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Kaja Høiseth Brugård
Center for Economic Research at NTNU and Department of Economics,
Norwegian University of Science and Technology

Department of Economics

Norwegian University of Science and Technology
N-7491 Trondheim, Norway
www.svt.ntnu.no/iso/wp/wp.htm

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Kaja Høiseth Brugård
Center for Economic Research at NTNU
and
Department of Economics, Norwegian University of Science and Technology

Abstract
This paper studies effects of the proportion of girls in compulsory education on further education. I use detailed Norwegian register data to estimate the influence of the proportion of girls in the last grade of compulsory education on high school education and university attainment. A higher proportion of girls is found to increase the probability of graduating from high school. The result is robust to several model specifications. The analysis also indicates a positive effect on enrollment in higher education. Heterogeneity and non-linearity analyses indicate that gender peer effects are most important for students most likely to be on the margin of graduating from high school and enrolling in higher education, and when the share of female students is low.

JEL Classification; I2, I21
Keywords; Gender peer effects; high school graduation; higher education

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1. Introduction

Do your schoolmates affect your school performance? This question concerning peer effects has received increased attention in the economics of education literature over the last decade.[1] Evidence on whether gender peer effects exist is of great interest to both policy makers and scientists. By identifying factors that improve educational performance, one may be able to reduce, e.g., unemployment and crime. This could result in a large gain for society, both in terms of increased tax revenues and reduced resource use in the criminal justice system.

Theoretical models suggest that students are influenced by their peers. One example is Lazear (2001), who models classroom education as a public good, which is subject to congestion effects. These congestion effects can take place in the form of students with bad behaviour disrupting teaching. In turn, this creates negative externalities that harm other students.

The main empirical challenge when analyzing peer effects is endogenous selection. Having detailed Norwegian register data, I try to address this issue by using an exogenous characteristic, gender, as the peer variable. I follow the identification strategy presented by Hoxby (2000), and use variation in gender composition in a grade over adjacent cohorts within the same school as the peer variable. As argued by Hoxby (2000), this approach is less vulnerable to selection bias than traditional measures of achievement. More specifically, I examine the effect of the proportion of girls in the last grade of compulsory education on high school education and university attainment.

After compulsory education, Norwegian 16-year olds select themselves into different high schools. Clearly, this might imply selection issues with regard to the proportion of girls in high school grades. I address possible selection problems in numerous ways. First, I follow Hanushek et al., (2003) and Vigdor and Nechyba (2007) and use the proportion of girls in the last grade (10th grade) of compulsory education as the peer measure. This is assumed to be random over adjacent cohorts because public schools use specific neighborhood catchment areas. As a result, I exploit the fact that the peer measure is both lagged, since the outcome variables are measured after compulsory education, and only weakly correlated to the students' current peer group. Second, following Lavy and Schlosser (2011), the peer variable

[1] See, for example, the survey of the literature by Sacerdote (2011).

is measured at the grade level, and not at the classroom level, in order to avoid problems with within-school sorting. Third, I also instrument the proportion of girls at the school level with the proportion of girls in their municipality birth cohort, in order to account for possible sorting across municipalities and for possible sorting across schools within a municipality.

When estimating peer effects based on the proportion of girls in a grade, the question of sufficient variation is of great importance. Norwegian compulsory education consists of several small schools, which contribute to variation in the proportion of female students. However, in small schools, students of different ages could be put into one common class, so-called grade mixing. To account for potential grade mixing problems, I estimate model specifications where schools that are candidates for grade mixing are excluded.

The dataset contains the three cohorts who finished compulsory education in 2002, 2003 and 2004. An extensive set of socioeconomic characteristics are included in the empirical model, and I am able to follow the students for five years after the completion of compulsory education. By including compulsory school fixed effects, I can control for unobservable school quality and other school factors. I find a positive and significant peer effect on high school graduation and on enrollment in higher education. I also perform heterogeneity analyses related to gender, student background, and GPA level. These analyses indicate that the relationships between the gender peer measure and the educational variables are driven by individuals in the middle of the ability distribution.

The paper is organized as follows: Section 2 gives an overview of previous literature, while section 3 presents the relevant institutions. Section 4 discusses the identification strategy and summarizes the data. Section 5 presents the results, while section 6 includes some robustness analyses. Section 7 concludes.

2. Literature review

Due to the potential selection problems discussed above, some papers have based their analysis on what they claim to be randomly assigned peer groups. Sacerdote (2001) and Zimmerman (2003) use random assignment of roommates in different colleges to study how roommates affect student outcomes. Sacerdote (2001) finds that roommates affect freshman year GPA and the decision to join a fraternity or sorority. Zimmerman (2003) estimates some small negative effects on GPA for students with middle SAT verbal scores who are living with students with low SAT verbal scores.

Carrell et al. (2009) argues that a student's roommate is only a small part of that student's peer group. This indicates that the studies of Sacerdote, (2001) and Zimmerman, (2003) may underestimate the importance of the peer effects. Carell et al. (2009) analyze peer effects based on a sample where students are randomly assigned to groups of 30, at the United States Air Force Academy. The students have limited possibilities to interact with other students during their freshman year. They find that peer effects measured at the roommate or dorm floor level are much smaller than peer effects within groups of 30 students.

It is suggested in theoretical models that high ability students create positive spillover effects onto other students (e.g., Epple and Romano, 1998). Empirical research in this area includes Gould et al. (2009) and Lavy et al. (2012). These papers find negative effects of low ability students, measured by grade repeaters by Lavy et al. and immigrants by Gould et al., on non-grade repeaters and on native students´ school performance, respectively.

Many peer studies examine the effect on elementary school students´ test scores. Examples include Ammermueller and Pischke (2006), Angrist and Lang (2004), Hanushek et al. (2003), and Vigdor and Nechyba (2007). The results of these analyses are mixed. While the three former claim to have found peer effects, Vigdor and Nechyba (2007) reject that the correlation between student achievement and their peer characteristics can be subject to a causal interpretation.

An increasing literature focus on outcomes other than student test scores. Evans et al. (1992) look at teenage pregnancy and school dropout behaviour. When they treat their peer measure as an endogenous variable, they find no effect on either outcome. Bifulco et al. (2011) investigate the effects of percent minorities and percent with college-educated mothers in the cohort. They find that higher levels of parental education in the cohort decrease the likelihood of high school dropout and increase the likelihood of college attendance. A paper investigating peer effects using Norwegian data is Bonesrønning and Haraldsvik (2012). They find that increases in the proportion of classmates with less-educated parents decrease individual student achievement.

Identification of peer effects is not trivial (Manski, 1993) because of the potential two-way causality. As a result, Hoxby (2000) uses sources of variation that she argues are credibly idiosyncratic; the gender and race peers of the students, and she uses data from Texas elementary schools. In models that use changes in the gender composition of a grade in a school over adjacent cohorts, she finds that an increase in the proportion of females in the classroom leads to higher test scores in math for both males and females. This encourages studies of gender peer effects as an interesting topic. Another analysis concerning gender peer effects is Whitmore (2005), who uses data from the Tennessee STAR project. Her results indicate that girls have a positive spillover effect onto both boys' and other girls' test scores in early grades. By following Hoxby (2000), using the proportion of girls as the peer variable, I am able to obtain credible identification of one specific peer group characteristic.

Lavy and Schlosser (2011) also argue that the social interactions between genders play an important role in academic achievement. They study gender peer effects in Israeli primary, middle and high schools and find that an increase in the proportion of girls has a positive effect on academic achievement for both boys and girls. Using additional survey information, they are able to explore some potential mechanisms through which peer effects might work. Their analysis indicates that a higher proportion of girls in the classroom contributes to lower levels of classroom disruption and violence, improved inter-student and student-teacher relationships, and reduced teacher fatigue. Oosterbeek and van Ewijk's paper (2010) is a recent analysis that studies gender peer effects in higher education. They do not find substantial effects on student performance.

A recent paper by Black et al. (2013) uses Norwegian data to analyze peer influence on various long-term outcomes. They use several methods to estimate the effect of different peer measures, including gender composition in a grade. Their dataset consists of Norwegian cohorts born between 1959 and 1973, and the only peer measure for which they find any effect is the proportion of female students. The present paper deviates from Black et al. (2013) in several important ways. First, I focus on other educational outcomes such as completion of high school and enrollment in higher education. Second, by considering the cohorts born in

1986-1988, I investigate educational outcomes after a major reform that took place in the Norwegian high school system in 1994, and thus consider effects within a fairly sTable institutional setting. Third, I address the potential problem of grade mixing in Norwegian schools. Further, the focus on recent cohorts should be most informative for the peer group effects that are most relevant for the present school system.

Iversen (2013) is another analysis which examines gender peer effects in Norway. He looks at gender peer effects for elementary school students, and investigates whether principals use special education resources to compensate for negative peer effects. Iversen (2013) finds that in schools with special education, the effects of the proportion of boys on student achievement are small and insignificant, while in schools with no special education, the effects of the proportion of boys are significantly negative.

3. Institutions

Compulsory education in Norway consists of 9 years of schooling. Starting at age seven, children first attend six years of elementary school and then three years of junior high school.[2] The school system is relatively homogenous. Less than two percent of all students attend a private compulsory school.[3] Public schools assign students based on catchment areas, and are single-sex schools only to the extent that the catchment area includes only one gender in the relevant age group. In 1923, the Norwegian government passed a law saying that it would not financially support municipalities where schools did not offer the same opportunities to all students. Today, there exist relatively few private schools; to be entitled to public financial support, they have to follow the same laws as public schools, which require schools to be open for students of both genders. There is no reason to believe that one gender chooses to go to private schools to a greater extent than the other.[4]

Another favourable feature concerning the Norwegian school system is the classroom structure. Students are usually in the same classroom the whole day with the same peers, while teachers in junior high schools move from classroom to classroom with different

[2] Some students started school at age six, due to early implementation of a compulsory school reform increasing compulsory schooling by one year.
[3] Private compulsory schools are mainly religious schools or schools with an alternative pedagogical approach.
[4] In 2002, 47.7 percent of the students at private schools were boys, and 52.3 percent were girls. These numbers are sTable during the empirical period.

subjects. Everybody graduates from compulsory education at the end of 10th grade, and grade repetition is basically non-existent (Strøm, 2004). The students receive a diploma containing 13 grades in different subjects on a scale from one (lowest) to six (highest), set by teachers.[5] It is not possible to fail a subject. In addition, students are randomly selected to complete a final written exit exam in Norwegian language, English language or mathematics.

Municipalities are responsible for providing compulsory education. Compulsory schools are free of charge, and tracking of students by ability is not allowed according to the Norwegian Education Act, § 8-2. Students are allocated to elementary and junior high schools based on fixed neighborhood catchment areas. School enrollment strictly follows these catchment areas, which implies that parental school choice between schools for given residence is not allowed (Black et al., 2013; Leuven and Rønning, 2011). Norway is characterized by relatively little student mobility (Bonesrønning and Iversen, 2013). Casual evidence indicates that very few students switch schools during the three years of junior high school.

Very small schools were subject to a grade mixing rule until 2003. This rule stated that, if there were less than 18 students at a junior high school, the three grades (8th grade through 10th grade) could be taught in the same classroom. Likewise, when the combined enrollment of two adjacent cohorts did not exceed 24 students, the two grades could be taught in the same classroom (Norwegian Education Act, § 8-3). Thus, on one hand, including small schools offers more variation in the variable of interest, but, on the other hand, they introduce a measurement problem because of potential grade mixing. I address this issue below.

After finishing compulsory education, students may choose to leave school or continue with a non-compulsory high school education. Around 95 percent of each cohort chose the latter, and enrolled in high school at age 16. When starting high school, students could choose between 15 different study tracks in the empirical period. Students enroll in two broad categories of study tracks: Academic study tracks and vocational study tracks. An academic study track consists of three years of schooling and leads to a high school diploma, which is required for university enrollment. Vocational study tracks certify for work in a number of professions and

[5] This indicates that students are supposed to be of the same age at the end of compulsory education. However, there are some exceptions. It is possible to start one year ahead of the birth cohort and the student may postpone starting school for one year if not considered mature enough. This decision is made by the parents together with the school and psychologists.

include industrial design, health and social work, mechanics, and electrical trades. Some of these study tracks are heavily dominated by one gender. An example is the study track for health and social work, where over 90 percent of the students are females. The general academic study track is the largest track and includes about 45 percent of enrolled students.

Students have a legal right to enroll in one out of three individually ranked high school study tracks, a rule that is followed without exception by each county. Whether the students are enrolled in the first, second, or third preferred study track depends solely on their grade point average (GPA) from compulsory education. All students have a legal right to complete high school, but it has to be within a time frame of five years.[6] Thus, I follow the students for five years after compulsory education.

4. Identification strategy and the data

4.1 Identification strategy

There are two main challenges when trying to identify peer effects. Selection problems occur because parents and students sort themselves into neighborhoods and peer groups respectively. Vigdor and Nechyba (2007) argue that, if unobservable higher achieving students select themselves into higher achieving peer groups, the estimated results will include a positive selection bias. To deal with the possible selection bias, researchers have tried to apply natural experiments in their analysis. As the current data set consists of observational data, I use the identification strategy presented by Hoxby (2000). I investigate how variation in the proportion of girls in a grade, over adjacent cohorts within the same school, affects the chosen educational outcomes.

The Norwegian school system provides some desirable features for conducting such an analysis. First, because grade repetition is basically non-existent (Strøm, 2004), variation in the proportion of girls over adjacent cohorts is not affected by endogenous decisions on students repeating a grade. Second, only a small proportion of Norwegian students go to private schools and, as mentioned earlier, the average share of girls in private schools is similar to the average share in public schools. Thus, the possibility of opting out of public schools should not affect the gender distribution in public schools. Finally, since public

[6] There is an option for students to apply for a transfer to another study track or school.

schools use catchment areas, it is difficult for parents and school leaders to manipulate the proportion of girls in a grade. It also seems unlikely that the proportion of girls is a factor that influences the sorting choices of parents and students.

As pointed out above, the proportion of girls in a class will probably be highly correlated with the proportion of girls in a grade. Consequently, the proportion of girls in a grade should be representative for classroom gender composition. In addition, by using the grade level as the observational unit, I can prevent biased results due to possible student and teacher sorting within the grade. Another way of controlling for sorting and selection is through fixed effects strategies and school specific time trends. Vigdor and Nechyba (2007) are able to include both school and teacher fixed effects to control for sorting both into and within schools. Black et al. (2013), Lavy and Schlosser (2011) and Haraldsvik and Bonesrønning (2012) include school specific time trends in addition to school fixed effects. I include school fixed effects in the regression model, but not trends due to the fact that the dataset only consists of three cohorts.

Another issue is the reflection problem, as formulated by Manski (1993). There is simultaneity in the determination of peer effects, because it can be hard to separate the influence of the peer group on the student from the influence of the student on the peer group. Both Vigdor and Nechyba (2007) and Hanushek et al. (2003) use lagged peer outcome measures to circumvent the reflection problem. Carrell et al. (2009) criticize this approach by claiming that the peers in a student's current peer group were also likely to have been his/hers peers in the previous period. It is a high correlation in peer group across years.

This is not the case in the present data. Because students choose different high school study tracks after compulsory education, and enroll in different schools, the peer group in high school is only weakly correlated with the peer group from compulsory school. The correlation coefficient between the proportion of girls in compulsory school and in high school the next school year is only 0.05 in the data used in the analysis below. In addition, when using an exogenous characteristic like gender, the reflection problem is not relevant in the sense that the individual student cannot affect the gender of the peer group and the group cannot influence the gender of the individual. I will still use a lagged peer measure due to the fact that the gender distribution in compulsory education is exogenous, while high school admission is based on student selection. With the combination of using plausibly exogenous variation in gender and the lagged gender composition as a peer variable, I am able to address both the reflection problem and the selection problem.

4.2 Model specification

Using the three cohorts of students that completed compulsory education in the years 2002-2004, I estimate the effect of the proportion of females (P) on several different outcome variables (y) for student i finishing compulsory education in school s in cohort c. The peer variable is adjusted by excluding student i from his or her own peer group. The general regression is shown in equation (1).

$$(1)\quad y_{isc} = \alpha_s + \beta_1 P_{i-1,sc} + X_{isc}\beta_2 + u_{isc}$$

α_s is compulsory school fixed effects. X includes a set of socioeconomic characteristics described later.

One concern for identification is that the variation in the peer group measure may be too low to identify an effect. Especially in large schools, the proportion of girls will probably be close to 50 percent in most cohorts. Hence, the variation in the proportion of girls in the data may mainly reflect the variation in the proportion of girls in small schools. This could potentially reduce the external validity of the present results, since the Norwegian school system includes a relatively large share of small schools. In addition, small junior high schools can be subject to grade mixing. Thus, the variation may not originate from variation in the gender distribution in different grades, but instead from the grade mixing rule. Leuven and Rønning (2011) find that students in mixed grade classrooms benefit from sharing a classroom with more mature peers. To address these problems, I perform robustness checks by estimating the model on different subsamples. First, excluding all schools with less than 24 students in 10th grade ensures that no school in the sample has grade mixing. However, because the variation in cohort size is limited, in practice schools with more than 15 students in the final grade do not have grade mixing either. If the results do not change much when excluding these small schools, then it is not the variation across the very small schools combined with grade mixing that drives the results.

Even though the model includes a large set of control variables and school fixed effects, one still cannot rule out omitted variables as a source of bias. One possibility, although not a very plausible scenario, is that parents believe that their children benefit from attending a school with a high proportion of girls, and thereby sort themselves into such schools and school districts. I will use an instrumental variables approach to investigate this issue. While using the proportion of girls in the relevant cohort at the municipality level as an instrument accounts for potential endogenous mobility across schools within municipalities it does not account for endogenous sorting across municipalities.

Figlio and Fletcher (2012) investigate the relationship between the share of elderly in a community and the support for school spending. They argue that age distributions could be endogeneous with respect to school revenues and spending due to Tiebout sorting. Thus, they predict the age distribution that would have occurred in the absence of any mobility, and use this as an instrument for the actual age distributions. Other papers which use historical measures of age composition as instruments are Borge and Rattsø (2008), Ladd and Murray (2001) and Harris et al. (2001). Following this approach, I instrument the proportion of girls at the grade level with the proportion of girls born in the municipality 16 years earlier. It seems reasonable to assume that this variable is correlated with the proportion of girls at the grade levels at the specific schools, but uncorrelated with any observable factors that may also affect the chosen outcomes.

In addition, I investigate whether the peer effects are non-linear, and undertake heterogeneity analyses related to gender, parental education and GPA level. If the gender peer effects are non-linear, it will have implications for the optimal allocation of girls across schools and classes.

4.3 Data and descriptive statistics

The student data, including school identifiers for both the compulsory school from which the students graduated, and the high school in which they enrolled, is obtained from the National Educational Database of Statistics Norway. It consists of all students finishing compulsory education during the years 2002-2004. The student information is matched with information about their parents and socioeconomic characteristics. I restrict the sample to normal-aged individuals, i.e., those who turned 16 the year they finished compulsory education. Details on data reduction are shown in appendix Table A1. As can be seen from this Table, limiting the sample to normal-aged individuals reduces the sample by almost 5.8 percent. A total of 6.5 percent of the population is excluded from the regression sample. Full descriptive statistics are presented in Table 1.

Table 1 Descriptive statistics

	Mean	Standard deviation
Graduated from high school	0.688	0.463
Started an academic study track	0.456	
Started a vocational study track	0.509	
Higher education	0.358	
Proportion of girls	0.488	0.076
Girl	0.488	
First generation immigrant	0.038	
Second generation immigrant	0.021	
Both parents have compulsory education only	0.150	
At least one parent has a high school education	0.465	
At least one parent has a bachelor's degree	0.284	
At least one parent has a master's or doctoral degree	0.101	
Benefits due to disabilities or diseases	0.024	
Benefits due to private nursing or care	0.033	
Birth month	6.407	3.360
Parents married	0.603	
Parents divorced	0.126	
Parents never married	0.271	
Parental income in quartile 1	0.217	
Parental income in quartile 2	0.260	
Parental income in quartile 3	0.262	
Parental income in quartile 4	0.261	
Both parents employed	0.697	
Only mother employed	0.109	
Only father employed	0.135	
Birth year 1986	0.320	
Birth year 1987	0.327	
Birth year 1988	0.353	
Number of students at the compulsory school	88.39	44.95
Observations	162,669	

4.3.1 The educational outcomes

I estimate the effect of several different educational outcomes, which include high school graduation, probability of choosing an academic study track and enrollment in higher education. The graduation variable is a dummy variable equal to 1 if the student graduated from high school within five years after the completion of compulsory education. About 69 percent of the regression sample graduated from high school within five years. This indicates that there is a serious dropout problem in Norwegian high schools.

Following Black et al. (2013), I also look at the choice of high school study track. This includes one binary variable defining whether the student started an academic study track. Table 1 shows that 45.6 percent started an academic study track right after compulsory education, while 50.9 percent started a vocational study track. 3.5 percent did not start high school in the fall following the completion of compulsory education.

Finally, I examine university attainment. The outcome variable is a binary variable equal to 1 if the student is reported as being enrolled in higher education in the fall five years after the completion of compulsory education. Thus, there is a long time spell from the peer influence to the measurement of the outcome variable. Table 1 shows that 35.8 percent were enrolled in higher education five years after the completion of compulsory education.

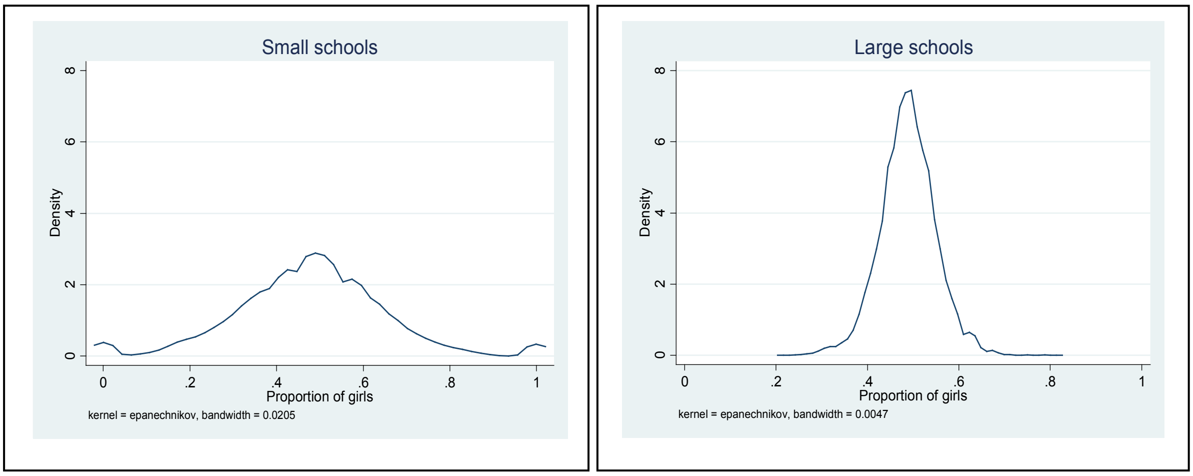
4.3.2 Control variables

I include a wide range of socioeconomic characteristics. These characteristics include students' gender, immigration status, birth month, and two health variables, and parents' education level, income level, employment status and marital status. In addition, I include the number of students at the compulsory school the student attended as a control for school factors. There are 3.8 percent first generation immigrants in the sample, and 2.1 percent second generation immigrants. Benefits due to disabilities or diseases before the age of 18 are received by 2.4 percent, while 3.3 percent have received benefits to support needs for private nursing or care. 15 percent of the students have parents who completed compulsory school only, while almost 40 percent have at least one parent with higher education (bachelor's degree or higher). At age 16, 60.3 percent of the individuals have married parents, 12.6 percent have divorced parents, and almost 70 percent have two employed parents. The students are pretty evenly distributed over the three cohorts.

4.3.3 The peer variable

The main independent variable is the peer measure. It is constructed as the proportion of girls at the grade level in the last grade of compulsory education (10th grade). I use the proportion of girls in a grade as opposed to in a class. This is partly due to restrictions in the data, but the specification does offer some positive features as well, as presented by Lavy and Schlosser (2011). The specific individual is removed when the peer measure is calculated, so as to represent the peer group accurately. Thus, the proportion of girls in the peer group will be slightly higher for boys than for girls. The mean proportion of girls is 48.8 percent for the whole sample. In small schools, which are schools with 24 students or less in the 10th grade, the mean proportion of girls is 47.9 percent (not shown in Table), and the standard deviation is higher, indicating more variation in the proportion of girls in small schools. This is illustrated in figure 1, which presents the variation in the proportion of girls in small and large schools separately. Large schools are defined as schools with more than 24 students in the 10th grade. There is clearly more variation in the proportion of girls in small schools.

Figure 1: Proportion of girls in small and large schools



Hoxby (2000) argues that variation in gender is credibly idiosyncratic. To investigate this in the present data, I estimate the peer measure against each control variable. This is presented in column (1) in appendix Table A2. Each row in column (1) represents a separate regression with the proportion of girls as the dependent variable. Regarding the dummy variable for gender, the correlation is negative due to the construction of the peer variable. When estimating the same regression with just the proportion of girls, without excluding the specific student, there is obviously a positive significant correlation between the gender variable and the peer variable. For the other variables included in the present analysis, the correlation with the proportion of girls at schools is not significant, with the exception of the dummy variables for first generation immigrant, health, and the birth year 1987.

In column (2) in appendix Table A2, all control variables are included in the same regression. The gender variable is still highly significant, and there is joint significance with an F-value of 20.38. When excluding the gender variable from the regression in column (3), the other variables are not jointly significant at conventional levels with an F-value of 1.24. This further supports the argument that gender variation is idiosyncratic.

5. Results

Table 2 presents results from OLS regressions using graduation from high school (panel A), enrollment in an academic study track (Panel B), and the probability of attending higher education (panel C) as outcome variables. Column (1) in panel A indicates that, when increasing the proportion of girls by 10 percentage points, the probability of completing high school within five years of compulsory education increases by 0.53 percentage points on average. This effect is 2.5 percent of a standard deviation of the graduation variable. The effect is significant at conventional levels. To put this in perspective, taken at face value, the estimate implies that having an all-female class, compared to an all-male class, would increase the probability of completing high school by about 5 percentage points. This effect is about the same as the matriculation outcome in Lavy and Schlosser (2011), for boys. However, they find twice the effect for girls.

Column (2) in Table 2 includes all of the socioeconomic characteristics. The gender peer effect is slightly reduced in magnitude, but still significant. As mentioned above, selection problems may bias the results if parents and students sort themselves into specific peer groups. In an attempt to control for this, I include compulsory school fixed effects in the regression. This further reduces the estimated coefficient. Increasing the proportion of girls by 10 percentage points increases the probability of completing high school by 0.36 percentage points. The effect is still statistically significant at the 5 percent level.

Table 2: OLS regressions

	(1)	(2)	(3)
Panel A. Dependent variable is graduation			
Proportion of girls	0.053**	0.044**	0.036**
	(0.026)	(0.020)	(0.015)
Panel B. Dependent variable is choosing an academic study track			
Proportion of girls	-0.007	-0.018	-0.022
	(0.031)	(0.023)	(0.018)
Panel C. Dependent variable enrolled in higher education			
Proportion of girls	0.049**	0.026	0.036**
	(0.023)	(0.017)	(0.016)
Socioeconomic characteristics	No	Yes	Yes
Compulsory school fixed effects	No	No	Yes
Observations	162,669	162,669	162,669

Note: Standard errors clustered at the cohort and compulsory school level are reported in parentheses; *, **, and *** denote significance at 10, 5, and 1 percent level, respectively.

Column (3) in panel B indicates that increasing the proportion of girls negatively affects the choice of an academic study track. However, the effect is small in magnitude and insignificant. This topic is also analyzed in Black et al. (2013). They find that a result of a higher proportion of girls is that boys are less likely to choose an academic study track. When looking at the effect of enrolling in an academic study track for each gender, I still find no significant results (not reported in Table). Hence, the findings of Black et al. (2013) are not replicated in these data. This could be due to the fact that the present study analyzes more recent data, in which very few individuals drop out after compulsory education.[7]

On the contrary, in panel C in Table 2, the probability of being enrolled in higher education is significantly increased with a higher proportion of girls in the compulsory school grade. Increasing the proportion of girls by 10 percentage points leads to a 0.36 percentage point increase in the probability of attending higher education five years after completing compulsory education.

The full regression results for the models in column (3) are presented in appendix Table A3. The Table indicates that the effects of the socioeconomic characteristics are as expected. Girls have a higher probability of graduating from high school and being enrolled in higher

[7] Excluding the individuals who did not start high school from the analysis does not change the results. I have also estimated a multinomial logit specification with three outcomes: started an academic study track, started a vocational study track and did not start high school in the fall following the completion of compulsory education. This analysis is performed without fixed effects, as this did not affect the results much in the OLS models. This analysis finds very similar results.

education. Married parents, parental employment and high parental education and income also contribute positively to both the completion of high school and enrollment in higher education.

6. Robustness analyses and heterogeneity

6.1 Robustness analyses

I then perform some robustness checks to address potential estimation problems. I focus on the outcome variables, which seem to be affected by the gender peer measure (high school graduation and university attainment). To address the problem concerning grade mixing, I exclude small schools that were candidates for grade mixing. All schools that had less than 24 students in the 10th grade are removed from the sample. Due to the construction of the grade mixing rule, by excluding these schools all possibilities of grade mixing are eliminated.[8] I also look at a specification where only the schools with less than 15 students in the 10th grade are excluded. These are the smallest schools and the most likely candidates for grade mixing.[9]

The results are presented in panel A (graduation from high school) and panel B (higher education) in Table 3. Column (1) in Table 3 is the same regressions as in column (3) of Table 2. In column (2), schools with fewer than 24 students in the 10th grade are excluded, reducing the sample to 150,349 observations. This leads to a decrease in the magnitude of the peer estimate for both outcomes, and only graduation from high school is significant at conventional levels. In column (3), only schools with less than 15 students are excluded. These regressions lead to similar results for the graduation outcome. The result for enrollment in higher education is very similar to the baseline result in column (1). The estimation indicates that small schools, whether or not they are subject to grade mixing, do not change the result qualitatively.[10]

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[8] I keep all three cohorts in these reduced sample regressions, even though the law of grade mixing was abolished before the 2003/2004 school year. Schools are typically organized in the same way for the 2004 cohort as well. I have performed regressions excluding the 2004 cohort (not reported). This does not affect the results much.

[9] The choice of cutoff at 15 students does not affect the results. Excluding schools with 16 to 23 students in the 10th grade all yield similar results.

[10] I also estimate a regression that includes only schools with between 15 and 30 students in the 10th grade. This represents the classroom level since, schools with this number of students probably only have one class of 10th graders. The result is qualitatively the same as before, but the estimates are imprecise, probably due to the small number of observations.

Table 3: Reduced samples without small schools

	(1)	(2)	(3)
	All schools	Only schools with at least 24 students in 10th grade	Only schools with at least 15 students in 10th grade
Panel A Graduation from high school			
Proportion of girls	0.036**	0.033*	0.032*
	(0.015)	(0.020)	(0.018)
Panel B Enrolled in higher education			
Proportion of girls	0.036**	0.030	0.035*
	(0.016)	(0.021)	(0.02)
Observations	162,669	150,349	156,396

Note: Standard errors clustered at the cohort and compulsory school level are reported in parentheses. The model specifications are similar to the model specification in column (3) in Table 2, except as indicated. *, **, and *** denote significance at 10, 5, and 1 percent level, respectively.

The proportion of girls can be subject to selection problems if parents actively sort themselves and their children into school catchment areas based on this measure. To address this issue, I instrument the proportion of girls at the compulsory school level with the proportion of girls in the municipality birth cohort. The reduced form regressions are reported in column (1) and column (2) of Table 4.

Table 4: The proportion of girls instrumented with the proportion of girls in the municipality birth cohort

	(1)	(2)	(3)	(4)	(5)
	Graduated reduced form	Higher education reduced form	First stage regression	Second stage Regression Graduated	Second stage Regression Higher education
Proportion of girls				0.032	0.177***
				(0.037)	(0.038)
Proportion of girls at the municipality level	0.020	0.110***	0.645***		
	(0.024)	(0.002)	(0.023)		
Observations	162,632	162,632	162,534	162,534	162,534
F value			775.31		

Note: Standard errors clustered at the cohort and compulsory school level are reported in parentheses. The model specifications are similar to the model specification in column (3) in Table 2, except as indicated. *, **, and *** denote significance at 10, 5, and 1 percent level, respectively.

The common first stage regression in column (3) indicates that the proportion of girls at the municipality level is a strong instrument, with a very high F-value of 775.31. The second stage regressions for high school graduation and higher education are presented in column (4) and column (5), respectively. The magnitude of the peer coefficient in column (4) is similar to that in the baseline regression in Table (2), but imprecise. However, for higher education, the coefficient is larger and highly significant.[11]

In Table 5, I examine non-linearities of the peer effects. The results are presented in panel A (graduation from high school) and panel B (enrollment in higher education). In column (1) and (2), I split the sample over and under the average of the proportion of girls. As the dataset only consists of three years, it is problematic to include fixed compulsory school effects in these regressions. When the proportion of girls is idiosyncratic, and, with only three years of observations, a lot of observations will drop out in fixed effects specifications. Column (3) in Table 2 indicates that fixed effects do not affect the results much. This should be the case concerning these regressions as well. In both panel A and B, there is a positive effect on the outcome variable for the proportion of girls below average and no effect for the proportion of girls above average.

The variation in the data limits the possible model specification. For example, a cubic functional form gives highly imprecise estimates. Thus, I only include a quadratic peer effects term. In column (3) of Table 4, the level gender peer effect is positive, but there is a negative quadratic effect. Using the specification in column (3) and looking at the graduation outcome, the gender peer effect is equal to 0 for a proportion of girls around 0.55, which is 0.82 standard deviations above the mean value. The effect is significantly positive below this proportion of girls, while the gender peer effects are significantly negative above this proportion of girls. The effect indicates the same pattern for enrollment in higher education. This is different from Lavy and Schlosser (2011) and Hoxby (2000), who find the highest impact on student performance when the proportion of girls is above 58 percent and 66 percent, respectively.

[11] The reduced form effect of the instrument in column (2) in Table 4 is surprisingly high. Thus, the instrument seems to have an independent effect on higher education. However, this is not the case for the graduation outcome. Even though the results for higher education differ from the baseline regressions in Table 2, it does not seem that OLS overestimate the effect.

Table 5: Non-linearites

	(1)	(2)	(3)
	Proportion of girls below average	Proportion of girls above average	All
Panel A Graduated from high school			
Peer	0.179***	-0.022	0.229***
	(0.041)	(0.037)	(0.077)
Peer squared	-	-	-0.199**
			(0.077)
Panel B Enrolled in higher education			
Peer	0.130***	-0.015	0.211***
	(0.035)	(0.035)	(0.070)
Peer squared	-	-	-0.180**
			(0.071)
Compulsory school fixed effects	No	No	Yes
Observations	81,060	82,609	162,669

Note: Standard errors clustered at the cohort and compulsory school level are reported in parentheses. The model specifications are similar to the model specification in column (3) in Table 2, except as indicated. *, **, and *** denote significance at 10, 5, and 1 percent level, respectively.

6.2 Heterogeneity analyses

To examine how the gender peer variable affects different sub-groups, I have performed several heterogeneity analyses. Following Lavy and Schlosser (2011), results for the two genders and various parental education levels are reported in Table 6, and different GPA levels in Table 7.

Regarding gender differences, girls seem to be positively affected by girl peers in terms of both outcome variables. Boys, however, do not seem to benefit from a higher proportion of girls. Regarding the probability of graduating from high school, students with both high and low parental education levels significantly benefit from increasing the proportion of girls. However, only students with highly educated parents have a higher probability of being enrolled in higher education five years after compulsory education.

Table 6: Heterogeneity effects for different genders and parental education levels

	(1)	(2)	(3)	(4)
	Boys	Girls	Low educated parents	High educated parents
Panel A: Graduated from high school				
Proportion of girls	0.018	0.054**	0.042**	0.040*
	(0.021)	(0.022)	(0.020)	(0.023)
Panel B: Enrolled in higher education				
Proportion of girls	0.015	0.044*	0.019	0.057**
	(0.020)	(0.024)	(0.018)	(0.028)
Observations	83,349	79,320	99,969	62,700

Note: Standard errors clustered at the cohort and compulsory school level are reported in parentheses. The model specifications are similar to the model specification in column (3) in Table 2, except as indicated. *, **, and *** denote significance at 10, 5, and 1 percent level, respectively.

In Table 7, students are split into four quartiles based on their GPA from compulsory education. When splitting the individuals based on their GPA, I find that the proportion of girls positively affects individuals with a GPA in quartile 2 in terms of high school graduation. Only those individuals with a GPA in quartile 3 are affected in terms of university attainment. A possible explanation could be that students in the upper part of the ability distribution are likely to graduate anyway, while students in the lower part of the ability distribution are highly likely to drop out, independent of the proportion of girls in the class. Thus, Table 7 suggests that gender peer effects are most important for students who are most likely to be on the margin of graduating and enrolling in higher education.

Table 7: Heterogeneity effects for different GPA levels

	(1)	(2)	(3)	(4)
	GPA in quartile 1	GPA in quartile 2	GPA in quartile 3	GPA in quartile 4
Panel A: Graduated from high school				
Proportion of girls	0.047	0.114***	0.031	0.012
	(0.032)	(0.036)	(0.027)	(0.018)
Panel B: Enrolled in higher education				
Proportion of girls	-0.004	0.033	0.097***	0.027
	(0.011)	(0.029)	(0.035)	(0.034)
Observations	42,547	38,053	42,134	37,068

Note: Standard errors clustered at the cohort and compulsory school level are reported in parentheses. The model specifications are similar to the model specification in column (3) in Table 2, except as indicated. *, **, and *** denote significance at 10, 5, and 1 percent level, respectively.

7. Conclusion

In this paper, I estimate gender peer effects on several educational outcomes. By using detailed Norwegian register data, I find that the proportion of girls in the last grade of compulsory education has a positive effect on the probability of graduating from high school and of being enrolled in higher education five years after the completion of compulsory education. By using an exogenous characteristic as the peer measure, which is based on strict school catchment areas, lagged, and only weakly correlated to the post-compulsory peer group, I am able to address two of the main empirical challenges in peer effect estimations. In addition, I perform several robustness checks. These analyses indicate that the proportion of girls is idiosyncratic, and that the estimated effects are robust to several model specifications.

The evidence provided in this paper suggests that girls are the main beneficiaries of a higher proportion of females in the classroom. The heterogeneity analyses also indicates that it is mainly students with an intermediate GPA who are affected by female peers. This indicates that most of the individuals with a high GPA (quartile 4) will graduate, while most of those with a low GPA (quartile 1) will not graduate, independently of the number of girl peers.

Unfortunately, the data available in this study cannot be used to formally distinguish between different mechanisms leading to the results. Numerous theoretical models try to explain how peer effects may influence individual outcomes.[12] One way that the proportion of girls could affect these outcomes is through positive spillover effects on academic achievement. Another theory, called the bad apple model, states that if one student makes a lot of noise and disrupts teaching, this could hurt other students. If boys are "bad apples" to a larger degree than girls, this is a possible mechanism for the positive gender peer effects. Lavy and Schlosser (2011) conduct a survey that supports this argument. Thus, investigation of possible mechanisms is left for future research.

[12] See Hoxby and Weingarth (2005) for an overview of the theoretical models.

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Appendix Tables

Appendix Table A1: Data reduction

	Observations	Percent of population
Total population. All students graduating from compulsory education in 2002-2004	174,067	100
Not 16 when finishing compulsory education	10,059	5.78
Missing birth month	234	0.13
Missing compulsory school identifier	1,044	0.60
Missing parents marital status	61	0.04
Fixed effects sample	162,669	93.45

Appendix Table A2: Proportion of girls as the dependent variable

	(1)	(2)	(3)
Girl	-0.0065***	-0.0065***	
	(0.0004)	(0.0004)	
First generation immigrants	-0.0011*	-0.0014**	-0.0013*
	(0.0006)	(0.0007)	(0.0007)
Second generation immigrants	0.00056	0.00010	0.00004
	(0.00080)	(0.00081)	(0.00081)
High school education	0.0002	0.0004	0.0004
	(0.0003)	(0.0005)	(0.0005)
Bachelor's degree	-0.0002	0.0003	0.0003
	(0.0003)	(0.0005)	(0.0005)
Master's or doctoral degree	0.0002	0.0007	0.0008
	(0.0003)	(0.0005)	(0.0005)
Benefits due to disabilities or diseases	0.0020**	0.0013	0.0012
	(0.0009)	(0.0011)	(0.0011)
Benefits due to needs for private nursing	0.00175**	0.00007	0.00095
	(0.00078)	(0.00089)	(0.00090)
Birth month	0.000007	0.000009	0.000003
	(0.000039)	(0.000038)	(0.000039)
Married parents	-0.0004	-0.0002	-0.0002
	(0.0003)	(0.0003)	(0.0003)
Divorced parents	0.0003	0.0002	0.0002
	(0.0004)	(0.0004)	(0.0004)
Both parents employed	-0.00008	-0.00037	-0.00032
	(0.00029)	(0.00071)	(0.00071)
Only mother employed	-0.0002	-0.0010	-0.0010
	(0.0004)	(0.0007)	(0.0007)
Only father employed	-0.0001	-0.0008	-0.0008
	(0.0004)	(0.0007)	(0.0007)
Parental income in quartile 2	-0.00002	-0.00046	-0.00045
	(0.00034)	(0.00050)	(0.00050)
Parental income in quartile 3	-0.0002	-0.0008	-0.0009
	(0.0003)	(0.0005)	(0.0005)
Parental income in quartile 4	-0.0002	-0.0011**	-0.0011**
	(0.0003)	(0.0005)	(0.0005)
Birth year 1987	0.00472**	-0.00004	-0.00004
	(0.00216)	(0.00009)	(0.00009)
Birth year 1988	0.0005	0.0070***	0.0069***
	(0.0021)	(0.0026)	(0.0026)
Number of students in compulsory school	-0.000003	0.00432*	0.00428*
	(0.000089)	(0.00262)	(0.00260)
Observations	162,669	162,669	162,669
F value		20.38	1.24

Note: Each row in column (1) represents a separate regression for the proportion of girls at school. All regressions include compulsory school fixed effects. Standard errors clustered at the cohort and compulsory school level are reported in parentheses. *, **, and *** denote significance at 10, 5, and 1 percent level, respectively.

Table A3: Full regressions of column 3 of Table 2

	Graduation	Academic study track	Higher education
Proportion of girls	0.0355**	-0.0217	0.0360**
	(0.0154)	(0.0176)	(0.0157)
Girl	0.094***	0.087***	0.170***
	(0.0023)	(0.0028)	(0.0025)
First generation immigrants	0.039***	0.181***	0.092***
	(0.0070)	(0.0073)	(0.0068)
Second generation immigrants	0.066***	0.187***	0.095***
	(0.0091)	(0.0105)	(0.0093)
High school education	0.113***	0.065***	0.071***
	(0.0040)	(0.0036)	(0.0032)
Bachelor’s degree	0.222***	0.254***	0.235***
	(0.0042)	(0.0042)	(0.0038)
Master’s or doctoral degree	0.262***	0.356***	0.327***
	(0.0049)	(0.0054)	(0.0054)
Benefits due to disabilities or diseases	-0.0193**	0.0182**	0.0067
	(0.0087)	(0.0090)	(0.0079)
Benefits due to needs for private nursing	-0.209***	-0.0815***	-0.105***
	(0.00783)	(0.00770)	(0.00633)
Birth month	0.00006	-0.00315***	-0.00115***
	(0.00033)	(0.00035)	(0.00033)
Married parents	0.125***	0.069***	0.096***
	(0.0029)	(0.0029)	(0.0028)
Divorced parents	-0.0028	-0.0154***	-0.0121***
	(0.0040)	(0.0041)	(0.0035)
Both parents employed	0.131***	0.038***	0.060***
	(0.0062)	(0.0060)	(0.0053)
Only mother employed	0.0986***	0.0469***	0.0479***
	(0.0064)	(0.0060)	(0.0052)
Only father employed	0.0717***	0.0202***	0.0227***
	(0.0063)	(0.0060)	(0.0053)
Parental income in quartile 2	0.0132***	-0.0003	-0.0017
	(0.0041)	(0.0040)	(0.0037)
Parental income in quartile 3	0.0531***	0.0513***	0.0396***
	(0.0043)	(0.0044)	(0.0041)
Parental income in quartile 4	0.083***	0.138***	0.096***
	(0.0044)	(0.0047)	(0.0045)
Number of students at compulsory school	0.00014*	0.00027**	0.00005
	(0.00008)	(0.00013)	(0.00008)
Birth year 1987	-0.0011	-0.0137***	-0.0002
	(0.0023)	(0.0028)	(0.0024)
Birth year 1988	0.0046**	-0.0162***	0.0085***
	(0.0023)	(0.0031)	(0.0024)
Observations	162,669	162,669	162,669

Note: Full results for the models in columns (4)-(7) in Table 3. Standard errors clustered at the county level are reported in parentheses; *, **, and *** denote significance at the 10, 5 and 1 percent level, respectively.