, this group of female students is likely to be the most suitable to pursue a degree in a math-intensive field as they already perform well in the subject.

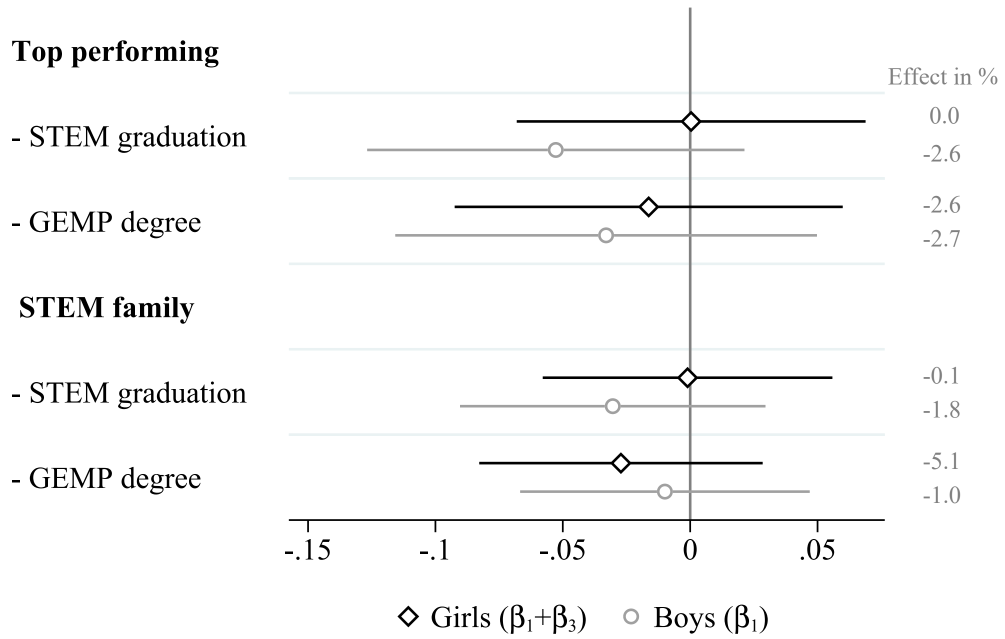
I define the top-performing students as those who belong to the top 25^{th} percentile with respect to the national mathematics exam in 9^{th} grade, and study this group of students separately. As the national exam data starts from the year 2004, there are a couple of cohorts who we cannot include to this analysis. The effect of a change in the share of female science teacher are shown separately for girls and boys in the top panel of Figure 3 and in Column 1 in Table A.9. The point estimates indicate a stronger effect on boys but the estimates are statistically insignificant. In contrast to previous studies, I do not find the effect to be particularly greater for the high-achieving students. However, as expected, top-performing students are more likely to choose a STEM track. Interestingly, the gender gap is notably greater among top-performing students than among all students.

In the main analysis, we have focused estimating the effect of the share of female science teachers within families. We are however exposed to different types of families and the extent to which role models at school matter on choosing STEM could be affected whether you already are exposed to such role models at home. To investigate this further, I estimate the results separately for a sample of families where at least at least one parent has a university STEM degree[16] or where at least one older sibling has either finished a STEM-track at upper secondary school or pursued a GEMP degree at university. On the

[16] Here I include degrees of at least three years in the following fields: science, mathematics, information and communication technology, engineering.

one hand we could imaging that having STEM role models at home would decrease the extent to which teachers have an effect as one is already exposed to such environment at home but on the other, it could be that one needs to be exposed to more role models in different environments before we could expect to see an effect from teachers. The effect on boys and girls within these samples are shown in the last two panels of Figure 3 and in Table A.9. While the point estimate for graduating from a STEM-track is negative only for boys, the point estimates for the long-term outcome are negative for both boys and girls. However, the estimates are small and statistically insignificant.

Figure 3 – Effect of share of female STEM teachers on girls and boys on choice of math-related study path for heterogeneity analysis.



Notes: All specifications include family fixed effects, sibling order, year of birth, share of qualified STEM teachers and average school level GPA as controls. Robust standard errors are clustered at school level. Vertical lines show 95% confidence intervals for each point estimate. Top performing includes individuals in the top 25th percentile of national math examination. STEM family includes those with at least one parent with a science degree or an older sibling who has completed STEM-track at upper secondary school or GEMP degree at university. The point estimates are shown in Table A.9.

6.2 Extrapolation of the results and the importance of family fixed effects

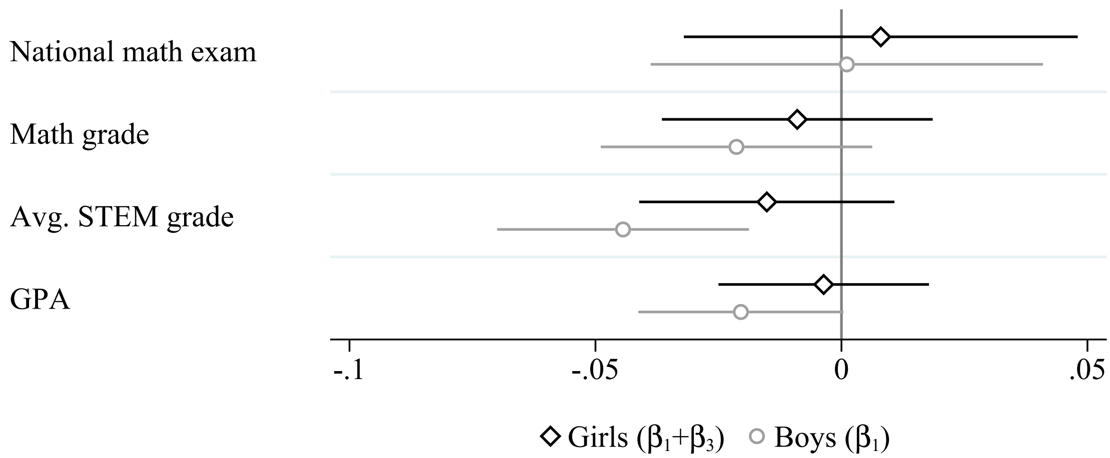
Different specifications (without sibling fixed effects and with school fixed effects instead) in different samples (full population and only those with siblings) are run for the same set of outcome variables as shown in Figure 2. The results with the full population are conducted to see whether it is possible to extrapolate the results in the sibling sample, where large families are overrepresented, to the whole population. Without controlling for school or family fixed effects, the results are very similar for the two different samples: the sample with siblings (Table A.5) and the sample where also children without siblings are included (Table A.4). When school fixed effects are applied, the same observation holds: the results of school fixed effects are almost exactly the same irrespective which sample is used (Tables A.6 and A.7). These similarities with the results on the two samples reassure that the results on the sibling sample, i.e. the sample used in the main analysis, are representative for the full population.

Further it is interesting to compare the results with the school fixed effects for the sample used in the main analysis, i.e. the sample with siblings. While the results are qualitatively very similar (Table A.7), the results with school fixed effects show slightly stronger negative effect on boys and weaker effects on girls. These differences between the two specifications indicate that even the environment at home matters for netting out the effect of the teachers at school, which is done in the main results by family fixed effects. Role model effects in the home environment are also netted out in papers where individual fixed effects could be used (e.g. Dee 2007, Hoffmann and Oreopoulos 2009, Lim and Meer 2020).

6.3 Alternative mechanisms

Female science teachers may affect same-gender students not only by acting as role models but also by affecting their grades. The effect on grades could be due to favoritism or due to affecting actual learning outcomes. If grades are affected, the found effect would be a combination of an effect on available options, as grades affect further possibilities for education, and effect on preferences via the role model effect. I run the main specification (Equation 1) on several relevant measures of achievement: the grade in the national mathematics exam, the final grade in mathematics, the final average grade in STEM subjects and the grade point average. All of the outcomes are standardized to have a mean zero and standard deviation of one by school year to achieve a comparable measure of performance across years. The results are shown in Figure 4 and in Table A.10.

Figure 4 – Effect of share of female STEM teachers on girls and boys on achievement.



Notes: All specifications include family fixed effects, sibling order, year of birth, share of qualified STEM teachers and average school level GPA as controls. Robust standard errors are clustered at school level. Vertical lines show 95% confidence intervals for each point estimate. The point estimates are shown in Table A.10.

While there are no effects on the national exam and final grade in mathematics, I find the average grade in STEM subjects to be negatively affected by higher share of female STEM teachers and this in turn has an effect on the final GPA. The negative effect on boys is stronger than that on girls and is statistically significant only for boys. However, even the effect on boys is minor; an increase of a standard deviation in the share of female science teachers decreases 1.0 percent of a standard deviation the STEM grade. Similar change in the treatment decreases the GPA by 0.5 percent of a standard deviation for boys. These effects on boys could explain at least partly the modest negative effect on choice of math-related field of study. Hence, the slight negative effect on boys' choice of STEM is most likely a combined effect of having less same-gender role models at school and that these teachers also affect the performance of boys. Multiple earlier studies have also found a negative effect, albeit small, on boys when thought by female teachers (Carrell et al. 2010, Dee 2007, Griffith 2014, Hoffmann and Oreopoulos 2009, Lim and Meer 2020).

I further investigate whether the effect differs in schools with fewer science teachers. I define schools with four or less science teachers as schools with low number of science teachers; schools with four or less science teachers belong to the bottom quarter in number of science teachers among all the schools in the data. Column 2 in Table A.14 shows the results for the outcome of graduating from a STEM-track in upper secondary school. For ease of comparison, Column 1 depicts the estimates for the main specification. The effect on boys and girls is qualitatively same as in the main specification but the effect size is notably smaller for boys and statistically insignificant. The smaller point estimate is likely an effect of the fact that schools with smaller number of science teachers are also schools which are located in more rural areas and the set of available programs is smaller than in urban areas.

Another source of role models for different influence at school are teachers in social sciences subjects. This is a group of subjects that in Sweden include history, geography, religion and citizenship studies. We can think of teachers in these subjects as competing role models. If a higher share of female teachers in these subjects would negatively affect girls' likelihood to graduate from a STEM-track we could interpret the effect as a competing role model effect. In Column 3 of Table A.14 we can see that the share of female social science teachers has no effect on the likelihood of graduating from a STEM-track.

7 Conclusions

In this study, I investigate whether the gender composition of science teachers at school affects the likelihood of students applying to and graduating from a STEM track and later pursuing a degree in a math-intensive field. The effect of increasing the share of female science teachers on girls is of particular interest as girls have less role models in science than boys and they are less often choosing math-intensive study tracks despite performing as well as boys in science and mathematics during school time. Overall this paper contributes with evidence concerning the importance of role models at relatively early stage of schooling when no choices of educational path have yet been taken, whereas the previous literature has focused mainly on the higher levels of education.

I find no effect on girls' likelihood to choose math-related education path later on when exposed to higher share of female science teachers at lower secondary school. Nether do I find that their math or science grades are affected by such treatment. If anything the share of female science teachers slightly decreases the likelihood of boys choosing a STEM track at upper secondary school. This effect is entirely driven by the already gender balanced science track—there are no effects on the male-dominant technical track. I find no effects on pursuing a math-intensive degree at university. Besides a slight negative effect on the likelihood of boys choosing a STEM track at upper secondary school, I find that their average STEM grade is also modestly affected by having a higher share of female science teachers at lower secondary school. Hence, the slight effect on boys is a combination of the effect on grades and a lack of male science teachers at school. However, the effects found are very modest in comparison to the previous literature.

Given that the previous literature has found mixed evidence both when the role model effect has been measured with the gender composition of the teachers and when it has been measured as a direct contact with a teacher or a professor, it is important for further research to understand what determines these differences. Some of the recent literature has found strong effects even from a rather short interaction with a same-gender role model on the choice of science and math-intensive field of study. Thus, it would be important to better understand in what type of settings these type of interventions have an effect and how much the timing of an exposure to a role model matters. Given the highly segregated labor markets, not only is it interesting to understand these effect on female students choice of male-dominant fields but also whether in certain settings such interventions could even affect male students to choose female-dominant fields of study.

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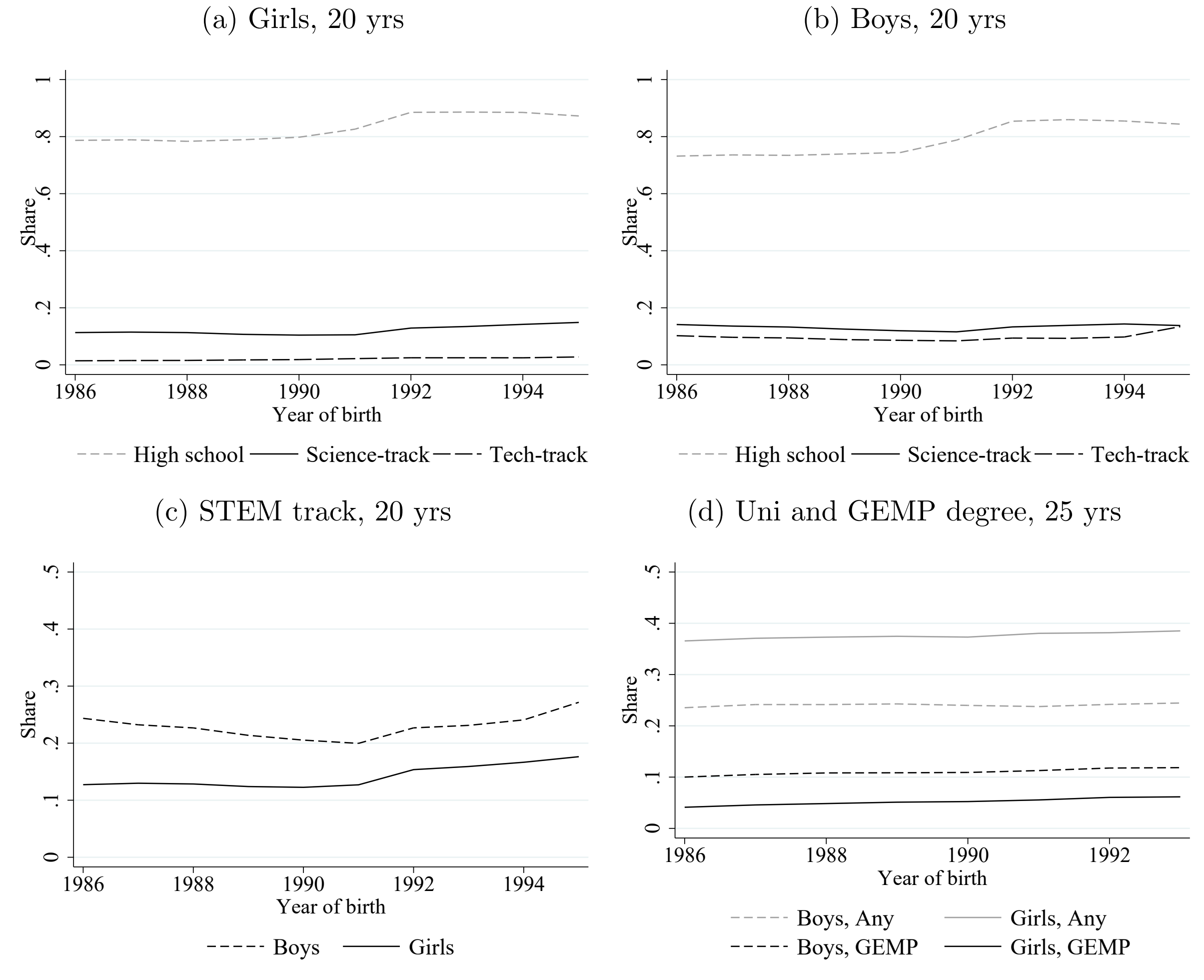
A Appendix

The development of outcome variables over time

Figure A.1 shows the development of the outcome variables for graduation from a STEM track at upper secondary school and for pursuing a degree in a GEMP field at university. In Figures A.1a and A.1b, we see that about 80 percent of each cohort has completed their upper secondary education by the year they turn 20. The share of girls and boys who graduate from the science track is fairly equal, but in contrast there are many more boys graduating from the technical track. This gender imbalance in the technical track accounts, to a large extent, for the gender difference in the STEM tracks (Figure A.1c). The reform of the early 2000s that separated the technical track from the science track is apparent in the figures. Additionally, the reforms of 2011 increased the share of students graduating from any upper secondary school program, which also affects the shares in both of the STEM tracks. Interestingly, even though the share of female STEM teachers has increased in lower secondary schools (Figure A.3), we do not see much of a change in the share of female students choosing STEM at upper secondary school over the research period. Additionally, I study the effect on pursuing a degree in a math-intensive field at the university level for those I am able to observe this outcome at the age of 25 (cohorts born between 1986 and 1993). In Figure A.1d we see that more women than men complete a 3-year university degree by the age of 25, but notably more men than women major in GEMP.

Figure A.1 – The share of 20 year old who have graduated from upper secondary school and those with a STEM track by gender, and the share of female and male students who have any university degree and specifically GEMP degree by the age of 25.



Notes: In 2011, the upper secondary school system went through a major change that, among other things, increased the difference between the vocational and the preparatory programs. In the 1990s, the technical program was a specialization option in the natural science program, but it was separated from the natural science program in the year 2000.

Sensitivity to different definitions of STEM fields

Across papers focusing on STEM fields, the definition of these fields differs. I follow Kahn and Ginther (2017), who define the specific group of more math-intensive fields as geosciences, engineering, economics, mathematics, computer sciences and physical sciences and call these subjects commonly as GEMP fields. However, to test the sensitivity of the results to the definition, I conduct the same specifications as in Table A.3 for GEMP fields (Column 7) with a couple of alternative definitions. These results are shown in Table A.1. To ease the comparison to the main results, the first column is the same as the Column 7 in Table A.3. In contrast to the GEMP fields of study, I include biology from the life sciences and exclude economics in Column 2, in Column 3 I exclude biology and in Column 4 I estimate the effect on medical degrees. Even with these different degree definitions, we do not find an effect on the likelihood on pursuing them.

Table A.1 – The probability of graduating with a math-related degree at university by different definitions.

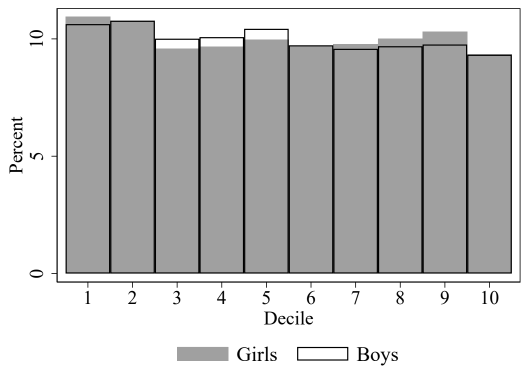
	Degree			
	(1) GEMP	(2) STEM	(3) STEM w/o bio	(4) Medical
Female STEM teachers	-0.001	-0.001	-0.001	0.000
	(0.004)	(0.004)	(0.004)	(0.001)
Girl	-0.059***	-0.056***	-0.059***	0.008***
	(0.003)	(0.003)	(0.003)	(0.001)
Girl × Female STEM teachers	-0.001	-0.001	-0.002	-0.001
	(0.005)	(0.005)	(0.005)	(0.002)
N	523,639	523,639	523,639	523,639
Mean outcome, girls	0.053	0.056	0.050	0.015
Mean outcome, boys	0.112	0.111	0.109	0.007

Notes: Estimates are conducted following the equation 1 explained in Section 4. All specifications include family fixed effects, sibling order, year of birth, share of qualified STEM teachers and average school level GPA as controls. Robust standard errors are clustered at school level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Figures

Figure A.2 – The share of boys and girls in each decile of the grade-distribution of 9th grade national mathematics exam and deciles of the GPA.

(a) National exam



(b) GPA

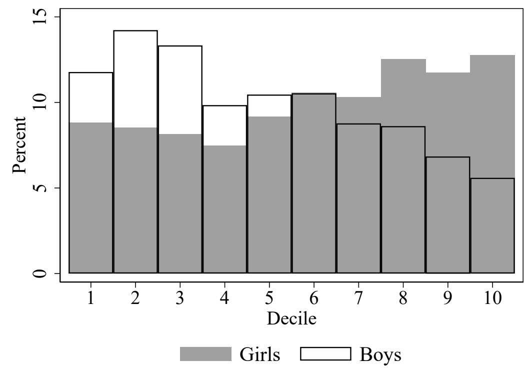
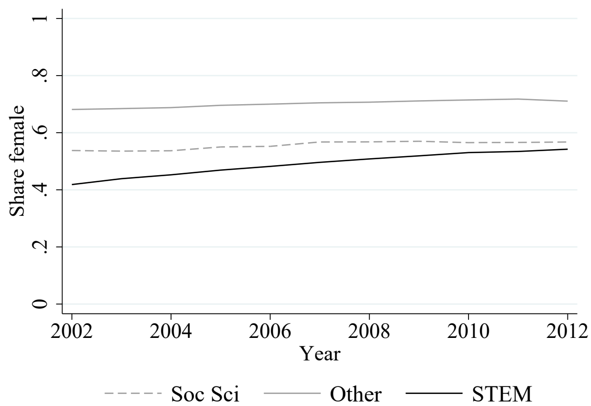


Figure A.3 – The share of female STEM and other teachers across years in lower secondary school.



Tables

Table A.2 – Balance test of school characteristics between siblings of different gender.

	Share female STEM	Share qualified STEM	Share female Soc.Sci.	# of students	Avg. GPA
	(1)	(2)	(3)	(4)	(5)
Girl	0.000	-0.002***	-0.000	0.111	0.009***
	(0.001)	(0.001)	(0.001)	(0.346)	(0.001)
N	711,276	711,276	695,069	711,276	711,276
Mean outcome, girls	0.487	0.476	0.554	317.529	0.057
Mean outcome, boys	0.486	0.478	0.555	317.949	0.047

Notes: In this table different school characteristics are regressed on girl-dummy and same controls are used as in the main specification (see Equation 1). Robust standard errors are clustered at school level. All specifications include family fixed effects, sibling order and year of birth as controls. In Column 3 the number of observations is smaller as not every school has indicated social science teachers in the school registry. In Column 5 the number of observations is smaller due to a small number of schools not reporting the GPA annually. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.3 – Effect of the share of female science teachers on choice of math-related study path. Estimates of Figure 2.

	Application			Graduation			Degree
	(1) STEM	(2) Science	(3) Technical	(4) STEM	(5) Science	(6) Technical	(7) GEMP
Female STEM teachers	-0.013**	-0.010**	-0.003	-0.011**	-0.007*	-0.003	-0.001
	(0.006)	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)	(0.004)
Girl	-0.089***	-0.009***	-0.080***	-0.068***	-0.005**	-0.062***	-0.059***
	(0.004)	(0.003)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)
Girl × Female STEM teachers	0.016**	0.010*	0.006	0.012*	0.007	0.005	-0.002
	(0.007)	(0.006)	(0.006)	(0.006)	(0.005)	(0.005)	(0.005)
N	711,276	711,276	711,276	711,276	711,276	711,276	522,020
Mean outcome, girls	0.135	0.115	0.020	0.118	0.100	0.018	0.053
Mean outcome, boys	0.215	0.121	0.094	0.179	0.103	0.076	0.112

Notes: All specifications include family fixed effects, sibling order, year of birth, share of qualified STEM teachers and average school level GPA as controls. Robust standard errors are clustered at school level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.4 – Effect of the share of female science teachers on choice of math-related study path, for all children (with or without a sibling) and without including family fixed effects.

	Application			Graduation			Degree
	(1) STEM	(2) Science	(3) Technical	(4) STEM	(5) Science	(6) Technical	(7) GEMP
Female STEM teachers	-0.006	-0.001	-0.004	-0.007	-0.003	-0.004	0.003
	(0.005)	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)	(0.003)
Girl	-0.089***	-0.011***	-0.078***	-0.069***	-0.009***	-0.060***	-0.061***
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Girl × Female STEM teachers	0.012**	0.008**	0.004	0.010***	0.008***	0.002	0.005*
	(0.005)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
N	1,088,024	1,088,024	1,088,024	1,088,024	1,088,024	1,088,024	882,858
Mean outcome, girls	0.136	0.117	0.020	0.118	0.101	0.017	0.053
Mean outcome, boys	0.218	0.123	0.095	0.181	0.105	0.077	0.111

Notes: All specifications include sibling order, year of birth, share of qualified STEM teachers and average school level GPA as controls. Robust standard errors are clustered at school level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.5 – Effect of the share of female science teachers on choice of math-related study path, for children with a sibling and without including family fixed effects.

	Application			Graduation			Degree
	(1) STEM	(2) Science	(3) Technical	(4) STEM	(5) Science	(6) Technical	(7) GEMP
Female STEM teachers	-0.005	0.001	-0.006	-0.008	-0.002	-0.006	0.005
	(0.006)	(0.005)	(0.005)	(0.005)	(0.004)	(0.004)	(0.003)
Girl	-0.088***	-0.011***	-0.077***	-0.069***	-0.008***	-0.061***	-0.061***
	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
Girl × Female STEM teachers	0.013**	0.007*	0.005	0.012***	0.008**	0.004	0.003
	(0.005)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.003)
N	711,276	711,276	711,276	711,276	711,276	711,276	522,020
Mean outcome, girls	0.135	0.115	0.020	0.118	0.100	0.018	0.053
Mean outcome, boys	0.215	0.121	0.094	0.179	0.103	0.076	0.112

Notes: All specifications include sibling order, year of birth, share of qualified STEM teachers and average school level GPA as controls. Robust standard errors are clustered at school level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.6 – Effect of the share of female science teachers on choice of math-related study path, for all children (with or without a sibling) and with school fixed effects included.

	Application			Graduation			Degree
	(1) STEM	(2) Science	(3) Technical	(4) STEM	(5) Science	(6) Technical	(7) GEMP
Female STEM teachers	-0.015***	-0.015***	-0.000	-0.013***	-0.013***	-0.000	-0.007**
	(0.005)	(0.004)	(0.003)	(0.004)	(0.003)	(0.003)	(0.003)
Girl	-0.089***	-0.011***	-0.078***	-0.069***	-0.008***	-0.060***	-0.061***
	(0.003)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)
Girl × Female STEM teachers	0.012**	0.008**	0.003	0.010**	0.008**	0.002	0.004
	(0.005)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)
N	1,088,024	1,088,024	1,088,024	1,088,024	1,088,024	1,088,024	882,858
Mean outcome, girls	0.136	0.117	0.020	0.118	0.101	0.017	0.053
Mean outcome, boys	0.218	0.123	0.095	0.181	0.105	0.077	0.111

Notes: All specifications include school fixed effects, sibling order, year of birth, share of qualified STEM teachers and average school level GPA as controls. Robust standard errors are clustered at school level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.7 – Effect of the share of female science teachers on choice of math-related study path, for children with a sibling and with school fixed effects included.

	Application			Graduation			Degree
	(1) STEM	(2) Science	(3) Technical	(4) STEM	(5) Science	(6) Technical	(7) GEMP
Female STEM teachers	-0.015***	-0.015***	0.001	-0.014***	-0.014***	-0.001	-0.005
	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)	(0.003)	(0.003)
Girl	-0.088***	-0.010***	-0.077***	-0.068***	-0.007***	-0.061***	-0.061***
	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)
Girl × Female STEM teachers	0.012**	0.007*	0.005	0.011**	0.007**	0.004	0.003
	(0.005)	(0.004)	(0.004)	(0.005)	(0.004)	(0.004)	(0.003)
N	711,276	711,276	711,276	711,276	711,276	711,276	522,020
Mean outcome, girls	0.135	0.115	0.020	0.118	0.100	0.018	0.053
Mean outcome, boys	0.215	0.121	0.094	0.179	0.103	0.076	0.112

Notes: All specifications include school fixed effects, sibling order, year of birth, share of qualified STEM teachers and average school level GPA as controls. Robust standard errors are clustered at school level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.8 – Effect of the share of female science teachers as average over three years on choice of math-related study path, for children with a sibling and with family fixed effects included.

	Application			Graduation			Degree
	(1) STEM	(2) Science	(3) Technical	(4) STEM	(5) Science	(6) Technical	(7) GEMP
Female STEM teachers	-0.009	-0.010	0.001	-0.014*	-0.012*	-0.002	0.002
	(0.009)	(0.007)	(0.007)	(0.008)	(0.007)	(0.006)	(0.009)
Girl	-0.087***	-0.007*	-0.080***	-0.067***	-0.004	-0.063***	-0.059***
	(0.006)	(0.004)	(0.005)	(0.005)	(0.004)	(0.004)	(0.005)
Girl × Female STEM teachers	0.019*	0.010	0.009	0.015	0.008	0.007	-0.003
	(0.010)	(0.008)	(0.008)	(0.009)	(0.007)	(0.007)	(0.009)
N	579,204	579,204	579,204	579,204	579,204	579,204	400,394
Mean outcome, girls	0.133	0.113	0.021	0.119	0.100	0.019	0.054
Mean outcome, boys	0.210	0.117	0.093	0.178	0.101	0.077	0.113

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Notes: All specifications include family fixed effects, sibling order, year of birth, share of qualified STEM teachers and average school level GPA as controls. Robust standard errors are clustered at school level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

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Table A.9 – Effect of share of female STEM teachers on girls and boys on choice of math-related study path for heterogeneity analysis. Estimates of Figure 3

	Top 25		Family STEM	
	(1) STEM	(2) GEMP	(3) STEM	(4) GEMP
Female STEM teachers	-0.046	-0.033	-0.031	-0.010
	(0.036)	(0.042)	(0.026)	(0.029)
Girl	-0.148***	-0.166***	-0.118***	-0.108***
	(0.022)	(0.025)	(0.017)	(0.019)
Girl × Female STEM teachers	0.042	0.017	0.021	-0.017
	(0.040)	(0.046)	(0.030)	(0.034)
N	147,010	103,539	121,705	84,228
Mean outcome, girls	0.322	0.146	0.257	0.126
Mean outcome, boys	0.456	0.290	0.362	0.234

Notes: All specifications include family fixed effects, sibling order, year of birth, share of qualified STEM teachers and average school level GPA as controls. Robust standard errors are clustered at school level. Top 25 pct includes individuals in the top 25^{th} percentile, parent (STEM uni) those with at least one parent with a science degree and sibling (STEM/GEMP) those who have an older sibling who has completed STEM-track in upper secondary school or GEMP degree in university. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.10 – Effect of share of female STEM teachers on girls and boys on achievement. Estimates of Figure 4.

	(1) Exam	(2) Math grade	(3) STEM avg	(4) GPA
Female STEM teachers	0.001	-0.021	-0.044***	-0.020*
	(0.020)	(0.014)	(0.013)	(0.011)
Girl	-0.005	0.069***	0.164***	0.308***
	(0.011)	(0.008)	(0.008)	(0.007)
Girl × Female STEM teachers	0.007	0.012	0.029*	0.017
	(0.020)	(0.015)	(0.015)	(0.013)
N	561,284	704,813	704,813	704,813
Mean outcome, girls	0.021	0.064	0.120	0.236
Mean outcome, boys	0.016	-0.018	-0.069	-0.089

Notes: All specifications include family fixed effects, sibling order, year of birth, share of qualified STEM teachers and average school level GPA as controls. Robust standard errors are clustered at school level. All outcomes are standardized to have mean zero and standard deviation of one. Since the national examination is available only from year 2004 the number of cohorts included is lower than for the other outcomes. The number of observations for outcomes including grades (Columns 2–4) are lower than for the main outcomes due to some individuals not meeting the requirements for having a final GPA at the end of the 9$^{\text{th}}$ grade. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table A.11 – The correlation between application, acceptance and graduation from a STEM track at upper secondary school separately for girls and boys and for the two different tracks.

	Girls			Boys		
	Application	Acceptance	Graduation	Application	Acceptance	Graduation
			STEM, both tracks			
Application	1.0000			1.0000		
Acceptance	0.9906	1.0000		0.9880	1.0000	
Graduation	0.7958	0.7964	1.0000	0.7862	0.7881	1.0000
			Natural science track			
Application	1.0000			1.0000		
Acceptance	0.9912	1.0000		0.9926	1.0000	
Graduation	0.7927	0.7930	1.0000	0.8051	0.8048	1.0000
			Technical track			
Application	1.0000			1.0000		
Acceptance	0.9893	1.0000		0.9849	1.0000	
Graduation	0.8091	0.8107	1.0000	0.7725	0.7770	1.0000

Table A.12 – Variation in the share of female STEM teachers by maximum age difference between siblings in a family.

	Mean	SD	Min	Max	Observations
All					
Overall	0.486	0.236	0.000	1.000	N = 711276
Between		0.200	0.000	1.000	N = 320613
Within		0.126	-0.314	1.286	T-bar = 2.218
1-3 years					
Overall	0.490	0.234	0.000	1.000	N = 402565
Between		0.205	0.000	1.000	N = 196607
Within		0.113	-0.185	1.240	T-bar = 2.048
4-6 years					
Overall	0.482	0.236	0.000	1.000	N = 228290
Between		0.191	0.000	1.000	N = 93375
Within		0.139	-0.318	1.232	T-bar = 2.445
Over 6 years					
Overall	0.479	0.244	0.000	1.000	N = 66006
Between		0.183	0.000	1.000	N = 23177
Within		0.162	-0.321	1.279	T-bar = 2.848

Table A.13 – Variation in the share of female STEM teachers by number of STEM teachers at school.

	Mean	SD	Min	Max	Observations
Any					
Overall	0.486	0.236	0.000	1.000	N = 711276
Between		0.200	0.000	1.000	N = 320613
Within		0.126	-0.314	1.286	T-bar = 2.218
≤4 teachers					
Overall	0.490	0.318	0.000	1.000	N = 207344
Between		0.291	0.000	1.000	N = 129416
Within		0.137	-0.310	1.290	T-bar = 1.602
5–8 teachers					
Overall	0.487	0.207	0.000	1.000	N = 331552
Between		0.195	0.000	1.000	N = 205078
Within		0.080	-0.098	1.040	T-bar = 1.617
Over 8 teachers					
Overall	0.480	0.159	0.000	1.000	N = 172380
Between		0.154	0.000	1.000	N = 112786
Within		0.056	0.048	0.991	T-bar = 1.528

Table A.14 – Schools with fewer STEM teachers and Social Science teachers effect on STEM graduation.

	Graduation		
	(1) STEM	(2) STEM	(3) STEM
Female STEM teachers	-0.011**	-0.003	
	(0.005)	(0.010)	
Girl	-0.068***	-0.064***	-0.066***
	(0.004)	(0.007)	(0.003)
Girl × Female STEM teachers	0.012*	0.007	
	(0.006)	(0.011)	
Female Soc Sci teachers			-0.007
			(0.004)
Girl × Female Soc Sci teachers			0.007
			(0.005)
N	711,276	207,344	695,069
Mean outcome, girls	0.118	0.114	0.118
Mean outcome, boys	0.179	0.171	0.180

Notes: All specifications include family fixed effects, sibling order, year of birth, share of qualified STEM teachers and average school level GPA as controls. Robust standard errors are clustered at school level. First column shows the result of the main specification for ease of comparison, second column includes only schools with four or less STEM teachers and column three uses share of female social science teachers as explanatory variable. The number of observations is smaller in the third column as not all schools have a specific social science teacher indicated. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.