WORKING PAPER 2020:10

Do girls choose science when exposed to female science teachers?

Aino-Maija Aalto

IFAU
INSTITUTE FOR EVALUATION OF LABOUR MARKET AND EDUCATION POLICY

The Institute for Evaluation of Labour Market and Education Policy (IFAU) is a research institute under the Swedish Ministry of Employment, situated in Uppsala.

IFAU's objective is to promote, support and carry out scientific evaluations. The assignment includes: the effects of labour market and educational policies, studies of the functioning of the labour market and the labour market effects of social insurance policies. IFAU shall also disseminate its results so that they become accessible to different interested parties in Sweden and abroad.

Papers published in the Working Paper Series should, according to the IFAU policy, have been discussed at seminars held at IFAU and at least one other academic forum, and have been read by one external and one internal referee. They need not, however, have undergone the standard scrutiny for publication in a scientific journal. The purpose of the Working Paper Series is to provide a factual basis for public policy and the public policy discussion.

More information about IFAU and the institute's publications can be found on the website www.ifau.se

ISSN 1651-1166

Do girls choose science when exposed to female science teachers?[a]

Aino-Maija Aalto[b]

5th June, 2020

Abstract

Same-gender teachers may affect educational preferences by acting as role models for their students. I study the importance of the gender composition of teachers in mathematics and science in lower secondary schools on the likelihood of continuing on math-intensive tracks in the next levels of education. I use population wide register data from Sweden and control for family fixed effects to account for sorting into schools. According to my results, if the share of female science teachers is increased from none to all, there is, if at all, only a slight positive effect on the likelihood of girls completing a STEM track at upper secondary school, while the probability of completing a math-intensive degree at university increases by 26 percent. There is no positive impact on the performance of students by the higher share of female science teachers. As only the likelihood of choosing science is affected, these results suggest that the effects indeed arise because female teachers of these subjects serve as role models for female students. However, compared to earlier studies, the effects found are very modest.

Keywords: Role models, gender segregation, human capital, STEM
JEL-codes: J16, J24

[a] I would like to thank Helena Svaleryd, Oskar Nordström Skans, Jonas Vlachos, Stefan Eriksson, Erik Grönqvist, Caroline Hall, Helena Holmlund, Björn Öckert, Georg Graetz, Lucas Tilley and Cristina Bratu for very valuable comments and discussions with me on the topic. Thank you also to all the seminar participants at the Annual Meeting of the Finnish Economic Association, the Department of Economics at Uppsala University and the Swedish Institute for Social Research at Stockholm University. Financial support from the Wallander-Hedelius-Browaldh and Wallenberg Foundations are gratefully acknowledged.

[b] SOFI, Swedish Institute for Social Research, Stockholm University.
E-mail: aino-maija.aalto@sofi.su.se

Table of contents

1 Introduction

Despite the fact that achievement in written tests in mathematics does not differ between girls and boys (see e.g. Kahn and Ginther, 2017), boys are much more likely to pursue more math-intensive degrees. Since these degrees often lead to higher paying jobs, it is thus very likely that societies are losing an important potential in human capital in some of the most productive jobs (Joensen and Nielsen, 2016). A possible explanation for this occupational segregation is gender-specific role models. In this paper, I therefore examine the possible effects of having a greater share of female science and mathematics teachers in Swedish lower secondary schools on the likelihood of specifically girls choosing to continue in math-intensive fields of study. However, I also investigate the effect on boys and the change in the gender gap in these educational paths. We can assume that girls will be more affected by same-gender role models from these fields of study as there are fewer women in these fields and additionally, girls tend to be less self-confident than boys as regards their mathematical skills (Dahlbom et al., 2011, Correll, 2001).

Previous literature shows mixed evidence regarding the role model effect of a same-gender teacher on the likelihood of studying math-related fields. A prominent paper by Carrell et al. (2010) studies the effect of the share of female professors in introductory science and mathematics classes on the probability of continuing in a STEM[1] field among college students in the US Air Force. They find positive effects on continuation and graduation with a STEM degree among female students who perform best in mathematics and no effects on male students. 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 top performers. Similar to Carrell et al. (2010), they find no effects on male students. In contrast to these studies, Griffith (2014) finds no effects on opting for STEM among female students if the instructor is female 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.

Achievement in mathematics and science is a related outcome that has also been studied extensively. Having a female teacher in mathematics and sciences

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

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 mo effect on achievement (Antecol et al., 2015, Griffith, 2014, Winters et al., 2013, Ehrenberg et al., 1995, Hoffmann and Oreopoulos, 2009 and Holmlund and Sund, 2008). An exception is Dee (2007) who 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. Also, Carrell et al. (2010) find positive effects on female college students' test performance but negative effects on boys in introductory science and mathematics courses.

A large part of the literature has focused on the college level to study the effect of the same-gender role models on educational choices (e.g., Carrell et al., 2010, Price, 2010, Bettinger and Long, 2005, Canes and Rosen, 1995, Robst et al., 1998, Hoffmann and Oreopoulos, 2009, Griffith, 2014). When the effect of potential role models on educational choices is studied at a higher level of education, the sample consists of individuals who have already made earlier decisions about their educational path.[2] An exception in the literature is Bottia et al. (2015) who study the effect at the upper secondary school level. However, even at this stage, students have already chosen some of their courses potentially according to their expectations about future studies.

In comparison with the earlier literature, my focus is at a lower level of education. Lower secondary school (grades 7–9, at age 13–15) is the final stage of compulsory schooling in the Swedish education system. At this point in their education, all students are still exposed to the same national curriculum and have not yet made specific choices about a field of further studies. I study the effect of the share of female mathematics and science teachers at this school level on the probability of continuing in a math-intensive program at upper secondary school and pursuing a degree in such a field at university. Additionally, in order to control for an alternative mechanism, I study the effect on achievement as same-gender teachers might improve the performance of the students. Much of the earlier literature has focused on single educational institutes. Rather than focusing on one single educational institute, I make use of register data for the full population of Sweden for the cohorts 1982–1995. To control for the endogeneity of teacher sorting across schools, I use sibling fixed effects and compare the effects between girls and boys.

[2]For instance Card and Payne, 2017 show the importance of having taken certain courses at the end of upper secondary education on the likelihood of majoring in STEM at university.

This method controls also for time invariant role models in the home environment.

I find that increasing the share of female science and mathematics teachers from none to all in lower secondary schools increases the likelihood of girls completing a STEM track at upper secondary school only slightly, if at all, and graduating from a math-intensive field of study at university by 26 percent. While boys are negatively affected concerning the likelihood of applying to the STEM tracks at upper secondary school, this negative effect loses its significance and magnitude by the time of graduation for both levels of education. According to my results, increasing the share of female science teachers from none to all decreases the gender gap regarding graduating from a STEM track at upper secondary school by 18 percent and the gap in pursuing a math-intensive degree at university by 25 percent. In upper secondary schools, there are two relatively more math-intensive programs which I define as the STEM tracks: the natural science and technical tracks. The effect on graduating from a STEM track at upper secondary school is fully driven by the science track—I find no effects on the more male-dominant technical track. The effects on educational choices for girls do not appear to arise via effects on student performance. In line with most of the existing literature, I find no evidence that the share of female science teachers affects their performance differently than boys. Thus, I find evidence that the higher share of female science teachers does increase the probability that female students will continue on a math-intensive educational path through choice and not performance, which is consistent with a role model effect. However, in comparison with the previous literature, the effect of increasing the share of female teachers in science and mathematics is modest on the outcomes studied.

In Section 2, I discuss the conceptual framework related to the potential effect of role models and how 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 continue to describe the data used to study the research question of interest in Section 5. In Section 6, I show the main results and conduct some heterogeneity analyses as well as investigate the robustness of the results and try to shed light on potential alternative mechanisms behind the effects. Finally, in Section 7, I discuss the findings in comparison with earlier literature and conclude in Section 8.

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. Bussey and Bandura (1999) write that we identify with our gender and the stereotypes associated with it, via the role models and the incentives and disincentives we experience in our social environment when behave in a certain way, and that it is more likely that a boy gains a stronger belief in his mathematical abilities than a girl, given today's social environment. This assumption is supported by Dahlbom et al. (2011) and Correll (2001) who show that girls are less confident than boys in their mathematical skills in both Sweden and the US respectively. 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.

[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.

However, the earlier literature has found little evidence that a same-gender teacher matters for performance in mathematics related subjects (Antecol et al., 2015, Griffith, 2014, Winters et al., 2013, Ehrenberg et al., 1995, Hoffmann and Oreopoulos, 2009 and Holmlund and Sund, 2008). An additional concern might be gender-specific grade discrimination. Previous studies have found some evidence of female students getting better grades if a female teacher corrects their exams (Lindahl, 2016, Lavy, 2008). 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). Thus, 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 we see today in terms of 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.

In this paper, I use the share of female science and mathematics teachers at the school level as a proxy for female role models. 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. Almost all 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 most of the 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 for a particular type of school.[6] Different schools may thus have students with different socio-economic 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

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

[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.

choice of 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, while the vocational ones only give this 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.

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. To capture the effect of same-gender teachers, I study particularly how this share affects female students. Analyzing the effect of the share of female STEM teachers directly on the full sample of students without additional controls would probably suffer from omitted variable bias as neither teachers nor students are randomly distributed across different schools. Parents with certain characteristics tend to live in specific areas, and teachers might choose their employment location with respect to similar characteristics. Some of these characteristics might matter more for the location choice of female teachers than for male teachers and could also affect the likelihood of children choosing STEM later in life. I use family fixed effects to control for any family-specific unobservable that is correlated with the share of female STEM teachers at a school and that may also affect the likelihood of the students choosing STEM. The same explanatory variable, share of female teachers, has previously been used, for example, by Lindahl (2016) and Bottia et al. (2015).

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. By including a family fixed effect, 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. 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.

My identification strategy relies on the assumption that the average exposure to female STEM teachers is randomly allocated across children conditional on family fixed effects. In the main specification (Equation 1),

$$Y_{ij} = \alpha_i + \beta_1 ShareSTEM_i + \beta_2 girl_i + \beta_3 ShareSTEM_i * girl_i + \gamma_j + \mathbf{X_i} + \epsilon_{ij}, \quad (1)$$

my explanatory variables of interest are the share of female teachers in STEM subjects ($ShareSTEM_i$) 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 ($\mathbf{X_i}$). 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. In order to analyze the effect on the gender gap in STEM education, I divide β_3 by the difference in outcome between girls and boys. This effect in the gap is thus affected by the impact of the share of female science teachers both on boys and girls.

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. The variation in the share of STEM teachers is likely to be more important for identification as only 16 percent of siblings of different genders experience the same share of female STEM teachers.

To investigate the importance of adding family fixed effect to the model, I also run an OLS model 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.

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. In Section 6.2, I test whether this type of sorting matters by introducing different school characteristics interacted with student gender into the main regression specifications. However, the results remain essentially the same across specifications when the additional controls are included, which indicates that such sorting is not a concern in my study.

In terms of the interpretation of 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 am able to rule out the effect on performance by investigating the effect of the share of female science teachers on achievement.

5 Data

The population of the study includes all individuals born between 1982 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. I define siblings as those who have the same mother. The sample of siblings is constructed by using the Swedish Multi-Generational register where I am able to select the sample by birth year and identify the persons with the same mother. This data also includes information about the registered sex. The register includes all persons who have been registered in Sweden at some point since 1961 and were born in 1932 or later. This register, as well as the other registers 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 registers. In order to define the population of compulsory school graduates, I make use of the graduation register. This register also includes information about the grade point average and final grades for each subject. During the final year of compulsory school, students sit national exams in sciences, mathematics, Swedish and English. The results of these exams are collected in a separate register 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 register 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 register over all schools in Sweden. Additionally, I am able to link information about the teachers at these schools from the teacher register with the help of the school identifier that exists in both registers.

The choices of further education are observed from variety of registers. The applications register 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 as information on whether the student has been accepted to a specific study program. The upper secondary school graduation register 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 register 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 registers, partly those that have already been mentioned above (graduation registers from compulsory and upper secondary schools) and also other registers such as the study credit registers of universities, population registers as well as register 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 1,000,000 studentsfrom about 430,000 families. In the majority of the families (70 percent), all the siblings have attended the same school.[7]

5.1 Explanatory variable of interest

My explanatory variable of interest is the share of female STEM teachers at a school. The share of female STEM teachers and the share of the teachers of other subjects are taken from the teacher register. The share is defined the year the children graduate from their schools.[8]

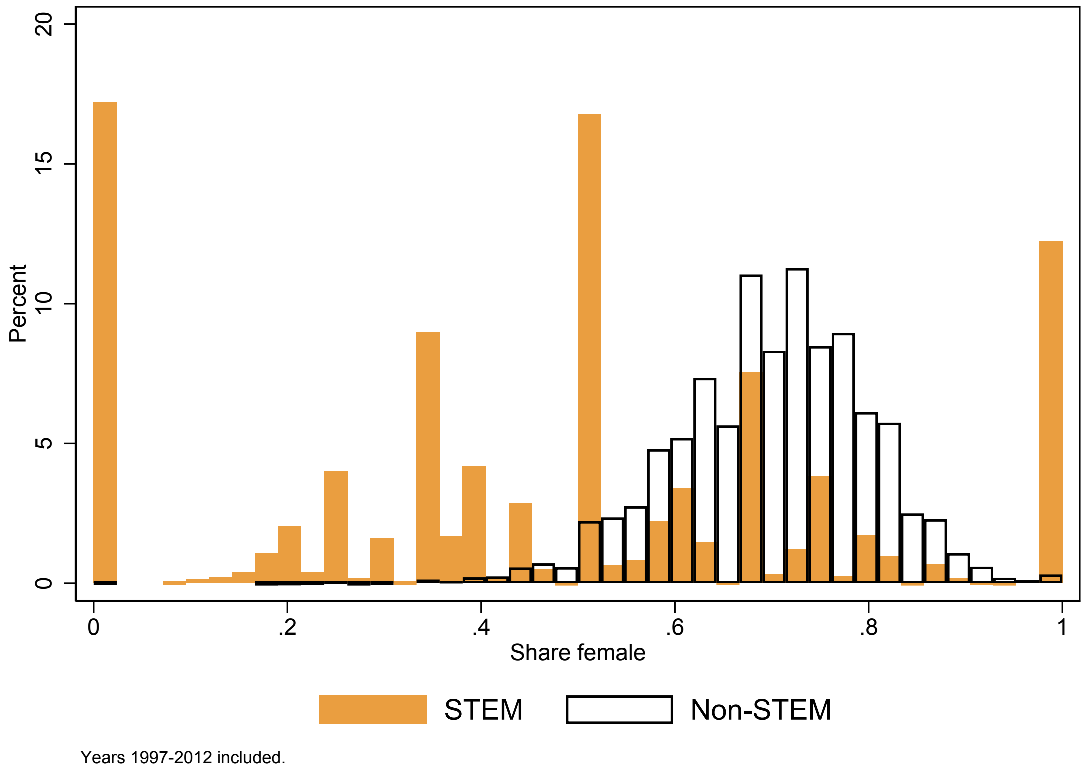
The STEM teachers are defined as those who teach sciences, technical studies and mathematics in grades 7–9. These teachers have a common subject identifier

[7] I have run the results also for the sub-sample of siblings who have attended the same school. The results are not sensitive to this restriction.

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

in the teacher register. In Figure 1, 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.[9] It is apparent from Figure 1 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.[10]

Figure 1: The share of female STEM and non-STEM teachers in lower secondary schools.



5.2 Outcomes studied

I wish to study the effect of same-gender teacher role models on further education and career 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

[9] I have also investigated the variation by age difference between siblings (Table A.8). The variation in the share of female teachers is somewhat greater in families with greater age differences.

[10] In Figure A.3, I also indicate separately the share of female teachers in social sciences. This group of teachers is relevant as they could act as competing role models to teachers in mathematics and science when students consider their options for higher education. We can see from the figure that the share of female teachers in social sciences has been relatively stable over the years.

math-intensive field at university. I categorize the science and technical tracks in upper secondary schools 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.[11] About 80 percent of each cohort has completed upper secondary school by the year they turn 20. 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).

I study the field of graduation in the year the students turn 28.[12] In line with Kahn 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 outcomes at university level. More women than men have completed a 3-year university degree by the age of 28, but notably more men than women major in GEMP (see Figure A.1d).

Additionally, I also 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 28 only for the sub-population of my sample who were born between 1982 and 1987.

In order to investigate an alternative mechanism, I also 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[13] 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).

[11] 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.

[12] The median graduation age is 28 for university degrees.

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

5.3 Descriptive statistics by sample

Table 1 shows descriptive statistics of the different samples used in the analysis. Column 1 includes all the children in the sample with or without a sibling and the 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 28. 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. 1982–1995 and 1982–1987 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 7 percent of the children have at least one parent with a STEM-degree from university. 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 other subjects 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 (means) of the different samples by year of birth and existence of sibling(s).

	≤ 1995, All	≤ 1995, Sib	≤ 1987, Sib
Family background			
# of siblings	2.03	2.45	2.12
Share parents, Uni degree	0.39	0.39	0.38
Share parents, STEM degree	0.07	0.07	0.06
School characteristics			
# of STEM teachers	5.86	5.98	5.00
Share female STEM teachers	0.46	0.46	0.41
# of Soc. Sci. teachers	4.16	4.22	3.65
Share female Soc. Sci. teachers	0.55	0.55	0.55
# non-STEM teachers	40.18	40.13	40.98
Share female non-STEM teachers	0.69	0.69	0.67
# of students	321.46	324.03	339.10
Outcome variables			
STEM track, application	0.18	0.18	0.19
-Natural Science	0.13	0.13	0.14
-Technical	0.05	0.05	0.04
STEM track, graduation	0.15	0.15	0.14
-Natural Science	0.11	0.11	0.11
-Technical	0.04	0.04	0.03
GEMP major, graduation			0.08
N	1,413,774	1,001,443	259,729

6 Results

Tables 2 and 4 display the main results across different specifications and samples. Table 2 shows the results for the outcomes at the upper secondary school level: the likelihood of applying to a STEM track and the likelihood of graduating from such a track.[14] Table 4 shows the results in a similar manner for the outcome for university graduation. In columns 1–2 and 5–6 in Table 2, I have included all the individuals from the relevant cohorts irrespective of whether they have a sibling or not. In these specifications, I do not control for family fixed effects, but as in all the specifications, I include sibling order and year of birth as controls. These results with the full population are conducted to see whether it is possible tp extrapolate the results in the sibling sample, where large families are overrepresented, to the whole population. In the third column for each outcome, I restrict the sample to those who have a sibling and, finally, in the last specification, I include family fixed effects as controls for the same sample.

[14] I have also run the regressions for the outcome of being accepted to a STEM track. The results are shown in Table A.4 and show qualitatively the same results as for the applications. This similarity in the results does not come as a surprise as most who apply to a STEM track are also accepted as is shown in Table A.7.

The estimates for the full population in columns 1 and 2 in Table 2 show very similar effects on the interaction term that indicates the difference in effect between girls and boys with respect to the changes in the share of female STEM teachers. However, we can also see that the direct effect on boys and girls changes between these specifications: the effect on boys turns negative, and statistically significant at the 95-percent level, when the school fixed effect is included, and the effect on girls diminishes greatly. The same pattern holds when the OLS specifications are compared to the specifications where sibling fixed effects are controlled for. The estimates for the sibling sample, without family fixed effects, are essentially the same as in the OLS specification with all the children. Given that the estimates in columns 1 and 3 are essentially the same, I conclude that the sibling sample is a good proxy for the whole population of students in lower secondary schools. The preferred specifications, where the family fixed effects are included, are shown in columns 4 and 8 in Table 2 for application and graduation respectively.[15] The estimates with the school fixed effects and sibling fixed effects are very similar for the outcome at the application level but differ notably at the graduation level. This change indicates that controlling for the family specific characteristics indeed captures relevant dimensions that school fixed effects do not account for. According to the estimates, girls are 0.6 percentage points more likely to apply to a STEM track at upper secondary school if the share of female STEM teachers is increased from none to all. However, boys are also affected; the likelihood of applying decreases among boys by 0.9 percentage points. Hence, in absolute terms boys are more affected at the application stage. Nonetheless, in terms of graduation from a STEM track, the effect on boys decreases in size and turns insignificant while on girls, the effect is an increase of 0.5 percentage points in the likelihood of graduating from a STEM track. However, when the effect on girls is tested for joined significance, we cannot rule out a zero effect at lower than 15 percent and 20 percent level for the effect on girls at the application and graduation stages respectively.[16] Thus, according to these results, the likelihood of girls opting for STEM at upper secondary school is if anything only slightly positively affected by having more female science teachers at lower secondary school. The point estimate indicates an increase of 4.3

[15] The gender gap in applications is greater than in graduations. This is due to the fact that girls are more likely to complete a STEM track conditional on applying than boys (see correlations in Table A.7).

[16] The joint significance is tested for the coefficients β_1 and β_3, where the null hypothesis is $\beta_1 + \beta_3 = 0$. At 95 percent confidence intervals, the estimate on application varies between -1.5 percent and 10.2 percent [-0.002, 0.014] relative to the mean for girls at the application stage and between -2.0 and 9.9 percent [-0.002, 0.0112] at the graduation stage.

percent in the likelihood of graduating from a STEM track for girls if the share of female teachers in these subjects is changed from none to all. As the effects go in opposite directions for boys and girls, the gender gap for graduation from a STEM track decreases by 17.5 percent with such an intervention.[17]

To investigate these findings further, I study the two STEM tracks in upper secondary schools separately in Table 3. The estimates for applications to the two separate tracks are shown in the first two columns and the last two show the results for graduation from these tracks. The slight positive effect on applying and graduating is entirely driven by the science track—no effect is found for the more male-dominant technical track.

[17] The change in the gender gap is calculated by dividing the coefficient of the interaction term (0.011) in Table 2 Column 8 by the difference in means between boys and girls (0.179-0.116=0.063).

Table 2: The probability of applying to or graduating from a STEM track at upper secondary school.

	Application				Graduation			
	(1) All	(2) Sch, FE	(3) Sib,OLS	(4) Sib,FE	(5) All	(6) Sch, FE	(7) Sib,OLS	(8) Sib,FE
Share STEM	0.002	-0.008**	0.004	-0.009**	0.001	-0.007**	0.002	-0.006
	(0.005)	(0.004)	(0.005)	(0.004)	(0.004)	(0.003)	(0.005)	(0.004)
Girl	-0.091***	-0.091***	-0.090***	-0.092***	-0.066***	-0.067***	-0.067***	-0.068***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.002)	(0.002)	(0.002)	(0.003)
Girl × Share STEM	0.010**	0.009**	0.011***	0.015***	0.006**	0.005*	0.008**	0.011**
	(0.004)	(0.004)	(0.004)	(0.006)	(0.003)	(0.003)	(0.004)	(0.005)
N	1,413,774	1,413,774	1,001,443	1,001,443	1,413,774	1,413,774	1,001,443	1,001,443
Mean outcome, girls	0.139	0.139	0.137	0.137	0.118	0.118	0.116	0.116
Mean outcome, boys	0.225	0.225	0.222	0.222	0.181	0.181	0.179	0.179

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

Notes: Robust standard errors clustered at school level. All specifications include sibling order and year of birth as controls.

Table 3: The probability of applying to or graduating from a STEM track, separately for science and technical tracks.

	Application		Graduation	
	(1) Science	(2) Technical	(3) Science	(4) Technical
Share STEM	-0.011***	0.001	-0.007**	0.001
	(0.004)	(0.003)	(0.003)	(0.003)
Girl	-0.019***	-0.073***	-0.012***	-0.056***
	(0.002)	(0.003)	(0.002)	(0.002)
Girl × Share STEM	0.017***	-0.002	0.012***	-0.001
	(0.004)	(0.004)	(0.004)	(0.004)
N	1,001,443	1,001,443	1,001,443	1,001,443
Mean outcome, girls	0.120	0.017	0.101	0.015
Mean outcome, boys	0.132	0.089	0.109	0.071

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

Notes: Robust standard errors clustered at school level. All specifications include family fixed effects, sibling order and year of birth as controls.

At university level, I find a positive effect among girls on pursuing a degree in a math-intensive field by the age of 28: according to the results in column 4 in Table 4, girls are 1.1 percentage points more likely to graduate with a GEMP degree if the share of science teachers is increased from none to all at lower secondary school. Compared to the mean, this entails an increase of 25.6 percent in the likelihood of girls gaining a math-intensive degree at university by the treatment. This result is only just statistically significant at the 5-percent level.[18] The effect on boys remains the same as for graduation from a STEM-track and is statistically insignificant. These effects lead to a decrease in the gender gap by 25.4 percent.[19] However, the estimates for the full population (Columns 1–2) differ greatly from those of the sibling-sample (Columns 3–4). A possible explanation is that the sample covers fewer cohorts and thus oversamples families with small age differences. Hence, extrapolating the results to the full population of students in lower secondary schools requires more of a leap of faith for the university level outcome.

[18] At the 95-percent confidence interval, the effect varies between 7.9 and 43.0 percent [0.003, 0.018] relative to the mean for girls.

[19] The same specifications are also run for two different definitions of STEM degrees: one where biology is included and economics not, and one where neither biology nor economics are included. These results are shown in Table A.1 and A.2. The results are essentially the same also in the two different definitions of mathematical fields of study. I have also run the regressions separately for the likelihood of obtaining a medical degree. I show the results for this outcome in Table A.3. I find no effect on the likelihood of pursuing a medical degree for either gender by increasing the share of female STEM teachers at lower secondary school.

Table 4: Probability to graduate with a GEMP degree by age 28.

	Degree			
	(1) All	(2) Sch,FE	(3) Sib,OLS	(4) Sib,FE
Share STEM	0.008**	0.002	-0.001	-0.006
	(0.003)	(0.003)	(0.004)	(0.004)
Girl	-0.079***	-0.079***	-0.073***	-0.071***
	(0.002)	(0.002)	(0.002)	(0.003)
Girl × Share STEM	0.002	0.001	0.016***	0.017***
	(0.003)	(0.003)	(0.004)	(0.006)
N	518,958	518,958	259,729	259,729
Mean outcome, girls	0.053	0.053	0.043	0.043
Mean outcome, boys	0.130	0.130	0.110	0.110

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

Notes: Robust standard errors clustered at school level. All specifications include sibling order and year of birth as controls.

6.1 Heterogeneity

Both 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 I explained in Section 3, 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$^{\text{th}}$ percentile with respect to the national mathematics exam in 9$^{\text{th}}$ grade, and study this group of students separately. As the national exam data starts from the year 2004, it is only possible to study the school-track choices at upper secondary school for this part of the analysis. The results are shown in Table 5. In contrast to previous studies, I do not find the point estimates to be greater for top-performing girls. However, as expected, top-performing students are on average more likely to choose a STEM track. Interestingly, the gender gap in applying and graduating is notably greater among top-performing students than among all students.

Table 5: Top 25th percentile of students in mathematics on the probability of applying to or graduating from a STEM track.

	(1) Application	(2) Graduation
Share STEM	-0.014	-0.042
	(0.043)	(0.043)
Girl	-0.154***	-0.150***
	(0.028)	(0.027)
Girl × Share STEM	0.027	0.045
	(0.049)	(0.048)
N	141,421	141,421
Mean outcome, girls	0.333	0.320
Mean outcome, boys	0.484	0.455

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

Notes: Robust standard errors clustered at school level. All specifications include family fixed effects, sibling order and year of birth as controls.

6.2 Alternative mechanism: effect on performance

It could be that female science and mathematics teachers affect achievement in mathematics and/or science and hence not only act as role models but improve the performance of female students. If achievement were affected, the effects would be a combination of the effect on options, in terms of grades, and preferences via the same-gender role models. The effect on achievement could be caused by different channels: teachers could have gender-specific ways of teaching that work best for the same-gender students or it could be that teachers favor students of same gender in their grading. In Table 6, I run the same specification as for the main results (Equation 1) on the outcomes of the national mathematics exam, the final mathematics grade, the final grades averages in STEM subjects and the grade point average.[20] All of the outcomes are standardized by school year to achieve a mean zero and standard deviation of one. There are certain differences in the effects depending on which outcome is used to measure the achievements. For all the other achievement outcomes, except for the national exam (Column 1), the point estimates indicate a negative effect on having more female STEM teachers. Given the negative point

[20] Here, I present the results by including only individuals for whom I may find all the relevant outcomes. This type of selection can over-represent those who do well at school as I condition on having final grades. In the Appendix, Table A.5, I show the results by the varying number of observations depending on the outcome variable. The effects remain essentially the same.

estimates on girls on most of the outcomes on achievement in STEM subjects, the previously found slight positive effect is not driven by an effect of female teachers on the grades. These findings support the interpretation of the effects found on choosing STEM as a role model effect.[21]

Table 6: Achievement in terms of the national mathematics exam, mathematics grade and average grade in STEM subjects and the GPA across all subjects at the end of compulsory school.

	(1) Exam	(2) Math grade	(3) STEM avg	(4) GPA
Share STEM	0.005	-0.007	-0.110**	-0.019
	(0.023)	(0.024)	(0.043)	(0.016)
Girl	-0.011	0.095***	0.157***	0.319***
	(0.013)	(0.015)	(0.013)	(0.010)
Girl × Share STEM	0.013	-0.006	-0.006	0.013
	(0.023)	(0.027)	(0.023)	(0.018)
N	548,584	548,584	548,584	548,584
Mean outcome, girls	0.085	0.039	0.169	0.364
Mean outcome, boys	0.099	-.043	0.017	0.048

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

Notes: Robust standard errors clustered at school level. All specifications include family fixed effects, sibling order and year of birth as controls.

6.3 Sorting to schools based on the gender of siblings

For an analysis of the possibility that families are sorting girls and boys differently based on school quality, I conduct robustness checks in Table 7 for the main results by interacting the gender dummy with different school-level characteristics, and I investigate whether the main effect is affected. I control for the share of STEM teachers at the schools with a teaching degree for the subject-specific area. The effect of the share of female STEM teachers remains essentially the same. For additional robustness, I control for the mean GPA at the school level in the last column of each outcome. The results also remain qualitatively the same. These results provide evidence that there is no sorting to different schools according to the gender of siblings that would correlate with the quality of the schools and would affect the exposure to different shares of female STEM teachers by gender.

[21] I have further run tests on competing role model stories by studying the effect of the share of female social science teachers. Unfortunately, there are only a limited number of schools where I am able to identify such teachers. The results (Table A.6) show no effect in these subjects indicating that same-gender role models in science have a particular importance for girls.

Table 7: Sensitivity analysis of the sorting of siblings of different genders to different types of schools by including school quality measures as controls.

	Application		Graduation		Degree	
	(1)	(2)	(3)	(4)	(5)	(6)
Share STEM	-0.009*	-0.008*	-0.006	-0.005	-0.004	-0.004
	(0.005)	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)
Girl	-0.093***	-0.130***	-0.067***	-0.102***	-0.075***	-0.085***
	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Girl × Share STEM	0.014**	0.016***	0.011**	0.011**	0.012**	0.015***
	(0.006)	(0.005)	(0.005)	(0.004)	(0.006)	(0.005)
Share Qualified	Yes	No	Yes	No	Yes	No
GPA	No	Yes	No	Yes	No	Yes
N	1,001,443	1,001,210	1,001,443	1,001,210	259,729	259,536
Mean outcome, girls	0.137	0.137	0.116	0.116	0.043	0.043
Mean outcome, boys	0.222	0.222	0.180	0.180	0.110	0.110

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

Notes: Robust standard errors clustered at school level. All specifications include family fixed effects, sibling order and year of birth as controls as well as the main effect of the variable that is interacted with the girl dummy. Columns (2), (4) and (6) include those individuals for whom I can observe the end of school GPA.

7 Discussion on the results relative to the earlier literature

In comparison with Bottia et al. (2015), who studied the effect of the share of female science and mathematics teachers at upper secondary school on the likelihood of girls applying to and graduating from math-intensive fields, my estimates are modest. I find that changing the share *from none to all* increases the likelihood only slightly, if at all, of completing a STEM track and by 26 percent regarding graduating from a math-intensive field of study. According to the results of Bottia et al. (2015), girls are 19.7 percent more likely to start and 35 percent more likely to graduate with a math-intensive major if the share of female mathematics and science teachers is increased from *one standard deviation* below the mean to one above. In contrast, Carrell et al. (2010) do not find an effect of the gender of the teacher in introductory courses at college level on the female students' probability of graduating with a STEM degree among all students but find the gender gap to be nearly closed among the highest performing students when the share of female professors in the introductory courses is changed from none to all. These two studies are very different methodologically: Bottia et al. (2015) control for a variety of individual controls to identify the effect of the share of female teachers in STEM at upper secondary school level on choosing STEM as major, whereas Carrell et al. (2010) study the direct linkage of the gender of the introductory STEM-course teacher on the probability of continuing with STEM in college and are able utilize a random allocation of teachers. However, both of the studies find the strongest effect among the high-performing female students. In contrast to these studies, I do not find the estimate to be greater for top-performing girls.

According to my results, there is a negative effect on boys applying to a STEM track if they have been exposed to more female science and mathematics teachers at lower secondary school. Additionally, I find that their average grade in all STEM decreases with a greater share of female teachers in these subjects. Neither Bottia et al. (2015) nor Carrell et al. (2010) find negative effects on boys with an increase in the female science-teacher exposure on choosing to continue in STEM. However, the negative effect on male students' performance of having a female STEM teacher has been found in some of the previous studies. For example, Carrell et al. (2010) found a negative effect on male students, above the positive effect on female students of having a greater share of first-year science and mathematics courses taught by female professors, on the subsequent STEM-course performance. Hoffmann and Oreopoulos (2009) found a negative effect on male students' probability of continuing a course if the instructor was female and found no effect on female students. Additionally, Price (2010) finds the effect of a greater share of courses taught by a female teacher during the first year of university leading to a decrease in the probability of male students continuing in the field and no effect on female students.

8 Conclusions

In this study, I investigate whether female science teachers at school increase the likelihood of female students applying to and graduating from a STEM track and later pursuing a degree in a math-intensive field. Overall this paper contributes with evidence concerning the importance of role models at an earlier stage when no choices of educational path have yet been made, whereas the earlier literature has focused mainly on the higher levels of education. In contrast to much of the previous literature, this study does not focus on a single educational institute but instead utilizes full cohorts of the Swedish population.

I find that if anything the share of female science teachers only slightly increases the likelihood of girls 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. At the university level, the share of female science teachers at lower secondary school seems to matter more. There is an increase of 26 percent regarding the likelihood of girls pursuing a math-intensive degree if the share of female science teachers is changed from none to all during their lower secondary education. These results translate into a decreased gender gap in STEM education by 18 percent and 25 percent at upper secondary school and university level respectively. However, the effects found are very modest in comparison to the previous literature. It is worth noting that part of the decrease in the gender gap is due to the fact that the effect on boys, even if statistically insignificant, is negative. I find support that the effects found are truly role-model effects as there are no positive effects on the performance of the students. The very modest effects of increasing the share of female science teachers from none to all indicates that training more female science teachers would not be a sufficient measure to take in the Swedish set up if you wish to increase the share of women in science. One potential reason why it is so difficult to increase the share of girls choosing a STEM education with such a measure is the fact that girls do on average well across different subjects when they also do well in mathematics and science.

The results lend support to the claim that same-gender role models matter even if the effects found are modest. Gaining a full understanding of the channels the role-model effect operates is an interesting question for future studies. The gender of a teacher correlates with a variety of dimensions that could affect the teaching style and the probability that same-gender students identify these teachers as their role models. The results of Carlana (2019) that female teachers have fewer stereotypical views about science being a masculine field than their male colleagues and that this bias in stereotypes affects the performance of students is an interesting step forward in understanding the different mechanisms behind the effects on how same-gender teachers may alter sorting into different fields of study.

References

Antecol, Heather, Ozkan Eren, and Serkan Ozbeklik (2015). “The Effect of Teacher Gender on Student Achievement in Primary School”. *Journal of Labor Economics* 33 (1), 63–89.

Bettinger, Eric P. and Bridget Terry Long (2005). “Do Faculty Serve as Role Models? The Impact of Instructor Gender on Female Students”. *American Economic Review* 95 (2), 152–157.

Bottia, Martha Cecilia, Elizabeth Stearns, Roslyn Arlin Mickelson, Stephanie Moller, and Lauren Valentino (2015). “Growing the roots of STEM majors: Female math and science high school faculty and the participation of students in STEM”. *Economics of Education Review* 45, 14–27.

Bussey, Kay and Albert Bandura (1999). “Social cognitive theory of gender development and differentiation.” *Psychological Review* 106 (4), 676–713.

Canes, Brandice J. and Harvey S. Rosen (1995). “Following in Her Footsteps? Faculty Gender Composition and Women’s Choices of College Majors”. *Industrial and Labor Relations Review* 48 (3), 486–504.

Card, David and A. Abigail Payne (2017). “High School Choices and the Gender Gap in STEM”. Working Paper 23769. National Bureau of Economic Research.

Carlana, Michela (2019). “Implicit Stereotypes: Evidence from Teachers’ Gender Bias”. *The Quarterly Journal of Economics* 134 (3), 1163–1224.

Carrell, Scott E., Marianne E. Page, and James E. West (2010). “Sex and Science: How Professor Gender Perpetuates the Gender Gap”. *The Quarterly Journal of Economics* 125 (3), 1101–1144.

Correll, J. Shelley (2001). “Gender and the Career Choice Process: The Role of Biased Self-Assessment”. *American Journal of Sociology* 106, 1691–1730.

Dahlbom, L., A. Jakobsson, N. Jakobsson, and A. Kotsadam (2011). “Gender and overconfidence: are girls really overconfident?” *Applied Economics Letters* 18 (4), 325–327.

Dee, Thomas S. (2007). “Teachers and the Gender Gaps in Student Achievement”. *The Journal of Human Resources* 42 (3), 528–554.

Ehrenberg, Ronald G., Daniel D. Goldhaber, and Dominic J. Brewer (1995). "Do Teachers' Race, Gender, and Ethnicity Matter? Evidence from the National Educational Longitudinal Study of 1988". *ILR Review* 48 (3), 547–561.

Griffith, Amanda L. (2014). "Faculty Gender in the College Classroom: Does It Matter for Achievement and Major Choice?" *Southern Economic Journal* 81 (1), 211–231.

Hinnerich, Björn Tyrefors, Erik Höglin, and Magnus Johannesson (2011). "Are boys discriminated in Swedish high schools?" *Economics of Education Review* 30 (4), 682–690.

Hoffmann, Florian and Philip Oreopoulos (2009). "A Professor like Me: The Influence of Instructor Gender on College Achievement". *The Journal of Human Resources* 44 (2), 479–494.

Holmlund, Helena and Krister Sund (2008). "Is the gender gap in school performance affected by the sex of the teacher?" *Labour Economics* 15 (1), 37–53.

Joensen, Juanna Schrøter and Helena Skyt Nielsen (2016). "Mathematics and Gender: Heterogeneity in Causes and Consequences". *The Economic Journal* 126 (593), 1129–1163.

Kahn, Shulamit and Donna Ginther (2017). "Women and STEM". *NBER Working Paper* No. 23525.

Lavy, Victor (2008). "Do gender stereotypes reduce girls' or boys' human capital outcomes? Evidence from a natural experiment". *Journal of Public Economics* 92 (10), 2083–2105.

Lindahl, Erica (2016). "Are teacher assessments biased? -evidence from Sweden AU". *Education Economics* 24 (2), 224–238.

Price, Joshua (2010). "The effect of instructor race and gender on student persistence in STEM fields". *Economics of Education Review* 29 (6), 901–910.

Riise, Julie, Barton Willage, and Alexander Willen (2019). "Can Female Doctors Cure the Gender STEMM Gap? Evidence from Randomly Assigned General Practitioners". *Discussion Paper, Institutt for samfunnsøkonomi, Department of Economics* SAM 18/2019.

Robst, John, Jack Keil, and Dean Russo (1998). "The effect of gender composition of faculty on student retention". *Economics of Education Review* 17 (4), 429–439.

Schleicher, Andreas (2019). “PISA 2018, Insights and Interpretations”. *Insights, OECD*.

Spencer, Steven J., Claude M. Steele, and Diane M. Quinn (1999). “Stereotype Threat and Women’s Math Performance”. *Journal of Experimental Social Psychology* 35 (1), 4–28.

Winters, Marcus A., Robert C. Haight, Thomas T. Swaim, and Katarzyna A. Pickering (2013). “The effect of same-gender teacher assignment on student achievement in the elementary and secondary grades: Evidence from panel data”. *Economics of Education Review* 34, 69–75.

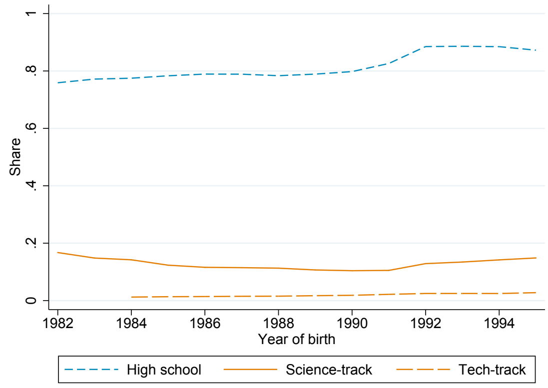
A Appendix

The development of outcome variables over time

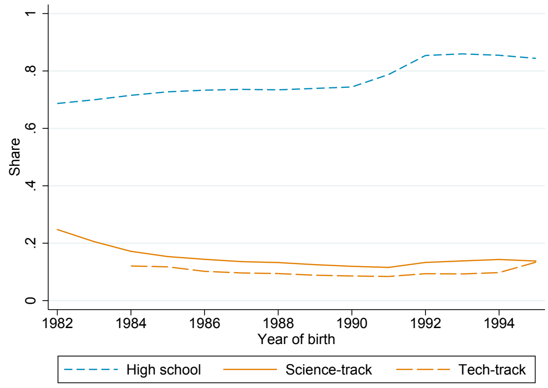
Figure A.1 shows the development of the outcome variables for graduation from a STEM track at upper secondary school and for pursuing a degree in a GEMP field at university. In Figures A.1a and A.1b, we see that about 80 percent of each cohort has completed their upper secondary education by the year 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 ab able to observe this outcome at the age of 28 (cohorts born between 1982 and 1987). In Figure A.1d we see that more women than men complete a 3-year university degree by the age of 28, but notably more men than women major in GEMP.

Figure A.1: The share of 20-year-olds 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 28.

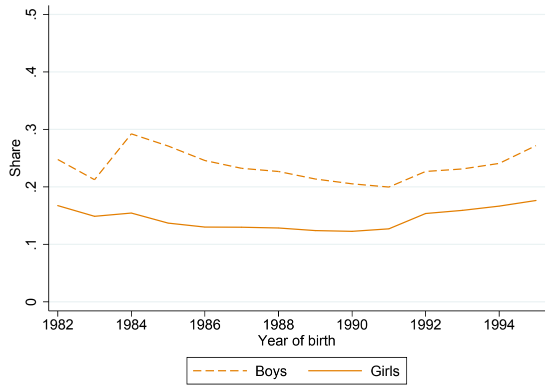
(a) Girls, 20 yrs



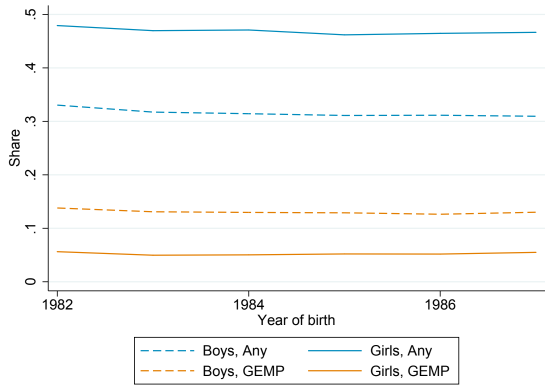
(b) Boys, 20 yrs



(c) STEM track, 20 yrs



(d) Uni and GEMP degree, 28 yrs



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 them differs. I follow Kahn and Ginther (2017), who define the specific group of more math-intensive fields to include geosciences, engineering, economics, mathematics, computer sciences and physical sciences as GEMP fields. However, to test the sensitivity of the results to the definition, I conduct the same specifications as in Table 4 with a couple of alternative definitions. In Table A.1, in comparison to the GEMP fields, I include biology from the life sciences and exclude economics. In Table A.2 I also exclude economics but do not take biology into account. Finally, in Table A.3, I investigate whether the probability of pursuing a medical degree is affected by the share of female science teachers at lower secondary school. I find the effect on the gender gap to be slightly lower when economics is excluded and biology included, the effect in column 3 in Table A.1 is a decrease of 19.4 percent in the gender gap when the share of female STEM teachers is increased from non to all. When biology is excluded from the definition, the effect is a 24.2 percent decrease in the gender gap (Table A.2). In Table A.3, we see that the share of female science teachers in lower secondary schools does not matter for the likelihood of pursuing a degree in medical studies (including medical studies to become a doctor, dentist or veterinarian).

Table A.1: The probability of graduating with a STEM degree by the age of 28.

	Degree		
	(1)	(2)	(3)
	All	Sib,OLS	Sib,FE
Share STEM	0.008**	-0.001	-0.004
	(0.003)	(0.004)	(0.005)
Girl	-0.072***	-0.066***	-0.064***
	(0.002)	(0.002)	(0.003)
Girl × Share STEM	0.000	0.012***	0.012**
	(0.003)	(0.004)	(0.006)
N	518,958	259,729	259,729
Mean outcome, girls	0.059	0.049	0.049
Mean outcome, boys	0.131	0.111	0.111

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

Notes: Robust standard errors clustered at school level. All specifications include sibling order and year of birth as controls.

Table A.2: The probability of graduating with a STEM degree without biology included by the age of 28.

	Degree		
	(1)	(2)	(3)
	All	Sib,OLS	Sib,FE
Share STEM	0.008**	-0.002	-0.005
	(0.003)	(0.004)	(0.004)
Girl	-0.079***	-0.073***	-0.071***
	(0.002)	(0.002)	(0.003)
Girl × Share STEM	0.002	0.015***	0.016***
	(0.003)	(0.004)	(0.005)
N	518,958	259,729	259,729
Mean outcome, girls	0.050	0.041	0.041
Mean outcome, boys	0.127	0.107	0.107

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

Notes: Robust standard errors clustered at school level. All specifications include sibling order and year of birth as controls.

Table A.3: The probability of graduating with a medical degree by the age of 28.

	Degree		
	(1)	(2)	(3)
	All	Sib,OLS	Sib,FE
Share STEM	0.002**	0.002**	-0.001
	(0.001)	(0.001)	(0.001)
Girl	0.009***	0.008***	0.008***
	(0.001)	(0.001)	(0.001)
Girl × Share STEM	0.002	0.001	0.001
	(0.001)	(0.002)	(0.002)
N	518,958	259,729	259,729
Mean outcome, girls	0.019	0.164	0.164
Mean outcome, boys	0.009	0.008	0.008

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

Notes: Robust standard errors clustered at school level. All specifications include sibling order and year of birth as controls.

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

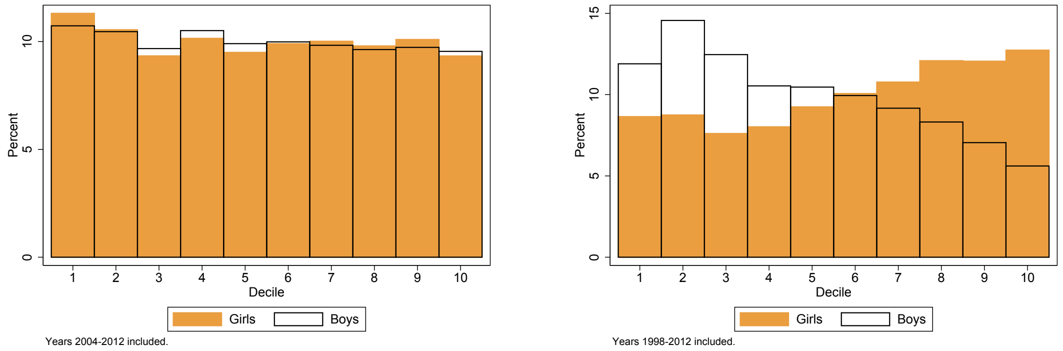
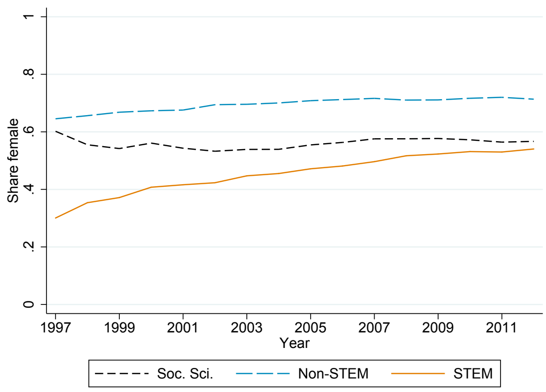


Figure A.3: The share of female STEM and non-STEM teachers across years in lower secondary school.



Tables

Table A.4: The probability of being accepted on a STEM track at upper secondary school.

	Accepted		
	(1)	(2)	(3)
	All	Sib,OLS	Sib,FE
Share STEM	0.002	0.004	-0.009**
	(0.005)	(0.005)	(0.004)
Girl	-0.090***	-0.089***	-0.091***
	(0.002)	(0.002)	(0.003)
Girl × Share STEM	0.010***	0.011***	0.015***
	(0.004)	(0.004)	(0.006)
N	1,413,774	1,001,443	1,001,443
Mean outcome, girls	0.138	0.136	0.136
Mean outcome, boys	0.223	0.220	0.220

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

Notes: Robust standard errors clustered at school level. All specifications include sibling order and year of birth as controls.

Table A.5: Achievement in terms of the national mathematics exam, mathematics grade and average grade in STEM subjects and the GPA across all subjects at the end of compulsory school.

	(1) Exam	(2) Math grade	(3) STEM avg	(4) GPA
Share STEM	0.001	-0.014	-0.111***	-0.015
	(0.022)	(0.021)	(0.037)	(0.010)
Girl	-0.009	0.092***	0.156***	0.322***
	(0.012)	(0.013)	(0.012)	(0.006)
Girl × Share STEM	0.017	-0.001	-0.001	0.005
	(0.022)	(0.023)	(0.021)	(0.011)
N	577,807	607,822	637,140	1,001,210
M Mean outcome, girls	0.005	0.045	0.094	0.195
Mean outcome, boys	0.013	-0.042	-0.065	-0.138

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

Notes: Robust standard errors clustered at school level. All specifications include family fixed effect, sibling order and year of birth as controls.

I have run a test on alternative role model effects by studying the effect of the share of female social science teachers at lower secondary school. Unfortunately, many schools do not have a teacher that would match the subject identifier for these teachers. This indicates that many of these classes are taught by teachers who mainly teach another subject. However, I have run the main specification (Equation 1) for the sample of students who attend a school where I am able to identify these teachers. I find no effect on the probability of either boys or girls on the main outcomes of interest (Table A.6).

Table A.6: Social science teachers as competing role models for the main outcomes of interest.

	Application	Graduation	Degree
	(1)	(2)	(3)
Share SS	0.000	-0.005	-0.004
	(0.004)	(0.004)	(0.005)
Girl	-0.083***	-0.064***	-0.063***
	(0.003)	(0.003)	(0.004)
Girl × Share SS	-0.005	0.001	0.004
	(0.005)	(0.004)	(0.006)
N	923,816	923,816	215,230
Mean outcome, girls	0.136	0.116	0.041
Mean outcome, boys	0.221	0.179	0.104

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

Notes: Robust standard errors clustered at school level. All specifications include family fixed effects, sibling order and year of birth as controls.

Table A.7: 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	0.9919	1.0000		0.9890	1.0000	
Graduation	0.7792	0.7799	1.0000	0.7662	0.7682	1.0000
			Natural science track			
Application	1.0000			1.0000		
Acceptance	0.9924	1.0000		0.9933	1.0000	
Graduation	0.7827	0.7833	1.0000	0.7855	0.7857	1.0000
			Technical track			
Application	1.0000			1.0000		
Acceptance	0.9895	1.0000		0.9853	1.0000	
Graduation	0.8008	0.8024	1.0000	0.7641	0.7684	1.0000

Table A.8: Variation in the share of female STEM teachers by maximum age difference between siblings in a family.

	Mean	SD	Min	Max	Observations
All					
Overall	0.463	0.260	0.000	1.000	N = 1001443
Between		0.212	0.000	1.000	N = 434795
Within		0.153	-0.365	1.278	T-bar = 2.303
Aged 1-3					
Overall	0.473	0.253	0.000	1.000	N = 469223
Between		0.218	0.000	1.000	N = 229295
Within		0.128	-0.202	1.223	T-bar = 2.046
Aged 4-6					
Overall	0.458	0.259	0.000	1.000	N = 316726
Between		0.205	0.000	1.000	N = 130023
Within		0.160	-0.342	1.208	T-bar = 2.436
Aged 6+					
Overall	0.449	0.275	0.000	1.000	N = 200666
Between		0.195	0.000	1.000	N = 68176
Within		0.196	-0.380	1.263	T-bar = 2.943