High-Ability Influencers?

The Heterogeneous Effects of Gifted Classmates

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ABSTRACT

We study the causal impact of intellectually gifted students on their nongifted classmates' school achievement, enrollment in post-compulsory education, and occupational choices. Using student-level administrative and psychological data, we find a positive effect of exposure to gifted students on peers' school achievement in both math and language. This impact is heterogeneous: larger effects are observed among male students and high-achievers, and female students benefit primarily from female gifted students. Effects are driven by gifted students not diagnosed with emotional or behavioral disorders. Exposure to gifted students increases the likelihood of choosing a selective academic track and occupations in STEM fields.

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I. Introduction

In a context where the inclusion of special-needs students in the main classroom ("mainstreaming") is becoming the norm and where special education programs are increasingly being abandoned, evidence on the effects of inclusion on students' wellbeing, achievement, and post-education opportunities is more needed than ever. One particular population, traditionally segregated into special education classes, needs to be thoroughly investigated in a mainstreaming context: *gifted students*—that is, students with an intellectual ability significantly higher than average.[1] It is a priori unclear whether and where such students exert a positive influence on their classmates, where—feeling bored and not fitting in—they are perceived as disruptive elements, and where they have no discernible effect on their peers. The aim of this work is to resolve this question by examining if and how gifted students affect their nongifted classmates' achievement in secondary school and enrollment in post-compulsory education. Given the heterogeneous nature of peer effects in the classroom,[2] our research emphasizes how the influence of gifted students differs for their male and female, high-achieving and low-achieving peers in math and nonmath school subjects.

We analyze the impact of gifted students on their classroom peers in the context of the Swiss education system, an inclusive academic setting that offers ideal conditions for the identification of spillover effects. One such feature is that no gifted students are segregated into gifted programs and that they are all included in regular schools, even though they may receive additional services or activities outside of the classroom. A second feature is that the status of gifted students is assessed and determined by the school psychological service, an independent and centralized institution that provides students and their families with diagnosis and counseling for school-related issues. This practice ensures that professional psychologists (not parents, teachers, or school administrators) diagnose students as gifted. This in turn allows us to differentiate gifted students from simply high-achieving students and to break the myth that giftedness is the same as high achievement. In fact, nearly 50 percent of gifted students in our sample are not in the top five students of their class. We use student-level administrative data on achievement combined with detailed psychological examination records, uniquely

values of the apprenticeship requirement level ratings. The authors declare no conflict of interest. Balestra and Sallin acknowledge financing from the Swiss National Science Foundation (Grant no. 176381). The authors certify that they have obtained Institutional Review Board (IRB) approval for this research. This paper uses confidential data from the School Psychological Service, the Ministry of Education of the canton of St. Gallen, the Stellwerk test service provider, the Swiss Federal Statistical Office, and the Swiss Central Compensation Office. Access to the data can be granted on-site at the University of St. Gallen after signing the data use agreement. Replication files are available upon request (Simone Balestra, simone.balestra@unisg.ch).

1. We understand gifted children or students as "Children, students or youth who give evidence of high-performance capability in areas such as intellectual, creative, artistic, or leadership capacity, or in specific academic fields, and who require services or activities not ordinarily provided by the school in order to fully develop such capabilities." (U.S. Federal government statutory definition of gifted students, P.L. 103-382, Title XIV, p. 388).
2. As pointed out by Black, Devereux, and Salvanes (2013); Booij, Leuven, and Oosterbeek (2017); Burke and Sass (2013); Hoxby (2000); Lavy, Paserman, and Schlosser (2011); and Lavy, Silva, and Weinhardt (2012).

linking students' school performance in a compulsory standardized test and administrative records from the school psychological service for ten consecutive cohorts of eighth-graders. To investigate career trajectories, we merge our data with administrative records containing detailed information on students' post-compulsory education choices.

For identification, we rely on the variation in classroom composition arising from within-school assignment of gifted students to classes when students transition from primary school (Grades 1–6) to secondary school (Grades 7–9). When transitioning from primary school to secondary school, students are assigned to new classes in their new school and remain in the same class for the rest of their mandatory education. For equity reasons and to avoid stigma, information on students' psychological profiles is usually not shared between primary and secondary schools. This practice implies that gifted students can be neither identified nor assigned to specific classrooms or teachers as students enter secondary school. Using several tests, we demonstrate that the observed within-school, between-class variation in the proportion of gifted classmates is consistent with variation generated from a random process. We also find no systematic assignment of gifted students to a specific class or teacher. Causal conclusions are further motivated by the fact that parents do not have a free choice of school in Switzerland: nearly all pupils attend public schools, and the geographical distribution of the population in the individual communities shows no regularities that would correlate with the distribution of talented pupils. Finally, the low prevalence of intellectual giftedness (approximately 2 percent of the population) is useful for the estimation of peer effects, allowing us to conduct the analysis exclusively on nongifted students without losing a significant portion of the sample. By excluding gifted students from the analysis, we explicitly distinguish between the subjects of a peer effects investigation (regular students) and the peers who potentially provide the mechanism for causal effects on these subjects (gifted students).

We document a positive effect of exposure to students identified as gifted in all school subjects. Our results indicate that exposure to gifted students on average raises achievement of the other students by 8.7 percent of a standard deviation in math and 7.8 percent in language. Exposure to gifted students is daily classroom exposure over two school years (Grades 7–8). When looking at who benefits the most from the presence of gifted students in the classroom, we observe the strongest effect for male students and for high-achievers. In addition, we uncover a clear effect heterogeneity across gender and school subject. In math, male students profit significantly more than female students from gifted classmates, amplifying the gender gap in math achievement by 16 percent. In contrast, we find no significant gender difference in the spillover effect for language. This gender–subject heterogeneity is quite striking because classrooms (and thus peer composition) remain the same for all subjects. Moreover, we detect no other significant effect heterogeneity for characteristics like student's age, their native speaker status, class size, or teacher's gender.

Which gifted students generate the positive externalities? We provide compelling evidence that both the gender and the behavior of the gifted students matter, and that they matter even more to female students. We show that male students benefit from the presence of gifted peers in all subjects regardless of the gender of the gifted, whereas female students benefit almost exclusively from gifted female students. This pattern is more apparent in math and suggests that exposure to high-ability female peers may provide female students with a role model in quantitative fields, alleviating the negative effects of gender stereotypes. Not every gifted student is, however, a good peer. By distinguishing between gifted students who suffer from behavioral, emotional, or social problems from the other gifted students, we are able to isolate gifted students who do not exhibit disruptive behavior in the classroom. We find that female students are negatively affected by the presence of classmates who are gifted but disruptive. The evidence suggests that well-behaved gifted students improve their classmates' performance through both ability spillovers and reduced classroom disruption.

In terms of human capital investment, we further analyze students' career trajectories after compulsory education. In Switzerland, after compulsory education, students must choose between vocational training or pre-university education (commonly known as "academic track") that provides them with the required skills to study at the tertiary level. By looking at whether students choose an academic track or a vocational track, we find that being exposed to gifted classmates in secondary school significantly increases the likelihood of choosing the academic track. This effect is entirely driven by male students who enter the academic track instead of the vocational track, which reflects the main findings and may offer an additional explanation to the persistent underrepresentation of women in math-intensive careers (for example, in STEM fields). We investigate this hypothesis by classifying each vocational occupation according to its STEM content. We find that exposure to gifted students increases the likelihood of choosing an occupation in STEM fields among students entering the vocational track, an effect observed only among men.

This work contributes to and brings together three strands of literature in economics. First, we contribute to the underinvestigated field of research on gifted students. Rather than looking at how gifted students perform when they are segregated into talented programs (for example, Booij, Haan, and Plug 2016; Bui, Craig, and Imberman 2014), we bring evidence on the situation of gifted students in an inclusive education system, and we propose a new approach to identify high-ability students in general. The literature so far has used previous achievement (for example, Booij, Leuven, and Oosterbeek 2017), individual fixed effects (for example, Burke and Sass 2013), socioeconomic background (for example, Black, Devereux, and Salvanes 2013), and parents' education (for example, Cools, Fernandez, and Patacchini 2019) to determine student ability. Instead, we use formal assessments by external specialists (school psychologists) to identify gifted students. These external assessments are reliable assessment of students' cognitive abilities, extend beyond pure school performance, and are less prone to biases arising from parents, teachers, or developmental factors. Given that being diagnosed as a gifted student does not automatically determine eligibility for targeted academic programs in Switzerland, our hybrid measure based on specialists' assessment and IQ tests is less likely to be manipulated.

Second, we contribute to the extensive literature on peer effects in education. This literature has provided quantified evidence that educational success cannot be explained only by students' own characteristics, parental background, and school environment, but that peers and the interactions between peers matter. One novel feature of our study is that, among the many peer dynamics occurring in the classroom documented so far, the heterogeneous influence of the population of gifted students has never been investigated. In addition, we are able to observe the classroom environment, where teaching occurs and students presumably directly affect their peers' learning. Although many scholars agree that classroom interactions play an important role in determining students' academic achievement and in shaping students' educational choices, most studies define peers at the school or cohort level. This definition of peer group may miss important interactions within classroom groups because the estimation of spillover effects differs depending on the accuracy with which one identifies the set of relevant peers (Carrell, Fullerton, and West 2009; Carrell, Sacerdote, and West 2013). Finally, by presenting evidence on both school performance and career trajectory, we complement an emerging literature examining how peer characteristics during adolescence influence later career choices (Anelli and Peri 2017; Black, Devereux, and Salvanes 2013; Card and Payne 2017; Carrell, Hoekstra, and Kuka 2018; Mouganie and Wang 2020; Zölitz and Feld 2019).

Third, we contribute to a growing strand of literature that aims to understand the roots of the persistent gender gap in math (for a recent review, see Buckles 2019). Although the gender gap in education enrollment and labor market participation has dramatically narrowed over the past 50 years, the gender gap in math achievement still persists in most developed countries (Ellison and Swanson 2010).[3] The reasons for this persistence are still not totally understood. Recent research shows that the gender gap in math achievement does not exist upon entry to school, supporting the idea that nurture (for example, gender stereotypes, culture) rather than nature (for example, innate biological differences between sexes) determines gender differences in achievement (Hyde and Mertz 2009; Nosek et al. 2009; Pope and Sydnor 2010). However, the gap appears to be large and significant in the middle school years and beyond (Fryer and Levitt 2010) and is in turn mirrored in the education and career choices of young women (Brenøe and Zölitz 2020; Card and Payne 2017; Carrell, Page, and West 2010). It is therefore crucial to understand what are the factors in the school environment that originate and widen the gender gap in math achievement, especially for students at the age of choosing their first important career direction. This study offers both new evidence on the formation of the gender gap in math and the likely mechanisms behind such gap.

II. Background and Data

A. Institutional Background

The education system in Switzerland has a federal structure and gives the cantons—similar to the states in the United States, the countries in Germany, or the provinces in Canada—great freedom in educational policy decision-making. In contrast to the other three federal states, however, the degree of coordination between the cantons is relatively high, and, depending on the language region (German, French, or Italian), the cantons now apply the same common curriculum in all subjects. In the Intercantonal Agreement on the Harmonization of Compulsory Education, which the majority of the

3. Data from the 2015 PISA study reveal that Switzerland has one of the highest gender gaps in math performance (2.3 percent), alongside with other countries exhibiting above-average gender gaps like the United States (1.9 percent), the United Kingdom (2.2 percent), and Germany (3.1 percent).

cantons—including the one we consider here—have joined, equal school structures were established. These include a two-year entry level (kindergarten) and nine years of compulsory schooling, of which the first six years are allocated to the primary level and the last three to the lower secondary level. Pupils change schools and classes when moving from primary to lower secondary education.

Within each canton, schools are organized at the municipality level, and children are assigned to schools on the sole basis of their location of residence. This strict assignment procedure is thoroughly implemented, such that parents have no say about their child's school other than moving permanently to a different municipality or enrolling their children in a private school. Despite this rule, private schooling remains very rare in Switzerland. As the 2018 Education Report by the Swiss Coordination Center for Research in Education shows, more than 95 percent of children in 2016 attend public-funded schools in their municipality of residence.

The present analysis focuses on all students enrolled in the secondary schools of the canton of St. Gallen (around 500,000 inhabitants). In this state, children are required to undergo 11 years of compulsory education, divided into kindergarten (two years), primary school (six years), and secondary school (three years). In most cases, secondary schooling takes place in larger schools administered by associations of municipalities (districts). Tracking occurs at the secondary school level and is based on students' academic performance in primary school, as well as their teacher's recommendation. Students are either sent to a high-track secondary school (Sekundarschule) or to a lower, more practice-oriented secondary school track (Realschule). Once allocated to one of the two secondary school tracks, students are assigned to classes within each school track. The administrative staff of each school has no prior knowledge about the students other than administrative data on gender, place of residence, primary school attended, and nationality. For equity reasons, information on students' disabilities, special needs, or high-ability status is usually not shared between primary schools and secondary schools. This practice potentially creates a situation where class composition is quasi-random with respect to students' psychological profiles, a situation that we evaluate in the empirical strategy section. Once assigned to a class, students share the same peers for all the lectures and subjects, and classes remain unchanged for the three years of secondary school.[4]

At the end of their eighth year of compulsory schooling (second year of secondary school), all students are subjected to a mandatory standardized test (the so-called "Stellwerk 8" test). This computer-based adaptive test automatically adapts the difficulty of questions to the ability and knowledge revealed by the student in the previous questions (in the same fashion as the GMAT or GRE test). It tests core knowledge of mathematics, language (German), and, depending on the track, foreign languages (usually English), as well as natural sciences (including biology, chemistry, or physics). The correction of the test is computer-based, which eliminates concerns of teachers' bias or stereotyping in the results. The results are important both for students, who will use the test scores when choosing their post-compulsory education, and teachers, whose relative performance can be reflected by the rate of success of their students. Although Stellwerk 8 is not needed to obtain the compulsory school diploma, students receive a

4. Grade repetition is not common in St. Gallen, as only about 1.5 percent of students in a cohort ever repeated a grade. Within-state and out-of-state mobility in St. Gallen are also low at about 2–3 percent (data are from the Swiss Federal Statistical Office for the years 2008–2017).

certificate with their results and usually submit it to potential employers when applying for Vocational Education and Training (VET) positions.[5]

The canton of St. Gallen bears the responsibility for the inclusion and education of children with high abilities and must guarantee the fulfillment of their educational needs. In this regard, emphasis is put on inclusion of students identified as gifted in regular classrooms (mainstreaming). Requests to send gifted children to special schools are accepted only under strict conditions: the child must have already skipped a grade, justify why the classroom environment is not adequate, and undergo a psychological evaluation. In all other cases (the vast majority), special activities, additional support, and enrichment programs are offered outside of class, depending on the school and upon request by parents and teachers. Acceleration (skipping a grade) or school start at a younger age are also possible in some rare cases.

The task of identifying and providing psychological support to children with high abilities is carried by the School Psychological Service (SPS), a centralized and independent office. It provides diagnoses of learning disabilities, behavioral difficulties and developmental deficiencies, assigns therapies and treatments to children, and offers counseling to children, parents, and teachers. For most students (about nine out of ten), services of the SPS are requested directly by the teacher, but some requests are also filed by the parents or the child's doctor. The referring party needs to justify the request by pointing out the reason for the child's registration with the SPS. The reasons most commonly brought up are learning disabilities, social or emotional problems, difficulties with the family and the parents, or challenging relationships with the teacher. After a request has been made, children and their parents are contacted directly by a caseworker from the SPS for an assessment of the situation and a health diagnosis. As part of the diagnosis, an intelligence test is often administered to children.

B. Data Sources

We use information on classroom composition, characteristics of students, and individual academic achievement from the Stellwerk test taken in eighth grade by the entire population of students in the canton of St. Gallen.[6] To this, we add information from the administrative records of the SPS on individual psychological profile, giftedness status, and learning disabilities of each child. After merging these two sources, we observe the academic achievement, psychological profile, and peer group composition for each student enrolled in Grade 8 in the canton of St. Gallen for ten consecutive school cohorts (2008–2017).

More precisely, the test score data allow us to observe the following for each cohort: composition of secondary school classes (with the school, the track, and the classroom as well as the teacher ID), basic characteristics of each student (birth date, gender, and whether the student is a native German speaker), and student academic achievement on

5. The Stellwerk test is used in many German-speaking cantons and Stellwerk scores are also used to describe occupation profiles in the Swiss German labor market. For example, one of the most common occupations in Switzerland—commercial employee—requires a math score between 425 and 525, a German score between 550 and 650, and an English score of between 550 and 650.

6. This section closely follows Balestra, Eugster, and Liebert (2022), who use an extended version of the same data set.

the Stellwerk test (scores for all examined materials). In this analysis, we focus primarily on the scores in math, language (German), and a composite of the two, which are compulsory subjects for all students in all tracks, and standardize them with mean zero and standard deviation one. As we mentioned in the previous section, the classroom composition we observe in the Stellwerk data is the classroom composition that remains fixed over the whole three years of secondary school in all subjects.

Information on the gifted status of students is given by the administrative records of the SPS. In these records, we find information on each child who has had contact with the SPS at any point in their school years. The records contain the reason of registration, the therapies assigned to the child, the number of visits to the SPS, the date of each visit, and all notes left by the caseworker about the child. These notes give a very detailed source of information about the child's situation, the topics discussed during each interview, and an overall idea about the diagnosis. Important for our study, we observe the IQ score for many of the children registered at the SPS. Most of the requests to the SPS are made when the child is between six and nine years old, and first contacts with the SPS in primary school often coincide with the time when children start receiving school grades (second semester of second grade).

Four restrictions are imposed on the data, reported in detail in Online Appendix Table A.1. First, we restrict our data set to students enrolled in the higher track (Sekundarschule, 62 percent of the original sample) and discard those in the lower track (Realschule). The reason for this is that the vast majority of gifted children (93 percent) pursue their education in the Sekundarschule. One advantage of focusing on the higher track only is that the sample is very homogeneous with respect to ability. Second, we focus only on students who were actually required to take the Stellwerk test. This leaves out students from special education institutions, for which we do not observe complete classes. Third, we exclude segregated classes that are composed only of students with special needs. Finally, we remove classes and students with missing or implausible values (for example, test scores exceeding the possible range, classes that are too small or large, or negative age at test). We are left with a final sample of 31,625 students in 1,592 classes from 80 schools.

C. Definition of the Key Variables

While remaining aware that intellectual giftedness is a multifaceted concept whose definition has never been generally agreed upon (Sternberg, Jarvin, and Grigorenko 2010), we understand intellectual giftedness as an intellectual ability significantly higher than average. Intellectual giftedness is believed to persist as a trait into adult life, with various consequences studied in longitudinal studies of giftedness over the last century (Gottfried et al. 1994). Albeit no generally agreed upon definition of giftedness for either children or adults has been reached, most school placement decisions and longitudinal studies over the course of individual lives have followed people with IQs in the top two percent of the population (Newman 2008)—that is, IQ scores above 130 (two standard deviations above the mean). However, there is substantial variation in the threshold used across theories of intelligence, intelligence scales, and individual psychologists.[7]

7. For instance, Silverman (2018) uses the threshold of 120 to identify "mildly gifted," 130 for "moderately gifted," 145 for "highly gifted," 160 for "exceptionally gifted," and 175 for "profoundly gifted." Moreover, the

IQ scores are known to mildly predict academic achievement (Deary et al. 2007; Neisser et al. 1996), since school success is also strongly determined by dedication, motivation, and parental background and investment. Criticism within the psychological community has raised doubts on the validity of the IQ score (see discussion in Sternberg, Jarvin, and Grigorenko 2010). The IQ score, which maps intelligence unidimensionally, might miss other cognitive dimensions relevant to intelligence, such as emotional intelligence (Mayer et al. 2001; Zeidner et al. 2005), creativity (although much debated; see Make and Plucker 2018), or domain-specific abilities. Nonetheless, the advantages of measuring cognitive ability with a uniform, normalized IQ scale and of tying the definition of "giftedness" to a particular threshold score on the IQ scale are manifold, such as psychometric advantages (easy quantification of intelligence, reliability, internal and test–retest consistency), transparency (the concept of IQ is widely known), predictive accuracy for intelligence in general (for example, Der, Batty, and Deary 2009), and external validity (measures of IQ exist for all ages and have been normed across cultures and countries; for example, Lynn and Meisenberg 2010; Lynn and Vanhanen 2012). As a consequence, in the United States, for instance, individual IQ testing is becoming less commonly used for identification of the gifted, and a more holistic identification procedure is preferred.[8]

Our data allow us to mitigate the potential limits of IQ as a unique and reliable measure of giftedness. Since the SPS records not only report the children's IQ scores, but also qualitative assessments of cognitive ability (as obtained from the diagnoses and comments of the caseworker), we are able to enhance the IQ scores with qualitative assessments. Qualitative assessments reliably complement quantitative scores, take into account other dimensions of intelligence not assessed by the IQ test, and allow for discarding false positives (Silverman 2018).[9] They also allow us to differentiate between high-achievers and gifted students, as the two do not necessarily overlap. In comparison to the previous literature, we can integrate a richer notion of high intelligence in our analysis.

We then proceed in the following three steps to construct our indicator of giftedness. First, we select one IQ score per child. For many children, we observe different scores, either taken at different points in time, and/or estimated with different intelligence tests. For each child with more than one score, we take the highest score reached by the child.[10] With respect to the chosen intelligence test, we know from the SPS that each child is given the test that suits their situation the best.[11] We classify the child as

scale must be adapted for students with a native language different than the one of their main environment. Some researchers also use an IQ threshold of 116 for nonnative speakers (Card and Giuliano 2016).

8. See the report from the National Association for Gifted Children 2015, www.nagc.org, and Peters and Matthews (2016).

9. We are aware of the existence of bias in qualitative assessments, such as documented in McDermott, Watkins, and Rhoad (2014). Unfortunately, we do not observe the caseworker ID so we cannot take bias into account in our analysis.

10. After discussion with the head of the SPS, we decided to take the highest score since many children need more than one attempt to be fully concentrated during the test. Using either the first IQ administered or the average of all IQ tests performed has no substantial impact on the results.

11. The available intelligence tests are Snijders–Oomen nonverbal intelligence tests (SON), Kaufman Assessment Battery for Children I and II (K-ABC and K-ABCII), the Wechsler Intelligence Scale for Children (WISC-Hawik), Raven's Progressive Matrices (Raven), Kramer-Test, and Culture Fair Intelligence Test (CFT).

gifted if their IQ score is equal to or greater than 130. We conduct our main analysis with a threshold of 130, and we show that our results are robust when applying more or less restrictive definitions of giftedness. In a second step, we code the written diagnosis of the caseworker—a trained psychologist—and assign the gifted status to the children who are diagnosed as such by the caseworker. In a final step, we remove false positives, that is, children with a high IQ score but whose assessment does not diagnose high ability. For example, we discard cases in which the child reaches a high IQ score, but the caseworker writes that the child had learned how to perform well on the test from their siblings. It is important to mention that we focus exclusively on gifted students who are identified prior to secondary school entry. By doing so, we make sure that gifted status does not depend on class composition in secondary school.

In sum, 20.5 percent of all our observations have been referred to the SPS, and 12.8 percent of all students have been assessed for IQ with a formal IQ test. Of the 578 students classified as gifted, 145 students were identified as gifted with both measures, IQ test and diagnosis, whereas 329 students were identified only with the diagnosis and 104 exclusively with the IQ test. Finally, there are 82 students who were referred to the SPS for an assessment of giftedness but were not diagnosed as gifted. Our measure of giftedness has never been used in the literature on ability peer effects, and we argue that using a metric based on experts' diagnoses is less prone to misreporting (for example, self-assessment), context-specific factors (for example, school or class composition), and external influences (for example, parents or teachers).

D. Summary Statistics

Table 1 reports the summary statistics for our final sample. The typical eighth grade class consists of 20 students, and there are 0.36 gifted classmates per class. Despite this low prevalence, 27 percent of all students are exposed to at least one gifted classmate in eighth grade. Every second student is a female student, one in ten students is non-native German speaker, and the average age at which students take the Stellwerk test is approximately 15.

The subsample of 578 gifted students is of particular interest, as shown in Table 1, Panel D. Around 1.9 percent of the sample is identified as gifted, which is slightly below the expected percentage of individuals with $IQ \geq 130$ under the normal curve (≈ 2.1 percent). This discrepancy is likely explained by the fact that some gifted individuals go through primary school undetected, thus never entering in contact with the SPS before reaching secondary school (for identification purposes, we only focus on gifted students identified during primary school). Consequently, as we only observe *identified* gifted students, our measurements of being exposed to gifted students on other students will underestimate the true effect (attenuation bias). In this sense, our findings can be interpreted only as the effect of being exposed to students identified as gifted.

Approximately 30 percent of the identified gifted students in our sample are female, which is similar in proportion to other European countries.[12] The underrepresentation of gifted female students, documented in many different contexts (Petersen 2013), might

12. Data are from the EASIE 2014 Dataset Cross-Country Report, retrieved from https://www.european-agency.org/data (accessed July 28, 2022).

Table 1
Descriptive Statistics

	Sample Mean (1)	SD (2)
Panel A: Outcome		
Test score: Mathematics	0.000	1.000
Test score: Language (German)	0.000	1.000
Test score: Composite	0.000	1.000
Panel B: Exposure to Gifted Children		
Gifted student	0.018	0.134
Gifted classmates (proportion)	0.018	0.035
Gifted classmates (number)	0.351	0.673
Exposure to gifted classmate	0.264	0.441
Panel C: Classroom Characteristics		
Female	0.524	0.499
Native German speaker	0.912	0.284
Age at test	14.81	0.699
Class size	20.52	3.378
Male teacher	0.649	0.477
Panel D: Characteristics of Students Identified as Gifted (*N* = 578)		
Female	0.296	0.457
With emotional or social problems	0.123	0.329
Referred to SPS by teachers	0.856	0.351
Referred to SPS by parents	0.126	0.332
Rank in the class (composite test)	6.242	5.238

Notes: Descriptive statistics for the main estimation sample, based on 31,765 students in 1,597 classes from 80 schools. In regressions analyses we exclude gifted students from the estimation sample, which reduces the number of students to 31,187. Data are from the School Psychological Service St. Gallen and the Stellwerk test service provider.

be explained by teachers' gender bias in referrals for giftedness assessment (which has been documented by Bianco et al. 2011) or by the fact that gifted female students are less likely to be identified by means of IQ testing and standardized tests (Petersen 2013). It can also be the consequence of a higher prevalence of disruptive behaviors (and thus a higher prevalence of references to the SPS) among male students in general, which makes female students pass unnoticed by the teachers and not assessed by the psychologist—in our data, while 25 percent of male students have been referred to the SPS in general, only 16.5 percent of female students were referred.

Online Appendix Figure A.1 shows the distribution of class size and gifted classmates in absolute and relative terms. The figure indicates that while most classes have no gifted student, nearly all classes exposed to gifted students contain exactly one gifted student.

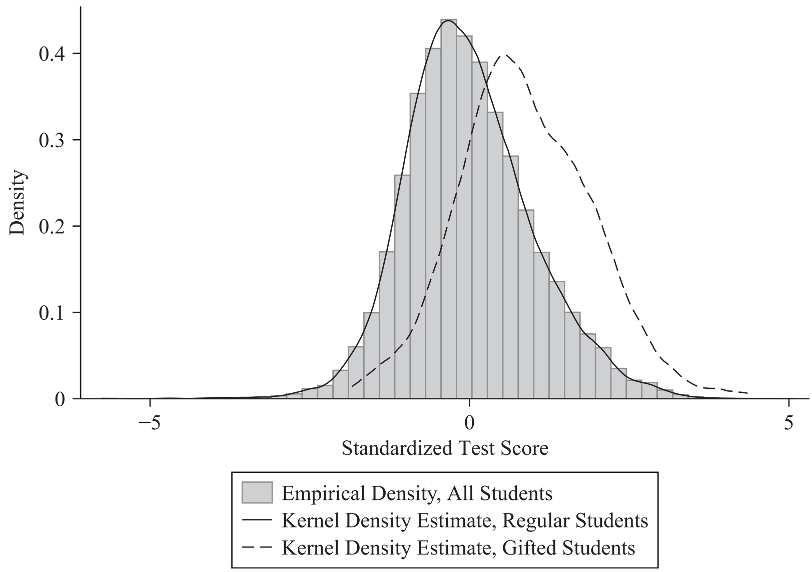

Figure 1
Distribution of Test Scores
Notes: Data are from the School Psychological Service St. Gallen and the Stellwerk test service provider.

Figure 1 exhibits the distribution of test scores by student type, showing that gifted students perform on average better than regular students—almost a standard deviation better. However, not all gifted students are high-achievers, and, at the same time, not every high-achiever is classified as a gifted student. This finding is confirmed in Online Appendix Figure A.2, which shows the distribution of gifted students' classroom ranks on the Stellwerk test and reveals that every second gifted student performs in the top five of their classroom, while the rest might perform even in the lowest ranks. This is likely because our definition of gifted transcends the test score dimension, featuring a measure of intellectual ability based on psychological examinations rather than previous achievement.

III. Empirical Strategy

The aim of this work is to evaluate the impact of exposure to identified gifted peers on student achievement. Empirically, we estimate the following linear model:

$$(1) \quad Y_{icst} = \alpha + \beta \, Exposure_{cst} + \gamma \, X_{icst} + \delta \, \bar{X}_{(-i)cst} + \varepsilon_{icst}$$

where Y_{icst} is the outcome of interest, such as the math test score of student i in classroom c, school s, and year t. X_{icst} is a vector of individual characteristics that include age at test, an indicator for gender, and an indicator for native German speaker. $\bar{X}_{(-i)cst}$ is a vector of average characteristics of i's class (class size, proportion of female students, proportion of native German speakers, and mean age). The variable of interest is $Exposure_{cst}$, a measure of exposure to *identified* gifted students in a given class. We parametrize such measure for each student as an indicator of being exposed to at least one gifted classmate in Grade 8, but the results are consistent to alternative specifications (for example, the proportion of gifted students per class). The peer spillover parameter is β, which represents the impact of being exposed to a gifted student on *i*'s outcome. The error term ε_{icst} is assumed to consist of two components: a school-by-year fixed effect and an idiosyncratic error term (that is, $\varepsilon_{icst} = \mu_{st} + e_{icst}$). Finally, standard errors are clustered at the classroom level throughout the paper.

The estimation of the interest parameter β suffers from three main identification problems. First, the well-known Manski (1993) reflection problem states that all behaviors in a peer group are affected by the behaviors of the other members of the group. Namely, a student simultaneously influences the outcome of the group, and the group influences the outcome of the student. We tackle this problem in two ways. First, all variables in Equation 1 are determined before secondary school, including the status of gifted student. This strategy ensures that neither the gifted status nor other individual characteristics are influenced by contemporary class composition.[13] Second, we exclude gifted students from all regressions in order to separate the subjects of our investigation (regular students) and the peers who potentially provide the mechanism for causal effects on these subjects (gifted students). As discussed by Angrist (2014), this distinction eliminates mechanical links between own and peer characteristics, making it easier to isolate variation in peer characteristics that is independent of subjects' own characteristics.

The second main identification problem stems from common unobserved shocks at the group level. These shocks at the class and school levels could tamper with the identification of peer effects of gifted students on their classmates. For instance, the outbreak of an epidemic or the introduction of new pedagogical methodologies for a lesson could impact the overall academic performance of a classroom or a school, which would confound the peer effects estimation if correlated with the proportion of gifted peers. To resolve this issue, we introduce a series of fixed effects that control for unobserved heterogeneity at multiple levels (namely the school-by-year level).

The third identification problem is endogenous peer selection and is the most challenging to tackle. If individuals are systematically assigned to groups according to a specific characteristic, the researcher cannot determine whether a difference in outcome is a causal peer effect or simply an artifact of group assignment. We take care of this problem by ensuring that gifted students are quasi-randomly assigned to classes at the secondary school level (that is, identification between classes within the same school–year). As we already mentioned, the transfer from primary to secondary school is regulated in such a way that students are assigned to schools based on their place of

13. Our measure of exposure could be weakened if students were regularly changing classes in secondary school. However, student mobility between schools is rare. Data from the official education statistics from the Swiss Federal Statistical Office (Statistik der Lernenden in German) indicate that, in the state of St. Gallen, approximately 40 students per year change school between Grade 7 and 8. This figure corresponds to a prevalence of 0.77 percent, and prevalence never exceeds 1 percent in the years considered (2011–2016). Note that school mobility is primarily due to students moving to another municipality, which accounts for 70 percent of total school mobility.

residence. In each school, students from different places of residence (and consequently different primary schools) are mixed. Importantly, students' psychological profiles are unknown to secondary school administrators, such that equity among students is guaranteed and stigma when transitioning between schools is avoided. We exploit this policy rule for identification and formally test the validity of the strategy with three types of balancing tests.

We begin by testing whether individual and group characteristics predict exposure to gifted peers. The aim of this test is to detect potential selection into classrooms. Table 2 shows the results, where each regression includes school–year fixed effects. Panel A focuses on individual-level characteristics (gender, native German speaker, and age), while Panel B focuses on classroom characteristics (proportion of female classmates, proportion of classmates who native speakers, classmates' mean age at test, and class size). None of the coefficients in Table 2 are statistically significant, and, in addition, the size of the coefficients is very small. We also test for joint significance of the individual characteristics (Panel A, Column 4) and group characteristics (Panel B, Column 5). We cannot reject the null hypothesis that the coefficients on gender, native speaker, and age are jointly zero, with a p-value of 0.550. Neither can we reject the null hypothesis that the coefficients on the class-level characteristics are jointly zero (p-value of 0.449).

Although we find no evidence for selection into classrooms according to observable characteristics, we might suspect selection into classrooms based on unobservables. We thus perform a direct test of our identification strategy that assignment of gifted students within school-years is as good as random. To do so, we follow closely the approach of Chetty et al. (2011) and regress the gifted indicator on both school–year fixed effects and class fixed effects. Then we test whether the class fixed effects are jointly significant. The coefficients on the class indicators estimate the difference in probability of being assigned to a given class relative to the reference classroom within the same school–year cell.[14] If these coefficients are not statistically different from zero, we conclude that the probability that a gifted student is assigned to a specific class within a given school–year is the same for all the classes of that school–year. The p-value of the F-test is 0.630, supporting the key identifying assumption that the observed variation in exposure to gifted students between classes of the same school–year is random.

We repeat the test presented in the last paragraph for teacher assignment. Because no teacher holds two classes in the same year, we separate the school and the year fixed effect, but the procedure remains the same. We regress the gifted indicator on school fixed effects, year fixed effects, and teacher fixed effects and test whether the teacher fixed effects are jointly significant. The resulting p-value is 0.285, suggesting that gifted students are not systematically assigned to certain teachers.

In sum, all the tests performed support the validity of our identification strategy. Further evidence on this is presented by Vardardottir (2015). Using PISA data from secondary schools in Switzerland, she shows that track-by-school fixed effects render peer group composition conditionally uncorrelated with a large set of students' characteristics,

14. Note that one classroom fixed effect within each school–year cell is always omitted to prevent multicollinearity between classroom and school–year fixed effects (see Chetty et al. 2011, p. 1609–10).

Table 2
Balancing Tests

	Exposure to Gifted Peers				
	(1)	(2)	(3)	(4)	(5)
Panel A: Individual Characteristics					
Female	0.004			0.004	
	(0.003)			(0.003)	
Native speaker		0.002		0.002	
		(0.009)		(0.009)	
Age at test			–0.001	–0.001	
			(0.003)	(0.003)	
Joint significance (*p*-value)				0.550	
Panel B: Classroom Characteristics					
Female classmates (%)	–0.119				–0.101
	(0.172)				(0.172)
Native speaker classmates (%)		0.115			0.134
		(0.150)			(0.152)
Classmates mean age at test			–0.042		–0.044
			(0.037)		(0.036)
Class size				0.010	0.010
				(0.008)	(0.008)
Joint significance (*p*-value)					0.449
School-by-year FE	Yes	Yes	Yes	Yes	Yes
Observations	31,187	31,187	31,187	31,187	31,187

Notes: Significance: $*p < 0.10$, $**p < 0.05$, $***p < 0.01$. Standard errors, shown in parentheses, are clustered at the school–year level (level of randomization). Data are from the School Psychological Service St. Gallen and the Stellwerk test service provider.

while track fixed effects and school fixed effects separately do not. The approach we follow is even more conservative, as we exploit variation within school–(track)–year. Note also that while families can potentially choose their district of residence, thereby influencing schooling options for their children, possible selection into schools does not confound the results. In any case, mobility in Switzerland is generally low: approximately 80 percent of people do not move within five years, and moving for school choice alone is likely to be a rare occurrence. In addition, municipalities within the canton of St. Gallen are very homogeneous in terms of demographics, indicating that such strategic behavior is most likely limited. The between-municipality variation in the unemployment rate (coefficient of variation: 0.42), the share of rich (0.19) and poor taxpayers (0.69), and the share with secondary (0.19), higher secondary (0.07), and tertiary education (0.22) is small.[15] Finally, we find low geographical variation when examining the prevalence of gifted students across municipalities, as Online Appendix Figure A.3 shows.

Having established that variation across municipalities is low, one might be concerned that estimated effects would be biased if students exposed to gifted classmates in Grade 8 were more likely to have superior educational inputs in years prior to treatment. The best strategy to address this concern would be to control for prior achievement. This is, however, not feasible in our context, for two reasons. First, no standardized test prior to Stellwerk 8 exists; second, we have no information on primary school GPA in the data. Even if we had primary school grades or GPA, such measures would not be comparable across classes because in Switzerland the responsibility for grading and assessing performance is left to the teacher. To resolve the issue of systematic differences in prior educational inputs by exposure to gifted students, we examine the correlation between exposure to gifted classmates and educational inputs at the municipality level. We use two measures of educational inputs previously used in the literature, namely per-student spending (for example, Jackson, Johnson, and Persico 2016) and socioeconomic composition (for example, Angrist and Lang 2004). The data on spending per primary school students comes from the official accounts published by municipalities at the end of the fiscal year, whereas the information on the socioeconomic composition of each municipality is provided by Competence Center for Statistics within the Department of Economic Affairs of the canton of St. Gallen.[16] Online Appendix Figure A.4 presents the result for per-pupil spending, while Online Appendix Figure A.5 presents the results for socioeconomic composition. Both figures clearly show a flat relation between either measure and exposure to gifted students, and neither of the two slopes is statistically significant. This evidence suggests—albeit indirectly—that students exposed to gifted classmates in Grade 8 did not have access to superior educational inputs.

One last concern related to our empirical strategy is selective attrition. If students exposed to gifted peers are more likely to be observed in the data, this might induce bias in our estimated effects. To resolve this potential issue, we conduct an attrition analysis by regressing exposure to gifted classmates on the following five outcomes: missing test score in math, missing test score in German, missing test score in both math and German, missing information on post-compulsory education, and missing information on occupation profile. Online Appendix Table A.2 presents the results and shows that exposure to gifted students does not significantly predict any of the outcomes analyzed. The table also reveals that attrition rates are generally low and even very low for test scores (around 0.4 percent). These results show that some attrition is present, but it is not related to the treatment, which alleviates any worry regarding selective attrition. Note

15. Data are provided by Eugster and Parchet (2019).

16. According to the data, municipalities spend on average 10,160 Swiss francs (approximately 11,140 USD) per primary school student. This figure is higher than the OECD average (8,733 USD) but comparable to the corresponding figure in the United States (11,319 USD), as the OECD documents (OECD 2017). The information on municipalities' socioeconomic composition consists of a "social index" calculated and provided by the Competence Center for Statistics within the Department of Economic Affairs of the canton of St. Gallen. The social index is based on the following four indicators: ratio of foreigners with citizenship of non-German-speaking countries in the population group of 5–14-year-olds, share of unemployed in the 15–64-year-old permanent resident population, ratio of 5–14-year-olds dependent on social assistance to the 5–14-year-old population, and quota of low-income households with 0–13-year-old children.

that attrition in the post-compulsory data originates primarily from the fact that the last two cohorts in the data are simply too young to appear in such data.

IV. Results

In this section, we present and discuss the results in three parts. First, we introduce the main results on the effect of exposure to gifted students on test scores and perform a comprehensive sensitivity analysis. Second, we investigate potential heterogeneous effects and mechanisms driving the main results. Third, we examine longer-term outcomes by estimating the effect of exposure to gifted peers on post-compulsory education trajectories.

A. Main Results

The main results are presented in Table 3. Specifications 1–3 show the effect of exposure to peers identified as gifted on the composite test score (math and language) for all students with different sets of added regression controls, whereas Specifications 4 and 5 consider math and language test scores separately. As regression controls, we include student-level controls (Column 2) and classroom-level controls (Column 3). Crucial for our identification strategy, school–year fixed effects are added to all specifications. Standard errors are clustered at the classroom level.

The estimated coefficients of exposure to identified gifted peers consistently reveal a positive effect on students' own academic performance. The most conservative specification indicates that exposure to gifted students raises the achievement of the other students by 9 percent of a standard deviation on average. All effects are statistically significant at the 1 percent level, and adding covariates does not substantially change the estimates. Note that because we exclude the gifted from the analysis, these results do not reflect the effect of giftedness on the gifted students themselves. Moreover, exposure measured in our results reflects daily exposure over two school years. In terms of individual characteristics, we find the well-documented results that female students score better in language but worse in math than male students and that nonnative speakers perform on average worse than native speakers (especially in language). Class-level characteristic appear to be quite irrelevant, except for the proportion of female students in the class: having more female classmates increases student achievement in all subjects. This finding corroborates previous studies conducted in the United States (Hoxby 2000; Whitmore 2005) and Israel (Lavy and Schlosser 2011). We also find that a higher proportion of nonnative speaker classmates reduces achievement in language (Column 5).

In order to assess whether the exposure to gifted peers impacts the gender gap, we examine potential gender-related heterogeneous effects in Table 4. We estimate the effect of the exposure to gifted peers, including an interaction between exposure and own gender. We reject the null hypothesis that the effect is similar for both female students and male students in math. The estimated coefficients show that not only female students perform on average less well than male students on the math test, but also that the presence of gifted peers in the classroom exacerbates this difference. In

Table 3
Spillovers from Gifted Classmates

	Composite Test Score (1)	Composite Test Score (2)	Composite Test Score (3)	Math Test Score (4)	Language Test Score (5)
Exposure to gifted classmates	0.093***	0.094***	0.095***	0.087***	0.078***
	(0.023)	(0.022)	(0.022)	(0.022)	(0.020)
Female		–0.199***	–0.181***	–0.353***	0.047***
		(0.012)	(0.015)	(0.014)	(0.014)
Native speaker		0.404***	0.406***	0.196***	0.512***
		(0.021)	(0.021)	(0.020)	(0.022)
Age at test		–0.189***	–0.189***	–0.166***	–0.161***
		(0.009)	(0.009)	(0.009)	(0.009)
Female classmates (%)			0.470***	0.420***	0.392***
			(0.170)	(0.162)	(0.148)
Native speaker classmates (%)			–0.149	0.025	–0.288**
			(0.142)	(0.137)	(0.128)
Classmates mean age at test			–0.011	–0.013	–0.005
			(0.037)	(0.039)	(0.031)
Class size			0.003	–0.002	0.008
			(0.008)	(0.008)	(0.007)
School-by-year FE	Yes	Yes	Yes	Yes	Yes
Observations	31,187	31,187	31,187	31,187	31,187

Notes: Significance: $*p < 0.10$, $**p < 0.05$, $***p < 0.01$. Standard errors, shown in parentheses, are clustered at the classroom level. Data are from the School Psychological Service St. Gallen and the Stellwerk test service provider.

math, the positive impact of the exposure to a gifted peer almost completely disappears for female students. However, female students do benefit from gifted peers as much as male students when it comes to performance in language.

Quantifying our results in terms of the gender gap, we find that female students exposed to gifted students are better off than female students without such exposure. However, compared to male students, the results suggest that the exposure to gifted students increases the gender gap in math performance by 16 percent (figures from Table 4, Column 2). This increase is due to a disproportional increase in male students' performance when exposed to gifted classmates. However, the interpretation of the result is subject to the following caveat. Since our descriptive evidence indicates that gifted female students are more likely to remain undetected than male gifted students, it is even more important to understand the effect we measure as the effect of *identified* gifted students.

The results are not sensitive to alternative specifications, treatment or outcome definitions, or identification strategies. More specifically, we conduct four sets of robustness

Table 4
Spillovers from Gifted Classmates by Subject and Gender

	Composite Test Score (1)	Math Test Score (2)	Language Test Score (3)
Exposure to gifted classmates	0.116***	0.115***	0.085***
	(0.026)	(0.026)	(0.024)
Female	–0.170***	–0.338***	0.050***
	(0.017)	(0.016)	(0.016)
Exposure * Female	–0.039	–0.055**	–0.013
	(0.027)	(0.027)	(0.026)
Individual characteristics	Yes	Yes	Yes
Classroom characteristics	Yes	Yes	Yes
School-by-year FE	Yes	Yes	Yes
Observations	31,187	31,187	31,187

Notes: Significance: *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$. Standard errors, shown in parentheses, are clustered at the classroom level. Individual characteristics include gender, native German speaker, and age at test. Classroom characteristics include class size, share of females, share of native German speakers, and average age at test. Data are from the School Psychological Service St. Gallen and the Stellwerk test service provider.

checks. First, to make sure that the results are not driven by our definition of exposure to identified gifted students, we conduct the same analysis while defining exposure as the proportion of gifted classmates. Online Appendix Table A.3 shows that our main results hold, showing that adding one gifted student to a class of 20 would increase achievement by approximately 5 percent of a standard deviation. We also explore potential nonlinearities in the share of gifted students per class by adding quadratic and cubic transformations of the share of gifted students per class. We do not find any nonlinearities in the relationship between average test scores and the share of gifted peers.

Second, we check that our results are not sensitive to a specific definition of giftedness. As mentioned previously, the cutoff in IQ score that determines whether a student is classified as gifted is debated in the literature. For this reason, we conduct the analysis by considering other IQ thresholds. Online Appendix Figure A.6 displays the results when IQs of 135, 130, 125, 120, 115, and 110 are used as thresholds for classifying a child as gifted. In addition, we follow Card and Giuliano (2016) and use the threshold of 116 for nonnative speakers (130 for native speakers). We find that all the alternative thresholds are within the 95 percent confidence interval of the main estimate (IQ threshold of 130).[17] The results are also robust to using alternative definitions of giftedness, namely gifted students identified only by means of IQ testing (quantitative assessment) and gifted students identified only by means of qualitative assessment.

17. To allow for comparability across different IQ thresholds, we keep the estimation sample equal by running all regressions in Online Appendix Figure A.6 on the sample of students with IQ below 110 (29,862 observations).

Third, we check whether the same patterns occur for academic performance in other subjects. Online Appendix Figure A.7 presents estimates of the main specification for performance in natural sciences (biology, chemistry, and physics) and foreign language (English) as outcomes. These findings reinforce our conclusion that a gender gap in performance for STEM-related fields exists. Similar to math, female students perform relatively less well than male students in natural sciences and do not benefit as much from gifted peers for science-related subjects. In contrast, and similar to the pattern we found for language, female students do perform relatively better than male students in foreign languages. The evidence thus suggests that the pattern we uncover in the main analysis for math and (first) language also extends to other STEM and non-STEM subjects.

Fourth, teachers are often mentioned as crucial determinants of students' performance and preferences for particular subjects.[18] To test whether the gender heterogeneity documented in the main specification arises from teachers' own characteristics (either observed or unobserved), we repeat the main analysis by adding teacher fixed effects. By doing so, we change our strategy from within-school-year, between-classes identification to within-teacher, over-time identification. This change is imposed by the data because no teacher holds two classes in the same year.[19] The results, presented in Online Appendix Table A.4, show the peer effect estimates net of teachers' time-constant characteristics. We bring evidence that the results do not change when within-teacher estimations are conducted: both point estimates and significance remain very much like those presented in the main analysis. From these findings we surmise that teacher characteristics do not explain the gender heterogeneity documented in the main analysis.

One might be concerned that teachers adapt their (instructional) behavior depending on the presence or absence of gifted students in their class. If so, teacher fixed effects would not totally account for teachers' adaptation in behavior, teaching style, or teaching goals induced by the presence of a gifted student. Teachers in the presence of a gifted student might either adapt their teaching style towards the whole classroom or provide gifted students with personalized teaching. In the first case, teachers must weigh the interests of the gifted students with the interest of the other students and the composition of the classroom, which we control for in our estimation. In the second case, our estimates are immune to the effect of gifted students on themselves. In both cases, teachers do not know ex ante the gifted status of their students when they are assigned to a class, which would make any adaptation slow and more costly.

Finally, we investigate whether other students' characteristics could alternatively explain heterogeneous effects of exposure to gifted students in the classroom. As presented

18. For instance, Dee (2007) shows that assignment of children to a same-gender teacher improves their school achievement significantly (in terms of scores, student's engagement with the subject as well as teachers' perception of student performance). Carrell, Page, and West (2010) exploit random assignment to teachers in the U.S. Air Force Academy to document that, while males are not sensitive to the teacher's gender, having a fe male instructor increases females' performance in STEM and likelihood to choose a STEM-related career path (see also Mansour et al. 2018). Focusing on stereotypes, Carlana (2019) shows that teachers holding implicit negative stereotypes about female students' ability to excel in math have a negative and quantitatively significant influence on female students' performance and career choices. Similar evidence is documented by Alan, Ertac, and Mumcu (2018).

19. In practice, we specify the error term as $\varepsilon_{icst} = \pi_s + \phi_t + \eta_{cs} + u_{icst}$, where η_{cs} represents the teacher fixed effect (π_s and ϕ_t are school and time fixed effects, respectively).

in Online Appendix Table A.5, we document that relatively young students, students with a foreign language as their mother tongue, and students with a school teacher of the same gender do not react differently to gifted peers. By looking at class size, we find that the impact of gifted peers is slightly larger in smaller classes. This effect is significant (5 percent level) and might indicate that there are dilution effects of putting one gifted student in a large class. In our main specification, we account for this dilution effect by always adding class size as a control variable. In conclusion, we are confident that these channels do not tamper with our main results and that gender is the main driving force behind our findings.

B. Heterogeneity and Mechanisms

Provided that we uncover no source of heterogeneity other than the gender–subject result we have presented, what exactly drives the effect heterogeneity across gender, and why does the gender gap in math achievement widen when students are exposed to gifted peers? In this section, we explore several possible explanations for the peculiar gender–subject heterogeneity in the ability peer effect proposed by the scientific literature in economics, psychology, and education science.

In a first step, we try to understand which students are affected the most by the presence of gifted classmates. We look at quantile effects of the exposure to a gifted peer. In Figure 2, we estimate the treatment effect of the exposure to gifted peers for classmates belonging to a given percentile of the test score distribution. The figure plots (unconditional) quantile treatment effects (following Firpo, Fortin, and Lemieux 2009) and the respective 95 percent confidence intervals for different percentiles of the achievement distribution. We find that while exposure to a gifted peer has positive effects throughout the achievement distribution, students in the lower tail of the distribution do not benefit as much as students at the top. The peer effect reaches a peak around the eighth decile, indicating that high-achieving but nongifted students react the most to the presence of gifted peers. Not only do these findings point out that mainstreaming of high-ability peers in the classroom has positive peer effects for children who are academically strong—as already suggested by Card and Giuliano (2014) and Duflo, Dupas, and Kremer (2011)—but they also show that children on the lower end of the performance distribution benefit from such peers.

When we assess gender-specific impacts of being exposed to a gifted peer for children in different quantiles of the test scores distribution, we do not only find a gender penalty of having a gifted peer in math across the whole performance distribution, but also that this gender penalty appears to be significant primarily among female students at the bottom of the score distribution. Online Appendix Figure A.8 displays this pattern: the gender penalty is distinguishable from zero for the lowest three deciles of the test score distribution. Moreover, as suggested by our previous results, this penalty disappears in language achievement. In summary, both male and female peers in the upper tail of the achievement distribution are positively impacted by their exposure to gifted students. However, low-achieving female students seem to be relatively more negatively impacted than their low-achieving male counterparts in math. These results suggest that the widening of the gender gap might be driven primarily by decreased performance of low-achieving female students.

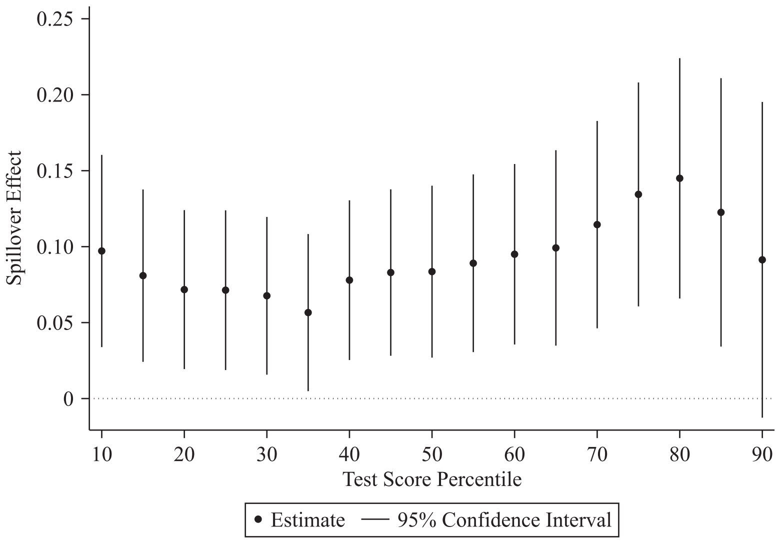

Figure 2

Quantile Treatment Effect of Exposure to Gifted Classmates

Notes: Data are from the School Psychological Service St. Gallen and the Stellwerk test service provider.

A possible—and much discussed—culprit for the reported gender difference in reaction to high-ability peers is the fact that male students and female students perceive competition differently (Iriberri and Rey-Biel 2019; Niederle and Vesterlund 2011). On the one hand, female students have a higher tendency than male students to experience test pressure, which puts them at disadvantage in standardized tests (for example, Gneezy, Niederle, and Rustichini 2003; Montolio and Taberner 2018; Saygin 2020). On the other hand, female students shy away from competitive environments (for example, Morin 2015; Niederle and Vesterlund 2007) because of lower self-confidence, lower academic self-concept, or lower willingness to compete against male students. This phenomenon is more prominent among high-ability students (Buser, Peter, and Wolter 2017; Preckel et al. 2008).

A further mechanism that could possibly explain the heterogeneous impact of gifted peers on both male and female students is a "role model" mechanism. Gifted students may be seen as a source of inspiration by their peers and may influence their peers' achievement and motivation positively, especially if the gifted students are themselves exemplary peers. In recent years, the presence of female role models—or the lack thereof—has been shown to have a significant impact on behaviors, preferences, and career choices of other female students and women, and it has emerged as a prominent explanation for the gender imbalance in STEM careers (Avilova and Goldin 2018; Buckles 2019; Porter and Serra 2020).[20] In this spirit, we investigate whether female students react differently

20. Female role models are defined as "women who can influence role aspirants' achievements, motivation, and goals by acting as behavioral models, representations of the possible, and/or inspirations" (Morgenroth, Ryan, and Peters 2015, p. 4).

Table 5
Spillovers by Gender of the Gifted

	Composite Test Score (1)	Math Test Score (2)	Language Test Score (3)
Panel A: Male Students			
Exposure to gifted male classmates	0.058**	0.075***	0.025
	(0.027)	(0.027)	(0.026)
Exposure to gifted female classmates	0.085**	0.094***	0.052
	(0.034)	(0.032)	(0.032)
F-test for equality of coefficients (*p*-value)	0.535	0.635	0.510
Panel B: Female Students			
Exposure to gifted male classmates	0.046	0.029	0.051*
	(0.029)	(0.028)	(0.027)
Exposure to gifted female classmates	0.105***	0.125***	0.055**
	(0.029)	(0.030)	(0.026)
F-test for equality of coefficients (*p*-value)	0.152	0.018**	0.921
Individual characteristics	Yes	Yes	Yes
Classroom characteristics	Yes	Yes	
School-by-year FE	Yes	Yes	Yes

Notes: Significance: *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$. Standard errors, shown in parentheses, are clustered at the classroom level. In Panel A, N = 14, 274; in Panel B, N = 16 203. Individual characteristics include gender, native German speaker, and age at test. Classroom characteristics include class size, share of females, share of native German speakers, and average age at test. Data are from the School Psychological Service St. Gallen and the Stellwerk test service provider.

to gifted female peers than to gifted male peers (and inversely). In addition, we look at whether gifted female or male students who are exemplary students influence their female and male peers more positively than disruptive gifted students.

In Table 5, we decompose the effect of exposure to gifted peers into exposure to gifted female students and gifted male students, and we estimate these effects on female students and male students separately. Note that we lower the IQ threshold to 115 for this analysis (one standard deviation above the mean instead of two) because the low prevalence of gifted students causes a loss of statistical power when using the 130-threshold. However, as presented previously in Online Appendix Figure A.6, the magnitude of the ability spillover is not greatly affected by the choice of the IQ threshold. We bring evidence that male students emulate their gifted peers irrespective of the gender of their gifted peers. As shown in Panel A of Table 5, coefficients of exposure to gifted male students are similar in magnitude to the coefficients of exposure to gifted female students. Interestingly, male students seem to be less affected by gifted peers when it comes to language: the size of the coefficient on language alone is twice as small as the coefficient on math. We conduct a simple F-test to show that the two coefficients are not statistically different from each other, which reinforces our conclusion that male students benefit from gifted peers irrespective of the gender of their gifted peer.

Turning our attention to female students, we find that female students react strongly to the gender of their gifted classmates. Panel B of Table 5 documents that female students react much less when they are exposed to gifted male students; however, they strongly react to the exposure to other gifted female students (around 10 percent of a standard deviation in overall test score). The only exception is in language, where female students are positively affected by gifted male students as much as by gifted female students. For math, we can conclude that female students are responsive to the gender of their gifted peer and that they experience a positive influence in the presence of gifted female students. Once again, we stress the fact that the presence of a gifted female student in a classroom is as good as random, allowing us to draw causal conclusions from our quasi-experimental setting. Not only is this finding in line with the above-mentioned literature, but it also adds valuable understanding on the importance of same-gender role models.

So far, we have implicitly assumed that all gifted students are "good peers," in the sense that they positively affect and influence their peers. However, this might not be true, especially if gifted students suffer from emotional, behavioral, or social problems and disrupt the classroom. Evidence that psychological disorders, such as ADHD, negatively impact academic performance, increase the tendency to underachieve, and impair executive functioning of gifted individuals as much as nongifted individuals is well documented (Antshel et al. 2008; Brown, Reichel, and Quinlan 2009; Gomez et al. 2019; Mahone et al. 2002).[21] It is therefore important to distinguish between gifted children who, by their disruptive behavior, are less likely to be seen as exemplary students by their peers and gifted students who are more likely to foster productivity and generate positive externalities in the classroom.

Having information on the psychological profile of each child sent to the School Psychological Service, we identify gifted students who have been also referred for exhibiting behavioral, emotional, or social difficulties (12.3 percent of all gifted students, see Table 1). Children with such difficulties are usually referred to the SPS for disrupting the classroom or for showing mental or emotional problems. In terms of school performance, we find no visible difference in the distribution of test scores for gifted children with and without emotional or behavioral disorders (see Online Appendix Figure A.10).

As presented in Table 6, we find that gifted children with emotional issues have a statistically insignificant influence on their peers, despite the negative sign of the coefficient. When looking at the effect of the presence of gifted children without emotional difficulties, the effect is not only significantly positive, but also 25 percent larger than the

21. Gifted students who suffer from other mental health disorders are also referred to as "twice-exceptional." There is a debate in the literature in psychology on whether gifted individuals are relatively more likely as the general population to develop psychological disorders (such as ADHD, anxiety, and mood disorders) or depression. Some researchers suggest that gifted individuals are more inclined to developing such disorders and defend an "overexcitability perspective," such as Karpinski et al. (2018), who survey adult members of Mensa (the largest and oldest high IQ society in the world, which is open to people who score at the 98th percentile or higher on a standardized, supervised IQ or other approved intelligence test), whereas others argue that the prevalence of psychological disorders is not higher among the gifted (for example, Peyre et al. 2016).

Table 6
Exposure to Gifted with and without Social, Behavioral, or Emotional Difficulties

	Composite Test Score (All Students) (1)	Composite Test Score (Male Students) (2)	Composite Test Score (Female Students) (3)	Composite Test Score (All Students) (4)
Exposure to gifted with difficulties	–0.045	–0.022	–0.076	0.009
	(0.047)	(0.057)	(0.061)	(0.053)
Exposure to gifted without difficulties	0.123***	0.166***	0.075**	0.139***
	(0.024)	(0.029)	(0.031)	(0.027)
Female	–0.181***			–0.170***
	(0.015)			(0.016)
(Exposure to gifted with difficulties) * (Female)				–0.110**
				(0.055)
(Exposure to gifted without difficulties) * (Female)				–0.029
				(0.028)
Individual characteristics	Yes	Yes	Yes	Yes
Classroom characteristics	Yes	Yes	Yes	Yes
School-by-year FE	Yes	Yes	Yes	Yes
Observations	31,187	14,709	16,478	31,187

Notes: Significance: $*p < 0.10$, $**p < 0.05$, $***p < 0.01$. Standard errors, shown in parentheses, are clustered at the classroom level. Individual characteristics include gender, native German speaker, and age at test. Classroom characteristics include class size, share of females, share of native German speakers, and average age at test. Data are from the School Psychological Service St. Gallen and the Stellwerk test service provider.

effect of exposure to all gifted children together. This suggests that only gifted peers who are not disturbing the classroom environment have positive impact on their peers; disruptive high-ability peers at best have no impact and at worst put their peers' performance in jeopardy. This finding can be made even more salient when we analyze which students in the test score distribution are affected. Online Appendix Figure A.9 shows, on the one hand, that gifted children with emotional issues do not affect their peers (although there are significant negative effects around the median). On the other hand, gifted children without disruptive tendencies positively inspire all their peers towards better performance, with the effect being slightly larger among high-achievers—as in our main analysis.

In addition, we find that female students are more sensitive to the presence of disruptive gifted students than male students. Whereas male students are not affected by the presence of gifted peers with behavioral, emotional, or social issues, female students react strongly and negatively. Column 4 of Table 6 reports the interaction effects of being a female student with the exposure to an emotionally unstable gifted peer. Female students perform dramatically less well when they are put in the same class as an emotionally unstable gifted student (about 28 percent of a standard deviation less than male students), while male students do not react at all to the same gifted peers. However, both male students and female students react positively to the presence of gifted peers who do not have emotional issues, and there is no statistically significant gender difference in this respect.[22]

In sum, our results strongly suggest that both the quality of high-ability spillovers and the sensitivity to disruption play a role in the widening of the gender gap for students exposed to gifted peers. In fact, being exposed to gifted classmates is no guarantee of improved school performance. Instead, the way high-ability peers behave in class is a critical factor for the development of virtuous spillover effects, especially when it comes to spillovers on female students. Our empirical findings are consistent with both the role model interpretation and previous research on the detrimental effects of disruptive students (for example, Carrell, Hoekstra, and Kuka 2018).

C. Trajectories after Compulsory Education

Although the results presented here already have far-reaching educational policy consequences, the question remains whether the impact that gifted students have on their peers is limited to academic achievement during the time spent together or whether it has longer-term consequences beyond that time? Linking our data with administrative data of the educational system allows us to follow the educational career of around 75 percent of students beyond the period of compulsory schooling. Attrition is almost exclusively due to individuals not having yet completed compulsory education (that is, the last two school cohorts in the data). Specifically, we are interested in whether the presence of a talented peer in the class influences the peers' educational choices. In Switzerland, tracking into a vocational track or academic track occurs after compulsory education, when students are about 16 years old. A minority (less than 20 percent) of the students opt for the selective academic track (baccalaureate schools), and the majority

22. The same patterns discussed here hold if we perform the analysis for math and language separately.

Table 7
Post-Compulsory Education Trajectories

	No Post-Compulsory Education Started (1)	Academic Track Started (2)	Vocational Track Started (3)	Vocational Occupation In STEM Field (4)
Panel A: Full Sample				
Exposure to gifted classmates	0.003	0.029***	–0.032***	0.029***
	(0.006)	(0.010)	(0.010)	(0.009)
Panel B: Male Students				
Exposure to gifted classmates	–0.004	0.041***	–0.037***	0.054***
	(0.008)	(0.012)	(0.012)	(0.016)
Panel C: Female Students				
Exposure to gifted classmates	0.013	0.015	–0.027**	0.001
	(0.008)	(0.013)	(0.013)	(0.006)
Individual characteristics	Yes	Yes	Yes	Yes
Classroom characteristics	Yes	Yes	Yes	Yes
School-by-year FE	Yes	Yes	Yes	Yes

Notes: Significance: *$p < 0.10$, **$p < 0.05$, ***$p < 0.01$. Standard errors, shown in parentheses, are clustered at the classroom level. Number of observations for Columns 1, 2, and 3: in Panel A, $N = 25{,}353$; in Panel B, $N = 12{,}036$; in Panel C, $N = 13{,}317$. Number of observations for Column 4: in Panel A, $N = 14{,}205$; in Panel B, $N = 7{,}241$; in Panel C, $N = 6{,}964$. Individual characteristics include gender, native German speaker, and year of birth. Classroom characteristics include class size, share of females, share of native German speakers, and average age at test. Data are from the School Psychological Service St. Gallen, the Ministry of Education of the canton of St. Gallen, and the Stellwerk test service provider.

(two-thirds of a cohort) choose a vocational track, which in the region under observation is usually offered in the form of apprenticeships.[23]

By looking at whether students choose an academic track, a vocational track, or no post-compulsory education at all, we examine whether being exposed to gifted students has longer-run effects. Results are presented in Table 7, divided into three binary outcomes as follows: no post-compulsory education started, vocational track started, and academic track started. In each regression, the reference category is always the other two trajectories combined, in order to avoid conditioning on downstream outcomes.

We find that being exposed to gifted classmates in secondary school significantly increases the likelihood of choosing the academic track. Interestingly, this effect is entirely driven by male students who enter the academic track instead of the vocational one. No effect is found for female students, except for a small and marginally significant

23. A detailed overview of the Swiss education system can be found here: https://www.edk.ch/en/education-system-ch/general-information/graphic (accessed July 28, 2022).

negative effect on the probability of starting vocational education. In general, we find that exposure to gifted peers during secondary school does not change the probability of pursuing any post-compulsory education degree. This result is expected, given our previous findings that low-achieving students are less affected than high-achievers by the presence of gifted students.

We complement the results by looking at whether exposure to gifted peers affects the choice of vocational career for those students starting Vocational Education and Training (VET). We use data from on the exact values of the apprenticeship requirement level ratings.[24] These ratings are made by experts who assess the requirement content of each VET occupation along the following dimensions: math, science, first language, and foreign language.[25] We code a VET occupation as "STEM-intensive" when its curriculum content in math and science belongs to the top quartile of the math and science content distribution among all occupations. When focusing on vocational education, we find that exposure to gifted students in the classroom increases the enrollment in STEM-intensive occupations among students who choose a vocational career. Again, we find that only male students are the ones affected by the exposure to gifted peers when choosing their vocational occupation. Our results are in line with recent evidence that peer characteristics during adolescence influence important career decisions (Anelli and Peri 2017; Black, Devereux, and Salvanes 2013; Carrell, Hoekstra, and Kuka 2018). They also highlight the importance of peer quality on the decision to pursue STEM-related careers among females, as highlighted by Mouganie and Wang (2020) and Card and Payne (2017).

However, unlike Mouganie and Wang (2020), who examine high school students in China, we do not find a negative effect of high-ability male students on women's likelihood to choose a science track during high school. One obvious explanation for this discrepancy is the difference in the institutional setting. Another difference is that we focus on gifted students, a population with higher ability on average but with heterogeneous school achievement. Thus, our results constitute an important complement to the findings for high-ability students in China.

V. Conclusion

This study sheds light on the relevance of gifted students and their heterogeneous spillover effects in the classroom. Heterogeneity is observable in at least three dimensions. First, not all gifted students impact their peers in the same manner, but the impact depends on the gender of the gifted student and also on whether gifted students show behavioral problems or not. Second, not all peers are affected in the same way, but effects differ by gender and ability of the peers, and third, peers are not affected in the same way in all subjects. We find that while male students benefit from the presence of gifted peers in all subjects regardless of their gender, female students benefit primarily from the presence of gifted female students. The nature of our data allows us to test a

24. Attrition on the data on occupational profiles is almost exclusively due to the impossibility of merging our data with the corresponding apprenticeship requirement level ratings (see Online Appendix Table A.2).

25. These data are the product of an initiative by the Swiss Cantonal Ministers of Education, with financial support of the State Secretariat for Education, Research, and Innovation (SERI).

number of potential mechanisms. We show that neither teachers nor classroom composition are responsible for driving the heterogeneity in the ability spillovers. Instead, we present suggestive evidence consistent with the hypothesis that academic role models and classroom behavior are important determinants of the gender gap in math.

Moreover, our results suggest that exposure to gifted students has powerful, lasting effects on career choices and post-compulsory education. The presence of gifted students in the classroom is a catalyst for pursuing an academic track or STEM-intensive vocational training. However, this catalytic effect is found to perpetuate (and even deepen) the gender gap in the likelihood of choosing occupations that require higher STEM skills. Indeed, men react to the presence of gifted peers by taking up STEM-intensive occupations, whereas women do not. With the disclaimer that our results measure the peer effect of *identified* gifted students, we corroborate existing evidence that social environment affects women's STEM career choices as early as high school.

In general, we find that gifted students are influential in fostering emulation and positively impacting the academic achievement and the career choices of their peers. They are therefore fundamental forces in the classroom production function that should not be ignored in designing successful educational policies, especially when considering whether gifted students should be segregated in more "elite" schools or pull-out programs. We also show that giftedness alone is no guarantee for positive externalities: gifted students diagnosed with socioemotional problems generate null-to-negative spillovers on their peers.

In terms of classroom composition policies in an inclusive education system, our results offer two major insights. First, it is desirable to spread gifted students without behavioral problems evenly throughout classrooms. This reassignment scheme would ensure that nongifted students have increased chances of being exposed to nondisruptive gifted students and benefit from positive learning spillovers. Second, reassignment policies should allocate disruptive gifted students randomly to classrooms because doing so would ensure that nongifted students have random chances of being exposed to disruptive gifted students, which is in line with the principle of equality of chances. These recommendations come, however, with one important caveat. Our models estimate the effect of gifted peers on nongifted students, but they do not provide us with the effect of gifted peers on fellow gifted students. As such, we miss an important ingredient of sound reallocation policies, that is, how much gifted students themselves benefit—or not—from each other and from their nongifted peers. Therefore, further research calls for a better understanding of optimal classroom allocation, possibly balancing the positive spillovers from high-ability students with negative spillovers from disruptive students.

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