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Adams and Eves: High school math and the gender gap in Economics majors

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Abstract

Why so few women graduate in Economics? We investigate the gender gap among Italian university graduates in Economics between 2010 and 2019. With women's probability of graduating in Economics being 27% lower than men's, the gap is larger than in Business and even STEM. The association between the gender gap and the mathematical content of high school curricula is especially strong in Economics. A triple difference analysis shows that a reform raising the mathematical content of traditionally low math curricula caused an increase in the gender gap, with women's probability of graduating in Economics decreasing by 12 percentage points.

KEYWORDS

Business Economics, Economics, education gender gap, higher education, major choice, mathematics, stereotypes

JEL CLASSIFICATION

I23, J16, A22

1 | INTRODUCTION

"Adams" is the name assigned to an anonymous college that first provided administrative data for a project launched by Claudia Goldin in order to understand why there are so few women majoring in Economics (Avilova & Goldin, 2018; Goldin, 2015). Then and now, at Adams and worldwide, women disproportionately do not major in Economics and, quoting Goldin (2015):

> Exactly why males decide to major in economics far more so than females [...] remains somewhat of a mystery.

Abbreviations: DD, difference-in-differences; DDD, triple difference; GEMP, Geoscience, Economics, Engineering, Math and Computer Science, and Physical Science; LPS, Life Science, Psychology, and Social Sciences; LS, Life Sciences; MIUR, Italian Ministry of Education; OECD, Organization for Economic Co-operation and Development; PE, Physical Sciences and Engineering; PNR, Piano Nazionale per l'Informatica; STEM, Science, Technology, Engineering and Mathematics; UNESCO, United Nations Educational, Scientific and Cultural Organization; UWE, Undergraduate Women in Economics.

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In OECD countries, women attain a higher level of education than men, on average (OECD, 2021). In 2020, 42% of women aged 25–64 hold a tertiary degree, against 35% of men of the same age. In the same year, among the 25- to 34-year old, 52% of women are tertiary-educated against 39% of men. Thus, the expansion of tertiary education in industrialized countries has largely benefited women. However, the reversal of deeply entrenched gender gaps in education has occurred despite a persistence of visible imbalances in the choice of major. The fact that women are unrepresented in STEM fields has long attracted the attention of scholars, policymakers, and the media, but the presence of similar or even larger gaps in Economics has instead been surfacing much more recently, despite their repercussions for women's occupational and earnings prospects and overall economic efficiency.

The available studies on the gender gap in Economics have thus far mostly focused on the US, so that even less is known about the European case. Yet, a peculiar feature of Economics curricula within the European university system is that they often overlap with those in Business Economics (hereafter, Business), despite the typically lower mathematical intensity and higher marketability of the latter. In the Anglo-Saxon system, instead, the two degrees are usually offered by separate university divisions (namely, schools of arts and sciences for Economics and business schools for Business). The partial overlap, in Europe, between Economics and its likely closest substitute may lend support to the expectation of a narrower gender gap in the former, whose extent and causes call for an investigation.

Among the determinants of gender gaps in major choice, mathematics requirements play a potentially crucial role, since as is well known they can deter women from choosing STEM degrees, while they might encourage them to go for Business rather than Economics. Again, a peculiar feature of the European system is that, unlike in the US, major choice is made prior to college enrollment. Hence, rather than the requirements within college curricula, that may deter women from majoring in Economics after being exposed to math in introductory courses, it is the math content of high school curricula—which displays considerable variation across school types—that can play a crucial and largely neglected role, which we intend to investigate.

In a nutshell, the scope of this paper is to shed new light on why "Adams" outnumber "Eves" among Economics majors in a European context. We base our empirical investigation on the AlmaLaurea dataset, a rich dataset which provides annually administrative and survey information about the near-universe of Italian graduates from the public university system. We focus on cohorts graduating between 2010 and 2019. The data include information on field of graduation, enrollment year, region of residence, high school type and graduation grade, parents' education and occupation, and students' motivations, which we complement with local level macroeconomic indicators such as the fertility rate and the employment rate.

First, we present stylized facts to assess the size, time evolution, and geographical distribution of the gender gap in Economics and also in all other fields, with special attention to Business. Since women outnumber men among graduates overall, a measure of the gap must be weighted. Thus, we compute the gender gap in a given field as the share among females of graduates in the field minus the same share among males, divided by the latter. Parity corresponds to a gender gap equal to zero (i.e., the same share among females and among males). On average over the period, the gender gap in Economics is equal to −0.405, that is, women are almost 41% less likely than men to graduate in Economics. In other words, only six women graduate in Economics for every 10 men graduating in the field, expressed relative to their numbers as degree recipients. The size of the gap is largest in Economics, compared to all other fields, including a broad definition of STEM.[1]

Second, we collect descriptive evidence to investigate the correlates of the observed gaps. We start with logit regressions where the dependent variable is the choice to graduate in Economics and controls include gender, region of residence and enrollment year fixed effects, and a broad set of covariates. We find a significantly negative association between being female and the probability to graduate in Economics: In a fully controlled specification, the estimated gender gap (i.e., the probability of graduating in Economics among females minus the same probability among males, divided by the latter) implies that women are 27% less likely than men to graduate in field. Among the covariates, our focal one is the math content of high school curricula. We find that it carries by far the highest explanatory power on the gender gap in Economics, while factors such as parents' characteristics and students' motivations only play a marginal role. Thus, the Economics gender gap is heavily influenced by decisions made by girls early on at age 14 when they choose between high school tracks, at least five years before enrolling at university.

In order to study the decision to major in Economics within a broader perspective accounting for the entire menu of available choices, we also run multivariate logit regressions where the dependent variable is a categorical reflecting four fields. Strikingly we find that, in the fully controlled specification, Economics displays the largest gender gap. STEM majors follow next, with women being 21% less likely than men of being STEM graduates, despite heterogeneities across majors and the gender gap peaking for Engineering. Women are 19% less likely than men of graduating in Business, while a strong reversal occurs in the Humanities, where graduations among women are 42% more likely than among men. To dig deeper into the role played by the high school math background, we perform a decomposition analysis using the Gelbach (2016) methodology. We uncover that, uniquely for Economics, the variation in the explained part of the gender gap is entirely influenced by the high school math background.

Third, in order to identify a causal relation between high school math and the gender gap in Economics, we take advantage of a high school reform that altered math requirements only for certain high school types and apply a quasi-experimental difference-in-differences (DD) approach. In our setting, the treated group is represented by university graduates coming from traditionally low math schools, with university graduates coming from high math schools representing the control group. The treatment, in the form of an increase in the hours of math being taught, is applied to students who enroll at university starting from 2015, so that within our sample we can observe the first and (part of) the second cohort of post-reform university graduates. Since our goal is to establish whether the reform induced gendered effects, that is, to assess a differential treatment effect between females and males, we apply a triple difference (DDD) approach. Our results point to a causal negative effect of the reform on Economics enrollments among treated females, with a less than compensating positive effect among treated males, resulting in a negative net treatment effect. Furthermore, an event study version of the DDD estimator validates our identification strategy by assuring the presence of parallel trends between treated and untreated students prior to the reform and, at the same time, allows to establish that the impact already manifests itself in the first post-treatment year, 2015, and becomes even stronger in 2016. Cumulatively, it implies an amplification of the gender gap in the post-treatment period involving a decrease of 12 percentage points in the likelihood of graduating in Economics among females from traditionally low math schools. In other words, increasing the math content of traditionally low math schools makes Economics even less attractive to female students coming from that background. Strikingly, for the other fields, the DDD estimates show instead a zero (placebo) effect on the gender gap, making the gendered impact of the reform a unique feature of Economics. Furthermore, heterogeneities in treatment impact emerge along several dimensions. Namely, the impact is driven by treated females with above median high school grade and is stronger with a more affluent family background as captured by parents' education and occupation.

Taken together, our results suggest that, on the one hand, the gender gap in Economics majors is smaller among students who attended high math schools and that, on the other, imposing more math in the other schools actually increased the gap. One explanation of these combined findings is that the key issue is not just the mathematical knowledge acquired in high math schools but rather selection into such schools. Another, potentially overlapping explanation is that the math content does matter, but the context in which additional math is introduced also does. Hence, our results allow to draw a distinction between the unobservable characteristics that lead students and families to choose certain high schools and the actual content of what is taught at those schools.

The paper is structured as follows. Section 2 reviews the relevant literature. Section 3 describes the data. Section 4 presents descriptive evidence. Section 5 presents a triple difference analysis of a high school reform that increased the math content of traditionally low math schools. Section 6 discusses our results and Section 7 concludes. A series of online appendices contain additional tables, figures, and extensions.

2 | LITERATURE REVIEW

While gender gaps in college graduation from STEM fields have been widely acknowledged and researched (Bertocchi & Bozzano, 2020; Delaney & Devereux, 2021; Kahn & Ginther, 2018; UNESCO, 2017), the presence of significant gaps in Economics is relatively less explored, despite early accounts such as Dynan and Rouse (1997). In the US, the share of Economics majors who are females is lower than in Chemistry, Mathematics, and Statistics. Moreover, while the highly male-dominated field of Engineering has witnessed an increase in the female share in the past decades, scarce progress has been detected for Economics (Avilova & Goldin, 2018; Bayer & Rouse, 2016). Using Eurostat data for 25 European countries over the period 2013–2018, Megalokonomou et al. (2021) report that, consistent with US data, the Economics gender gap has been stable or increasing over time, and higher than for Business. STEM performs worse but shows a mild improvement over the period. The consequences of a reluctance of girls to enroll in Economics majors affect multiple realms such as their occupational and earnings prospects and their ability to develop a career, including an academic one (Bertocchi, 2020; Lundberg, 2020; Lundberg & Stearns, 2019), as well as overall economic efficiency.

Several explanations for the gender gap in Economics majors have been suggested, including interest in the subject, expected marketability, mathematics aptitudes and training, parents' beliefs and expectations, availability of role models, teaching and assessment methods, grade sensitivity, classroom climate, and representation of women in textbooks. Allgood et al. (2015) review the available research on teaching Economics to undergraduates and conclude that the gap remains an unsolved puzzle. Subsequent contributions include Tonin and Wahba (2015) who, based on UK administrative data, rule out the hypothesis that universities discriminate against female applicants along the admission process, possibly because women are perceived as less competent in the discipline, or out of fear that they are less likely to accept an offer due to the low ranking of Economics in their preferences. Based on a field experiment performed at a US college, where students taking Economics introductory classes were exposed to successful women who had majored in Economics at the same college, a beneficial influence of female role models has been found by Porter and Serra (2020). However, over a panel of US institutions Emerson et al. (2018) find no evidence that female faculty attract female students to Economics majors. The effectiveness of nudges (consisting for instance in encouraging messages) is also controversial, as shown by field experiments conducted in the US: Li (2018) finds a positive effect on female students' probability of majoring in Economics,[2] but Pugatch and Schroeder (2021) report no such effect. Recent papers signal that making introductory courses more attractive represents a promising avenue: Using institutional US data Ahlstrom and Asarta (2019) show that persistence in studying Economics for female students increases with this intervention; Bayer et al. (2020) present a case study on a newly designed introductory course—based on innovative teaching methods and content presentation—that nearly achieved a gender balance; Avery et al. (2021) report about an intervention on the content and structure of an introductory course that greatly reduced the gender gap in the likelihood of continuing on with Economics.

Among the determinants of gender gaps in major choice, the mathematics background—together with the stereotypes associated with female mathematics aptitudes (Guiso et al., 2008)—plays a potentially crucial role, which has been investigated with reference to STEM (Card & Payne, 2020; Chise et al., 2021; Granato, 2023; Tchuente, 2016), but not as much to Economics. Exceptions are Emerson et al. (2018), who show that quantitative requirements within college curricula deter women from majoring in Economics, and Ahlstrom and Asarta (2019), who expose a gendered asymmetry in Economics degree selection, such that men's is correlated with math aptitudes, while women's is correlated with both math and verbal ones. The high math intensity content of Economics curricula is stressed by Kahn and Ginther (2018) who, as an alternative to STEM (i.e., Science, Technology, Mathematics and Engineering), introduce the taxonomy of GEMP (Geoscience, Economics, Engineering, Math and Computer Science, and Physical Science) versus LPS (Life Science, Psychology, and Social Sciences)—excluding Economics—based on different math requirements. They also argue that the drivers of gender gaps in mathematical ability are not biological differences but psychological and cultural factors that manifest themselves both at home and at school through negative gender stereotypes proposed by family, teachers, and peers. The fact that high school teachers' negative gender stereotypes cause an increase in the gender gap in math performance is reported by Carlana (2019), while the influence of parents and peers is choosing gender-stereotypical subject (such as literature for girls and math for boys) is explored by Carlana and Corno (2021).

The causal impact on major choice of reforms aimed at increasing the math content of high school curricula has been examined only with reference to STEM. Gorlitz and Gravert (2018) and Biewen and Schwerter (2022) show that a German reform led to asymmetric gendered effects, with females reacting less than males or even negatively. Joensen and Nielsen (2016) and De Philippis (2021) reach contrasting conclusions on the effect of programs targeting high ability students, respectively in Denmark and the UK: While the latter's results align with those previously reported for Germany, the former report a shift for females toward more math intensive fields.

The literature on the determinants of college major choice is surveyed by Patnaik et al. (2021), while Zafar (2013) focuses on the involved gender gap to show that males care about pecuniary outcomes in the workplace more than females. Anelli and Peri (2015) relate gender differences in major choice to differences in psychological attitudes toward competition and altruism: Since women tend to be less competitive and more altruistic, they are driven to more socially oriented majors (Education, Social Sciences) rather than profit oriented ones (Engineering, Business). Anelli and Peri (2019) find evidence of an influence of high school experience, with male students being more likely to choose high-paid majors if they attended high school classes with a large male share, while class gender composition is not so important for women. They also suggest that recommendation of college majors by teachers—which is very gender-biased—exerts a strong impact of students' choice. A role for self-confidence is suggested by Bordón et al. (2020), who find that males apply to selective programs even when they are marginal candidates, while equally qualified female candidates tend to apply less often to these programs.

Turning to major switches, Astorne-Figari and Speer (2019) discover that students switch to majors where their gender is more represented, so that females tend to switch to female-heavy majors. Moreover, women are more likely to leave STEM fields for less competitive majors. Kugler et al. (2020) show that women switch out of a major more often than men only when they experience a combination of low grades on the one hand and, on the other, a prevalence of men or else a major's reputation for being stereotypically male-oriented. Emerson and McGoldrick (2019) concentrate on major switching into and out of Economics within the course of US four-year degrees and find that females from other majors are less likely than males to switch into Economics. Regarding college dropouts, a review of the international literature provided by Aina, Baici, et al. (2022) indicates that across all majors men tend to drop out of university more often than women, despite exceptions. Within a variety of Italian samples, this tendency is confirmed by Aina (2011, 2013) but the reverse occurs in Belloc et al. (2010) for Economics and Business students, while in Aina, Lombardi, and Mussida (2022) women drop out more frequently in Economics and men do so in Business.

The next three papers investigate the specific choice between Economics, Business, and related majors within a European institutional context. Aina, Lombardi, and Mussida (2022) find that, after their first year in college, female students are more likely than male to switch from Economics to Business but less likely to do the opposite, despite the absence of differences in students' pre-enrollment characteristics. Within an Economics bachelor program, Arnold (2020) examines differences in major choice among Economics subfields and shows that female students are strongly underrepresented in Finance and overrepresented in Accounting. Zölitz and Feld (2021) investigate how the gender composition of peers affects women's and men's choices within business schools. They find evidence of gender segregation, as women assigned to teaching sections with more female peers are less likely to choose male-dominated majors (like Finance) and more likely to choose female-dominated ones (like Marketing). Men instead, when exposed to more female peers, are more likely to choose male-dominated majors and less likely to choose female-dominated ones.

3 | DATA AND DESCRIPTIVE STATISTICS

We use stacked cross-sectional data from the AlmaLaurea survey covering the 2010–2019 cohorts of graduates from Italian public universities (the *Profilo dei Laureati* survey).[3] The dataset collects students' responses, upon graduation, to a detailed questionnaire concerning the place of residence at graduation and birth, characteristics of students' educational career both at high school and university, the level of education of both parents and their last occupation, and students' expectations and motivations on their studies and future jobs. The dataset is complemented by administrative information provided by universities.[4]

The coverage of the AlmaLaurea data increases during the period, from 57 to 78 universities, from 192,358 to 280,230 respondents, and from 67% to 90% of all Italian graduates.[5] We focus on graduates from the first level university degrees they can access right after high school, that is, the population of students who graduated from either a three-year degree program (called *Laurea*, corresponding to a bachelor's degree) or from a five- or six-year degree program (called *Laurea magistrale a ciclo unico*, or single cycle master's degree). The sample includes 1,489,048 graduates.[6]

We split upper secondary schools according to the relative weight of the mathematical, scientific or technological content of their curricula, to build a binary variable, denominated High School Math, that takes value one when the content is relatively high, and zero otherwise.[7] Among university fields, we separately consider Economics and its potential closer substitutes, that is Business,[8] and we group the other disciplines into two macro-fields: STEM and Humanities.[9]

Finally, we extract yearly data on fertility and employment rates at a local level from the ISTAT database[10] and merge them with the AlmaLaurea data on the basis of the place of residence at graduation and the year of enrollment. We employ the fertility rate as a proxy for women's sexual emancipation (see Braga & Checchi, 2008) while the employment rate is meant to measure the extent to which available labor resources are being used.

Table A1 in Appendix A presents variable definitions and Table A2 summary statistics. The share of women graduating in Economics, out of all female graduates, is nearly half the corresponding share of men. The share of graduates in Business and STEM subjects is also lower among females than among males, even though to a lesser degree compared to Economics, while the reverse occurs in the Humanities. To visualize differences in graduation rates between females and males in each field in the raw data, in Figure 1 we rely on a weighted measure of the gender gap, computed as females graduating in a given field over total females minus the same share among males, divided by the latter.[11] The resulting ratio indicates the weighted proportion of female graduates below or over parity with respect to male graduates. Parity corresponds to a difference of zero, with the same shares of graduates among females and among males. As shown in Figure 1, graduations in Economics are 41% less frequent among females than among males. They

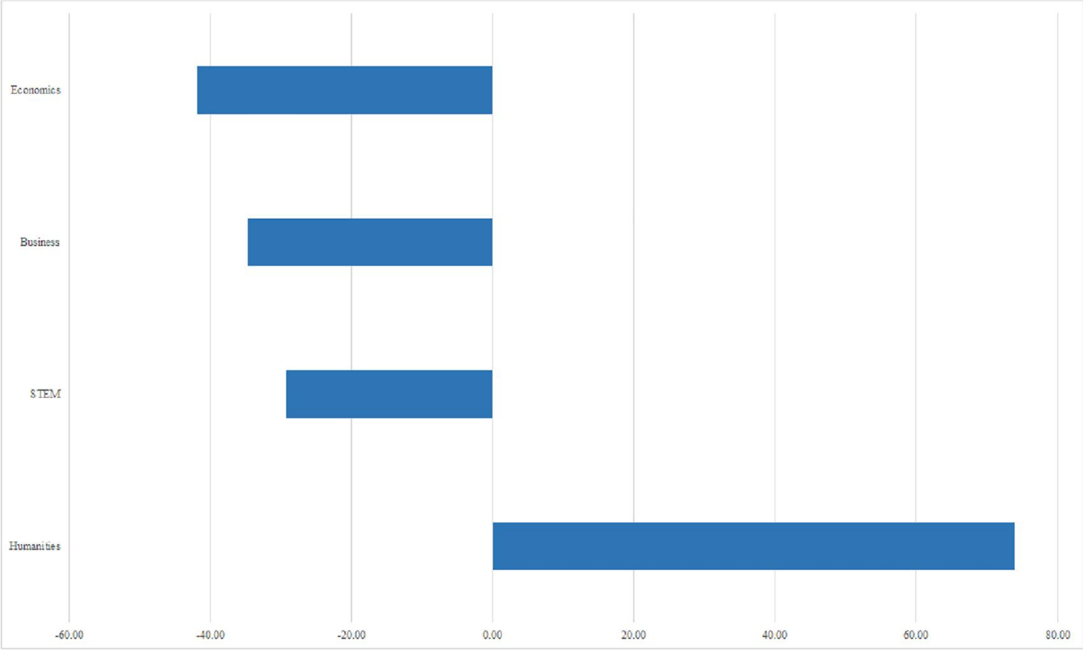

FIGURE 1 The gender gap by field. The gender gap is a weighted measure computed from sample data as (share in field j among females − share in field j among males)/share in field j among males, where j = Economics, Business, STEM, Humanities. It indicates the weighted proportion of females below or over parity with respect to males. Parity corresponds to a zero value, with the same shares of graduates among females and among males.

are 35 and 30% less frequent, respectively, in Business and STEM, while they are 71% more frequent among females in the Humanities.

As shown in Figures A1 and A2, the distribution of female and male students across fields varies with time and space, but the above mentioned stylized facts are persistent and widespread across areas. To be noticed is that, during the sample period, the negative Economics gender gap is widening. Business displays a similar, albeit attenuated trend, while the trend is constant in STEM. The Humanities, on the other hand, witness an increasing gender gap of positive sign. Across macro-regions, the gap in Economics is largest in the Center and lowest in the North-West.

Further inspection of the summary statistics in Table A2 reveals that females are much more likely than males to attend a high school with a low math content and to obtain a higher exit grade. Females are also slightly more likely than males to undertake a single cycle degree.

Since the AlmaLaurea data are conditional to graduating, they do not contain information about those students that enroll at university but do not graduate, so that the extent to which students drop out of college cannot be observed. In order to assess how the subsequent analysis can be affected by this ex-ante selection, which could vary with gender and major, we collect from the Italian Ministry of Education (MIUR) aggregate administrative data on the universe of yearly enrollments and graduations, by gender and major, in the period 2010–2019.[12] By comparing yearly enrollments in 2010–2016 with yearly graduations in 2013–2019 (i.e., by comparing enrollments at year t with graduations at year $t + 3$), we compute a proxy measure of dropouts as the difference between the overall share of enrollments and the share of graduations 3 years later. The corresponding differences by gender and macro-field are weighted by the respective overall shares. The data reveal that, overall, the frequency of dropouts is lower among females. Across fields, dropout rates are above average in Economics, followed by Business and STEM, especially among females. Conversely, dropout rates are below average in the Humanities, especially among men. Namely, on average over the seven academic years that we can observe in the MIUR data, women are 35.1 less likely than men to enroll in Economics, and 39.7 less likely to graduate in the field.[13] Hence, part of the gender gap at graduation is correlated with events occurring after enrollment. If dropout rates were equal across genders, then there would be more females at graduation, especially in Economics, and the gender gap in the field would be slightly smaller than the one captured by the AlmaLaurea data. This conclusion is validated by a comparison between the MIUR and AlmaLaurea samples of Economics graduates since, against the 39.7% lower proportion among females in MIUR, as shown in Figure 1 we count a lower relative proportion of 40.5 in AlmaLaurea. Hence, AlmaLaurea only slightly overestimates the gender gap in Economics graduations, relative to MIUR.

4 | DESCRIPTIVE EVIDENCE

We start by estimating the correlates of the decision to graduate in Economics, rather than in another field, with a logit specification which can be formally outlined as follows:

$$Economics^*_{igsypu} = \alpha + \delta_y + \delta_r + \beta Female_g + X_i'\chi + Z_{yp}'\zeta + \epsilon_{igsypu} \quad (1)$$

where $Economics^*_{igsypu}$ is a latent variable and $Economics_{igsypu}$ is a binary variable observed according to the rule:

$$\begin{cases} Economics_{igsypu} = 1 \text{ if } Economics^*_{igsypu} > 0 \\ Economics_{igsypu} = 0 \text{ if } Economics^*_{igsypu} \leq 0 \end{cases}$$

where $Economics_{igsypu}$ takes value one if student i of gender g from school type s, enrolled in year y and residing in place p at time of graduation from university u, graduates in Economics, and zero if student i graduates in another field. We control for enrollment year and region of residence at graduation fixed effects, respectively δ_y and δ_r, in order to capture unobserved characteristics that vary at such levels.[14] The key regressor is $Female_g$, a binary variable taking value one if student i is female, and zero if male. The coefficient β will capture the impact of gender on the probability to graduate in Economics rather than in any other field. X_i includes other individual characteristics, namely, the math content of the high school curriculum, the high school exit grade, mothers' and fathers' education and occupation, and cultural and work-related motivations regarding the degree choice. Z_{yp} includes two macroeconomic indicators, the municipality level fertility rate and the province level employment rate, both measured in the year of enrollment. The error ϵ_{igsypu} is clustered at the university level, in order to avoid to overstate the estimator precision due to correlation within clusters.[15]

In order to investigate all the available field choices besides Economics, we also estimate a multinomial logit version of Equation (1) where the dependent variable is a categorical capturing whether a student graduates in Economics, Business, STEM, or Humanities. Formally, we generalize Equation (1) and estimate a system of three equations, one for each category relative to the reference category.

4.1 | The decision to study Economics

We start by estimating Equation (1), where the dependent variable is a binary capturing whether a student graduates in Economics as opposed to any other field, using logit regressions. For three alternative specifications (one for each row), Table 1 reports the estimated gender gap, that is, the difference between the probability among females of graduating in Economics and the corresponding probability among males, divided by the latter. Probabilities for each gender are computed as predictive margins.

TABLE 1 The gender gap in Economics.

			Observations
(1)	Female	−0.407***	1,489,037
		(0.026)	
(2)	High school math	−0.268***	1,489,037
		(0.033)	
(3)	Full	−0.270***	1,235,522
		(0.035)	

Note: Logit estimates. The dependent variable is a binary that takes value one if a student graduates in Economics, and zero if a student graduates in another field. For each model, the table reports the estimated gender gap, computed as (probability of graduating in Economics among females − probability of graduating in Economics among males)/probability of graduating in Economics among males. Parity corresponds to a zero value. All models include enrollment year and region of residence fixed effects, and a constant. Model 1 also includes Female, Model 2 adds High School Math, and Model 3 all the other controls (High School Grade, Parents, Motivations, and Macro Indicators). The null hypothesis is that the estimated gender gap is zero.

Robust standard errors clustered at the university level in parentheses: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

The results disclose the presence of a sizeable gender gap in Economics graduations. In the first parsimonious specification, where gender is the only control besides enrollment year and region of residence at graduation fixed effects (Model 1),[16] women are almost 41% less likely than men to graduate in field.[17] In Model 2, where we also control for the math content of high school curricula, the size of the gap shrinks to 27%, and remains approximately the same when in Model 3 we enter all the other controls (i.e., high school grade, parents' characteristics, students' motivations, and macro indicators).

The fact that the gender gap in Economics shrinks but does not disappear after all controls are included indicates that the latter do carry an explanatory power, while at the same time a sizeable portion of the gap remains unexplained even after including them. Furthermore, the estimates suggest that the gap is heavily associated with the math content of high school curricula. Even though the analysis in the present section remains descriptive and not causal—also due to selection into the high math schools—it should be stressed that, since tracking starts at age 14, five years before university enrollment, it is unlikely that students (and/or parents) choose the math content of high school based on their planned college major, since the math content of curricula is only one of many considerations that may play a role, and others may prove even more important. One example is educational career prospects, which cut across the high versus low math categorization.[18] Furthermore, information and preferences on specific majors can still be largely incomplete at age 14, while different preconceptions of boys and girls on the study of mathematics may be an important factor.

Robustness checks leading to very similar results include running all regressions (i) over a balanced sample of observations; (ii) using linear probability models in place of logit and multinomial logit; (iii) confining the sample to those universities that are always comprised in the dataset, (iv) replacing the macro indicator capturing overall employment with a gender specific measure such as female labor force participation, and (v) confining the sample to three-year graduates. The last check yields a slightly smaller gender gap, which can be due to females being relatively less represented than males in the complete sample (14% of males go for single cycle degrees vs. 17% of females, see Table A2).[19]

Table A3 presents a further specification where a set of interactions between gender and all the other controls are added together to the full specification in Table 1. The table reports the estimated gender gaps corresponding to each value of the interacted variables.[20] The heterogeneous effect of the High School Math variable is confirmed when the latter is interacted with gender: Among students with a high math background, women are only 22% less likely than men to graduate in Economics, while they are 53% less likely among students with a low math background. The substantially smaller gap within the first group is related to the fact that girls are much less likely than boys to choose a high math track, but those who do choose it increase their probability of studying Economics relatively more than boys. Some interesting findings also emerge, for instance, when the Female dummy is interacted with the grade obtained at graduation from high school (High School Grade): Among high performing students, women are only 5% less likely than men to graduate in the field, and this difference is not even significant, but it grows to minus 32% among medium performers, and to minus 56% among low performers. Thus, a high grade contributes to parity. Also in this case, as grades increase, the probability of women of graduating in Economics increases more than that of men. However, as it will be seen in more detail in the decomposition analysis in Sub-Section 4.2, grades do not contribute to explain the whole gap as much as the math background. Using information about parents' education and occupation, we uncover that females are relatively more likely to graduate in Economics when parents, and especially mothers, hold a low level of education. The influence of parents' occupations is instead not so clear-cut. Even though the declared motivations of the choice of field, either cultural or work-related, display limited variation (as shown in Table A2), their interaction with gender does matter: The gap is absent when cultural concerns are deemed less important, while as far as considerations regarding job prospects are concerned, the gap is lower when they are deemed more important. Lastly, some heterogeneities emerge also in terms of macro indicators, with a larger gender gap being associated with higher fertility and lower employment rates.

In Table 2 we broaden our perspective by investigating in full depth the available choices besides Economics. To this end, we run multinomial logit regressions using as dependent variable a categorical for the following four fields: Economics, Business, STEM, and Humanities, where the latter two are broadly defined. A first general finding is that the gender gap in Economics is remarkably similar to that reported in Table 1 for the logit specification. This consideration, together with the results of Hausman and McFadden (1984) tests, which did not reject the assumption of Irrelevance of Independent Alternatives, support our choice of the multinomial logit specification. Moreover, strikingly, the table also reveals that Economics always displays the largest gender gap (with a lower likelihood among women of 28% in the fully controlled Model 3), followed by STEM (21), with Business coming next (19), and a reversal in the

TABLE 2 The gender gap in all fields.

		Economics	Business	STEM	Humanities	Observations
(1)	Female	−0.407***	−0.350***	−0.291***	0.738***	1,489,048
		(0.026)	(0.026)	(0.023)	(0.065)	
(2)	High school math	−0.275***	−0.200***	−0.193***	0.375***	1,489,048
		(0.032)	(0.029)	(0.022)	(0.040)	
(3)	Full	−0.278***	−0.187***	−0.213***	0.422***	1,235,531
		(0.034)	(0.030)	(0.021)	(0.039)	

Note: Multinomial logit estimates. The dependent variable is a categorical capturing whether a student graduates in Economics, Business, STEM, or Humanities. For each model/field, the table reports the estimated gender gap, computed as (probability of graduating in Economics among females − probability of graduating in Economics among males)/probability of graduating in Economics among males. Parity corresponds to a zero value. All models include enrollment year and region of residence fixed effects, and a constant. Models 1 also include Female. Models 2 add High School Math, and Models 3 all the other controls (High School Grade, Parents, Motivations, and Macro Indicators). The null hypothesis is that the estimated gender gap is zero. Robust standard errors clustered at the university level in parentheses: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

Humanities (with a 42% higher likelihood). Interestingly, the gap in Business is significantly smaller than in Economics, despite the partial overlap of the curricula, a fact that likely reflects its lower math content. Again, the influence of the math background remains very strong (Model 2), suggesting its role as a mediator of the influence of gender.[21]

Even though, given our focus on Economics and Business, we prefer to use broad aggregations for the other fields, it is instructive to unpack STEM, for instance, between Physical Sciences and Engineering (PE) and Life Sciences (LS). Fully controlled logit regressions yield, for the former, a 57% lower probability among women than among men and, for the latter, a 59% higher probability, pointing to marked heterogeneities within our broad definition of STEM. Moreover, within PE, the largest gender gap is reached in Engineering with women being 73% less likely than men to graduate in the field. Unpacking our definition of Humanities yields a 38% higher probability among women for its Social Sciences (other than Economics and Business) component, and a 60% higher probability for women to graduate in the remaining, more narrowly defined Humanities majors.[22]

Keeping our broad classifications and turning to interactions between gender and other controls, we run for each field a separate logit model including interactions between gender and all the other controls (analogously to Table A3 for Economics). The results in Table A5 show that differences in the math background matter also for Business and the Humanities, but much less so for STEM where, perhaps non-intuitively, the gender gap is slightly smaller among students with a lower math background.[23] A possible explanation is that women with a low math background that choose STEM are strongly motivated. In the Humanities, the gap is smaller among students with a low level of school math because men from schools with high math content are relatively less likely to graduate in this field.[24]

4.2 | Decomposition analysis

The purpose of this sub-section is to dig deeper into the role played by the high school math background. To this end, to estimate the relative importance of covariates in explaining the gender gaps in each field, we perform a decomposition analysis using the Gelbach (2016) methodology. The Gelbach method quantifies how much of the change in the coefficient on the dummy for gender—from a baseline regression including only gender to a full regression with all variables and fixed effects—is influenced by each covariate.[25]

For the decomposition analysis in Table 3, we use a linear probability model (OLS), with the dependent variable being the binary indicating whether the student graduates in a given field. Results are reported in terms of coefficients and models are presented by column. Concerning Economics, Model 1 shows that the explained variation (Δ) of the coefficient on Female is entirely influenced by students' mathematical knowledge from high school, without any other factor significantly affecting it. Mathematical knowledge from high school is also important for Business, although less than for Economics (Model 2), since High School Math influences about 91% of the variation in the Female coefficient, while the remaining part is affected by other covariates. Mathematical knowledge from high school also influences most of the gender gaps in Humanities and STEM,[26] but Economics remains unique in displaying high school math as an exclusive significant correlate of the variation in the Female coefficient.

TABLE 3 Gelbach decomposition.

	(1) Economics	(2) Business	(3) STEM	(4) Humanities
Δ Female coefficient	−0.006***	−0.022***	−0.054***	0.081***
	(0.000)	(0.002)	(0.004)	(0.004)
High school math	−0.006***	−0.020***	−0.063***	0.089***
	(0.001)	(0.001)	(0.002)	(0.003)
High school grade	0.000	−0.001**	0.016***	−0.015***
	(0.000)	(0.001)	(0.001)	(0.001)
Mother education	0.000*	0.001***	−0.001***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Father education	0.000	0.000***	−0.003***	0.003***
	(0.000)	(0.000)	(0.000)	(0.000)
Mother work	0.000***	0.000***	−0.001***	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
Father work	−0.000***	−0.001***	0.001***	0.000**
	(0.000)	(0.000)	(0.000)	(0.000)
Motivations culture	−0.000***	−0.001***	0.000***	0.001***
	(0.000)	(0.000)	(0.000)	(0.000)
Motivations jobs	−0.000***	−0.001***	−0.001***	0.002***
	(0.000)	(0.000)	(0.000)	(0.000)
Fertility	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Employment	0.000	0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)

Note: OLS estimates. The dependent variables are binary variables that take value one if a student graduates in each specific field, and zero otherwise. The table reports coefficients. All models include enrollment year and region of residence fixed effects, and a constant. The number of observations in all models is 1,235,531. Robust standard errors clustered at the university level in parentheses: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

5 | A TRIPLE DIFFERENCE ANALYSIS OF A HIGH SCHOOL REFORM

Our analyses so far have uncovered a negative association between a high school math background and the decision to study Economics for females. In this section, in order to identify a potential causal relation, we take advantage of a high school reform that altered the math requirements for certain high school types but not for others. The reform therefore allows us to apply a quasi-experimental DD approach. Since our goal is to assess the heterogeneous impact of the reform between females and males, it is appropriate to apply a DDD estimator.

Starting from the school year 2010–2011, the Gelmini high school reform introduced an increase in the hours of math taught in schools traditionally characterized by a lower math content, while other schools were unaffected.[27] The first cohort of post-reform students obtained a high school diploma after five years in 2015 and a first level degree starting 3 years later, that is from the summer of 2018.[28] Thus, within our sample period, we can distinguish between graduates coming from each school type, pre- and post-reform, within a DD approach.[29] The post-reform period includes the first and part of the second cohort of post-reform graduates, that is, the cohorts that enrolled at university in 2015 and 2016.[30] Thus, the previous descriptive analyses pooled over the entire sample still remain useful, especially because the reform reduced but did not remove the distinction between high schools in terms of math content. At the same time, however, we can take a first glance at the impact of the reform, at least in the short term, and exploit it in order to identify a potentially causal effect of high school math on major choice.

In our setting, the treatment (i.e., the school reform) is applied to all students from traditionally low math schools who enroll at university starting from 2015, with students from high math schools representing the control group. Our goal is to establish whether the reform induced gendered effects, which can be properly dissected within a DDD approach. After pooling across high school types, pre- and post-reform periods, and gender, the DDD estimator for the choice to graduate in Economics takes the following form:

$$\begin{aligned} Economics_{igsypu} &= \alpha + \beta_1 Treat_s + \beta_2 Post_y + \beta_3 Female_g \\ &\quad + \beta_4 (Treat_s * Post_y) + \beta_5 (Treat_s * Female_g) + \beta_6 (Post_y * Female_g) \\ &\quad + \beta_7 (Treat_s * Post_y * Female_g) + X_i'\chi + Z_{yp}'\zeta + \epsilon_{igsypu} \end{aligned} \tag{2}$$

where $Economics_{igsypu}$ indicates the probability of graduating in Economics for student i of gender g from school type s, enrolling in year y and residing in place p at time of graduation from university u. $Treat_s$ is a binary variable that takes value one for traditionally low math schools subject to the reform and zero otherwise, so that β_1 measures pre-reform differences between treated and control groups of male students. $Post_y$ is a binary variable that takes value zero up to 2014 and one from 2015. $Female_g$ identifies female students. The interaction $Treat_s$*$Post_y$ captures the effect of the reform on male students, so that β_4 represents the DD estimate of the treatment effect on males. $Treat_s$*$Female_g$ captures time-invariant characteristics of females in reformed schools, while $Post_y$*$Female_g$ captures characteristics of all females in the post-reform period. The key coefficient β_7 identifies the effect of the triple interaction term $Treat_s$*$Female_g$*$Post_y$, that represents the difference between females and males in the treatment effect. Thus, the DD estimate of the causal impact of the treatment on females is $\beta_4 + \beta_7$. A variant of the baseline DDD estimator described so far also includes other individual characteristics X_i and macroeconomic indicators Z_{yp}, as described for Equation (1). The error ϵ_{igsypu} is clustered at the university level.

To be noticed is that identification of the reform's effects would be hampered if other major provisions had complemented the increase in math hours in treated schools. However, while the reform did imply a general reorganization of school tracks, it did not alter their distinction along the math content dimension. Likewise, the reform did decrease the total number of hours being taught, but it did so for both types of schools, again lending plausibility to our approach. Furthermore, the reform did not address gender issues, so that it did not introduce other innovations that could explain its gendered effects.

Table 4 presents the size and statistical significance of the DDD estimated coefficients from Equation (2), for a baseline and a fully controlled specification. In both specifications, the coefficient on *Treat***Post* (i.e., β_4), that represents the effect of the reform on males, is positive and significant, while the coefficient on *Treat***Post***Female* (i.e., β_7), that represents the gender difference in the treatment effect, is negative and highly significant. Both coefficients are remarkably stable across specifications. The coefficients' sum (i.e., $\beta_4 + \beta_7$), in turn representing the reform effect on treated females relative to untreated ones, in the post-treatment period relative to the pre-treatment one, is negative. In terms of magnitudes, the coefficient −0.013 in, for example, Model 1 quantifies in 1.3 percentage points the DDD estimated negative treatment effect on the probability of treated females of graduating in Economics. The figure represents the difference between the pre- and post-treatment probabilities for treated females and the difference between the pre- and post-treatment probabilities for treated males. At the same time, the sum of the coefficients $\beta_4 + \beta_7$ shows that the probability of females of graduating in Economics is 0.3 percentage points below what it would have been without the reform.[31]

The key identifying assumptions for our empirical strategy are the absence of anticipatory effects and the presence of parallel trend prior to treatment. To inspect the plausibility of these assumptions and examine pre-treatment coefficients, we rely on an event study approach according to:

$$\begin{aligned} Economics_{igsypu} &= \alpha + \delta_{sg} + \delta_{gy} + \delta_{sy} + \sum_{y=2004}^{2016} \beta_y (Treat_s * Female_g * Year_y) \\ &\quad + X_i'\chi + Z_{yp}'\zeta + \epsilon_{igsypu} \end{aligned} \tag{3}$$

where the terms δ_{gs}, δ_{gy}, and δ_{sy} denote a full set of interactions between gender, year, and school type fixed effects, that are respectively meant to control for time-invariant characteristics of females in reformed schools, yearly changes among females nationwide, and school type-specific shocks over time. The term $\sum_{y=2004}^{2016} \beta_y (Treat_s * Female_g * Year_y)$ is

TABLE 4 The effect of the high school reform on the probability of graduating in Economics.

	(1) Baseline	(2) Full
Treat	−0.020***	−0.018***
	(0.004)	(0.003)
Post	0.012**	0.009**
	(0.005)	(0.004)
Female	−0.009***	−0.009***
	(0.002)	(0.002)
Treat*Post	0.010**	0.010**
	(0.004)	(0.004)
Treat*Female	−0.003*	−0.003*
	(0.002)	(0.002)
Post*Female	−0.006**	−0.005**
	(0.002)	(0.002)
Treat*Female*Post	−0.013***	−0.014***
	(0.004)	(0.004)
Fixed effects	√	√
Covariates		√
R-squared	0.006	0.008
Observations	1,488,345	1,234,949

Note: OLS estimates. The dependent variable is a binary that takes value one if a student graduates in Economics, and zero if a student graduates in another field. The table reports coefficients. Both models include a constant. Model 2 also include all the other controls (High School Grade, Parents, Motivations, and Macro Indicators). Robust standard errors clustered at the university level in parentheses: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

the treatment effect on females for each year in the sample. Hence, the triple interaction captures the dynamic effects of the treatment, that is, the treatment effect on females for each sample year before (i.e., between 2004 and 2013) and after (i.e., in 2015 and 2016) the onset of the reform. We omit 2014, the year prior to enrollment for the first cohort of post-reform students.

Figure 2 plots the OLS estimation results for the β_y's and the corresponding 95% confidence intervals using the baseline specification of Equation (3), which excludes individual characteristics and macroeconomic indicators as controls. Each dot represents the gap in graduating in Economics between females and males coming from treated and untreated schools in a particular year, relative to the same gap in the year prior to treatment. Reassuringly, as the pre-treatment dots indicate, overall the differential trends in the outcome of interest are statistically indistinguishable from one another in the years preceding the reform. In other words, the absence of differential pre-treatment trends suggests that outcomes would have been the same for each school type/gender in the absence of treatment. After treatment initiation, we instead observe a sizeable change in patterns of graduation in Economics, with a marked increase in the gap between females and males.

Table 5 reports the estimated coefficients of the triple interaction from the event study in Equation (3). Even though, as in Figure 2, regressions are run including also pre-treatment years, the table displays only the coefficients for the two post-treatment years. Inspecting both a baseline and a fully controlled specification reveals that the initial negative effect on treated females in 2015, the first post-treatment year, is followed by an even stronger negative effect in 2016. Consistent with the magnitude of the impact over the entire post-treatment period detected in Table 4, the coefficients indicate a reduction between 0.9 nd 0.8 in 2015 and between 1.6 and 1.8 percentage points (depending on the specification) in 2016.[32]

Table A6 presents complementary DDD estimates of the impact of the reform on the gender gap and extends them to the other fields. The results for Economics are displayed in Column 1, first for the baseline and then for the fully

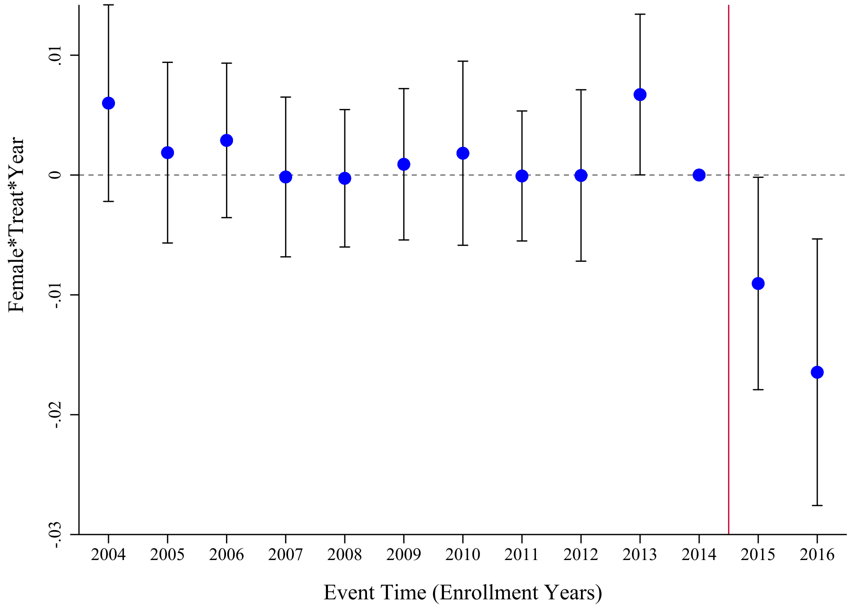

FIGURE 2 The effect of the high school reform on the probability of graduating in Economics - Event study plot. OLS estimates. The dependent variable is a binary that takes value one if a student graduates in Economics, and zero if a student graduates in another field. The coefficients are estimates of the β_y's, in a baseline specification that includes a constant and a full set of interactions between gender, year, and school type fixed effects. The omitted enrollment year is 2014. Capped vertical lines represent 95% confidence intervals based on standard errors clustered at the university level. The vertical line marks the onset of the school reform.

TABLE 5 The effect of the high school reform on the probability of graduating in Economics - Event study coefficients.

	(1) Baseline	(2) Full
Treat*Female*Year$_{2015}$	−0.009**	−0.008*
	(0.004)	(0.004)
Treat*Female*Year$_{2016}$	−0.016***	−0.018***
	(0.006)	(0.006)
Fixed effects	√	√
Covariates		√
R-squared	0.007	0.009
Observations	1,488,345	1,234,949

Note: OLS estimates. The dependent variable is a binary that takes value one if a student graduates in Economics, and zero if a student graduates in another field. The table reports only the post-reform coefficients β_y's corresponding to the years 2015 and 2016. Both models include a constant and a full set of interactions between gender, year, and school type fixed effects. Model 2 also include all the other controls (High School Grade, Parents, Motivations, and Macro Indicators). Robust standard errors clustered at the university level in parentheses: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$.

controlled specification. The magnitude of the impact is similar across the two specifications, with an increase in the gender gap by 0.116 and 0.128 respectively, which corresponds to women becoming about 12 percentage points less likely than before to graduate in Economics relative to men. In the next three columns of Table A6 we report analogous DDD estimates of the treatment effect on gender parity for Business, STEM, and the Humanities. Strikingly, the estimates always show a zero (placebo) effect on the gender gap, making the gendered impact of the reform a unique feature of Economics. In particular, the reform increases both male and female enrollment in the Humanities and decreases both in STEM, but does not affect the gaps between genders. This suggests that exposing to more math students of either gender that had opted for a traditionally low math school made their field choice even more radical. For Business, no effect of the reform is detected for males, while a negative effect on females emerges only in the controlled specification. Differently from the other fields, for Economics male enrollment rates significantly increase while females' decrease. Hence, the strong and highly significant effect of the reform on the gender gap is unique to Economics.

Lastly, in Figure 3, we perform heterogeneity analysis along a number of dimensions, by running separate event study regressions over sub-samples. Namely, in subsequent panels we split the sample between graduates residing (at graduation) in the North versus the Center/South, with below versus above median high school grade, with both parents holding a higher degree versus all other graduates, with both parents holding a high skill level occupation versus all other graduates, and residing in locations with below versus above median fertility rate and employment rate. To ease the reading, vertical lines representing 95% confidence intervals are staggered by sub-sample. Interesting heterogeneities in treatment impact emerge along several dimensions. The fact that the impact is stronger in the Center/South may be related to the fact that the opportunity cost of giving up a relatively lucrative career in Economics is smaller in this area due the general macroeconomic conditions, or else to the fact that experimental, often math intensive curricula were more widespread in the North prior to the reform. Turning to students' characteristics, the impact is driven by treated females with above median high school grade. To the extent that the final grade should proxy for ability, and assuming that ability is correlated with self-confidence at least within the female sample, this suggests that self-confidence is not at the root of the phenomenon. In terms of family background, the impact is stronger when both parents are highly educated, and when both hold managerial jobs. As the latter two characteristics tend to proxy for income, this implies that female students from wealthier families are those who are more likely to give up Economics when exposed to more math, possibly because they are the ones that can afford it. Turning to macroeconomics indicators, the reform impact is stronger in locations with above median fertility, which may reflect the above mentioned performance of the Center/South, while a heterogeneous influence of the employment rate is less clear cut.

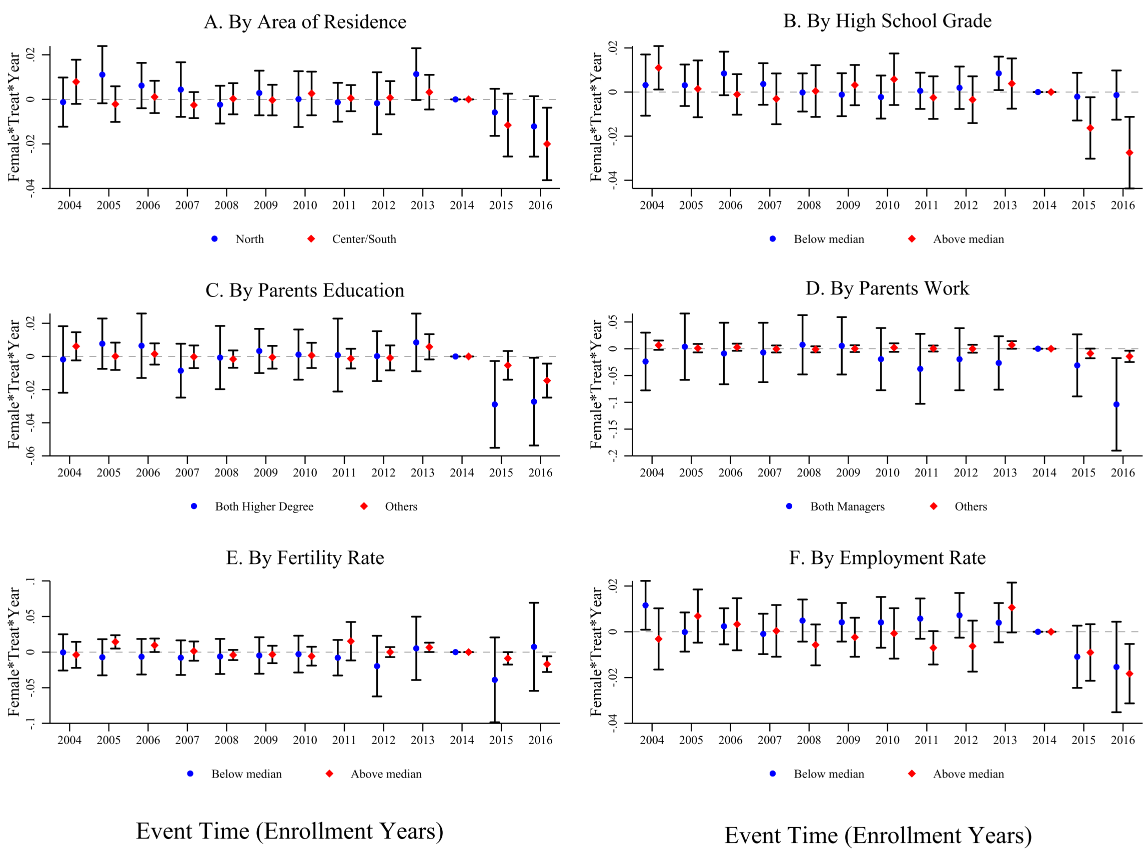

FIGURE 3 The effect of the high school reform on the probability of graduating in Economics - Heterogeneity. OLS estimates. The dependent variable is a binary that takes value one if a student graduates in Economics, and zero if a student graduates in another field. The coefficients are estimates of the β_y's, in a baseline specification that includes a constant and a full set of interactions between gender, year, and school type fixed effects, over sub-samples respectively defined by Area of Residence, High School Grade, Parents Education, Parents Work, Fertility Rate, and Employment Rate. The omitted enrollment year is 2014. Capped vertical lines represent 95% confidence intervals based on standard errors clustered at the university level and are staggered by sub-sample.

To conclude, the DDD analysis presented in this section shows that the causal impact of an increase in the math content of traditionally low math curricula is an increase in the gender gap in Economics, by making the field less attractive for females through the negative net treatment effect on females from low math schools, while the reverse occurs for males.[33]

6 | DISCUSSION

To sum up, the descriptive evidence presented in Section 4 shows that the gender gap in Economics majors is much smaller among students who attended high math schools compared to students from low math schools: Girls are less likely than boys to choose a high math school but, when they do, their probability of studying Economics increases more than that of boys choosing this type of school. However, Section 5 establishes that the reform, which increased the math content of traditionally low math high schools, decreased the probability that treated women majored in Economics. This result may appear puzzling.

One way to reconcile both pieces of evidence—and to understand why being imposed more math within a traditionally low math curriculum does not sort the same effect on girls as choosing a high math curriculum in the first place—is to acknowledge that the mathematical knowledge acquired at school is actually not the key to our findings. In other words, what is actually driving the association emerging in Section 4 is not so much the difference between what is taught and learned in high and low math schools, but rather selection into each type of school. The latter may in turn be driven by unobservable characteristics that lead boys and girls, and their families, to choose each type of school.

Yet, another potentially overlapping explanation of our results is that the math content does matter, but the context in which the reform is introduced also does. Indeed, the fact that females are further discouraged to take Economics after being exposed to more math, while males are not, may depend on several factors, which the heterogeneity analysis performed in Section 5 helps sorting out. Namely, by looking at exit grades we can rule out that our findings are explained by girls' worse performance after the reform, since the effects are driven by treated girls with higher grades. To the extent that performance is correlated with self-confidence, lack of it for girls is also ruled out. Likewise, we can rule out that a lower socioeconomic background makes the treatment effect stronger. The fact that the opposite is true is consistent with the fact that giving up Economics—and the associated more promising labor market prospects—is more affordable for the wealthier. Another contextual consideration which could produce gendered effects, but which we are not able to evaluate with the available data, is how the additional math content is blended with the other disciplines that characterize low math curricula. Furthermore, since we are able to observe only the initial cohorts of post-reform graduates, one possible reading of the evidence rests on the different timing of the reaction of girls to the new curricula. In turn, girls' reaction can be explained by their limited appreciation of the potentialities of the renewed content, or else by their higher psychological barriers in confronting it. A related channel is the lingering effect of stereotypes induced by the preponderance of girls in low math schools that may also result, through teachers' and parents' attitudes, in persistent negative peer pressure. Since we are able to observe only the initial cohorts of post-reform graduates, future research into the medium- and long-term effects of the reform should investigate whether its negative short-term effect on gender parity in Economics shall die out or even reverse over time.

7 | CONCLUSION

The causes and consequences of women's underrepresentation in STEM fields are widely researched and debated, but the low female presence in Economics is much less recognized, especially in Europe. Over high-quality Italian data from survey and administrative sources we investigate whether women study Economics as much as men and, if not, why. Differently from the Anglo-Saxon system, in the European system, including the Italian one, Economics and Business are usually taught together in the same departments. This institutional setting calls for a joint investigation of major choice that we also extend to all other fields. Another feature of the European system is that major choice is made before college enrollment, which makes the background developed at high school, and in particular its math context, particularly important.

Using the AlmaLaurea dataset on Italian graduates from 2010 to 2019, after controlling for the characteristics of students and their families and for region and time fixed effects we find that graduations in Economics are 27% less frequent among females than among males. Hence, the Economics gender gap in Italy is similar to that reported for other countries and even larger than that in (broadly defined) STEM, while the gap in Business is significantly smaller despite the partial overlap of the curricula.

We also find a significant association—which plays a unique role in Economics—between the mathematical content of high school curricula and the gender gap. Decomposition analysis shows that, only for Economics, the explained part of the gender gap exclusively depends on high school math, trumping family background, other students' characteristics, and even students' declared motivations for the choice of field. Since the Italian school system starts tracking at 14, and girls tend to be underrepresented in schools with curricula requiring more hours of math, their disadvantage in accessing Economics majors is a deeply rooted one. Those choices made early on by girls prove very hard to reverse and may persistently limit their subsequent options at university, with life-long consequences for their labor market outcomes.

Lastly, a triple difference analysis of a high school reform aimed at intensifying the math content of curricula in traditionally low math schools reveals a negative treatment effect of the reform on gender parity in Economics, since as a result females—but not males—are less attracted toward this field, with a negative net treatment effect on the number of students from low math schools who graduate in Economics. Even though we can observe the effect of the reform only through a restricted end-of-sample window, this finding suggests a crucial role for gendered differences in preferences in shaping major choice and that being imposed more math within a traditionally low math curriculum does not sort the same effect on girls as choosing a high math curriculum in the first place.

Taken together, our results allow to draw a distinction between the unobservable characteristics that lead students and families to choose certain high schools and the actual content of what is taught at those schools. This is a crucial distinction that policymakers need to understand when pursuing the goal of closing the gender gap and that calls for policy interventions either targeting very young girls and their families, and/or removing tracking at such a young age.

More generally, the fact that the reform also increased Humanities majors and decreased STEM majors among the treated irrespectively of gender suggests that, if a policymaker's goal is to promote science education, a policy of simply increasing math hours could backfire and actually discourage it.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from AlmaLaurea. Restrictions apply to the availability of these data, which were used under permission for this study. See Bertocchi et al. (2023) for replication instructions.

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ENDNOTES

[1] Similarly, Avilova and Goldin (2018) compute a gender conversion rate defined as the ratio of the share of Economics graduates among males to the same share among females. The conversion rate for Adams College is 1.8 and corresponds to a gender gap of −0.444, or to women being 44% less likely than men of graduating in Economics. Thus, Italy as a whole fares only slightly better than Adams College.

[2] The field experiments in Li (2018) and Porter and Serra (2020) were conducted within an ongoing broader research project, the Undergraduate Women in Economics (UWE) Challenge (Avilova & Goldin, 2018).

[3] Aggregate data can be accessed from the AlmaLaurea website at https://www2.almalaurea.it/cgi-php/universita/statistiche/tendine.php?LANG=it&config=profilo. While we are the first to use these data to study the decision to major in Economics, Chise et al. (2021) and Granato (2023) and have used them for the case of STEM.

[4] Since the survey is administered upon graduation, data do not contain information about those students that enroll at university but do not graduate.

[5] We include respondents who graduated starting in 2010 and enrolled after 2004 at age up to 25. We exclude respondents with a foreign high school diploma.

[6] The fields with five-year programs are Pharmacy, Law, Primary Education, Veterinary, Architecture, and Chemistry. Those with six-year programs are Medicine and Dentistry.

[7] Italy has three main tracks of upper secondary schools: Lyceums, Technical, and Vocational (see Bertocchi & Spagat, 1997; Brunello & Checchi, 2007). Tracking starts at age 14, an early age compared to most other countries (see Hanushek & Woessmann, 2006). To be noticed is also that tracking takes an extreme form, with a choice of a separate type of high school (rather than separate coursework within the same high school), and that the subsequent college choice occurs five year later. Following AlmaLaurea main disaggregation, High School Math takes value one when the student attended a lyceum with a scientific curriculum (*Liceo scientifico*) or a technical or vocational school, and zero otherwise.

[8] Business majors include a broad range of subjects such as Management, Accounting, Marketing, Organizational Studies, Finance, etc.

[9] Since our focus is on Economics and Business, we allocate all other subjects to only two broadly defined fields. STEM takes value one when the student graduates in Science (Physics and Mathematics), Engineering, Architecture, Chemistry, Pharmaceutics, Biology, Geology, Medicine or Veterinary, and zero otherwise. Humanities takes value one when the student graduates in Political Science, Sociology, Literature and Languages, Law, Teachers Training, Psychology, Physical Education or Defense Sciences, and zero otherwise.

[10] Data can be downloaded from https://dati.istat.it/.

[11] Namely, the weighted measure is defined as:

$$\text{Gender Gap}_j = \frac{\frac{\text{Females in Field}_j}{\text{All Females}} - \frac{\text{Males in Field}_j}{\text{All Males}}}{\frac{\text{Males in Field}_j}{\text{All Males}}} = \frac{\frac{\text{Females in Field}_j}{\text{All Females}}}{\frac{\text{Males in Field}_j}{\text{All Males}}} - 1$$

with j = Economics, Business, STEM, Humanities. Parity corresponds to a null gender gap.

[12] Data can be downloaded from http://dati.ustat.miur.it/organization/miur.

[13] Similar figures would be obtained by comparing the entire number of enrollments and graduations over the period 2010–2019.

[14] We refer to enrollment year rather than graduation year, since the time of enrollment is more likely to influence subsequent choices. As for residence, the survey provides information either at birth or at the time of graduation. We employ region of residence fixed effects at the latter point in time, because it is closer to enrollment time.

[15] The basic setting for the logit specification follows the one employed by Granato (2023) for an analysis of the gender gap in STEM fields.

[16] For all specifications presented in Table 1, a version with region of residence at birth fixed effects yields nearly identical results (unreported for brevity).

[17] The corresponding estimated gender gap reported in Model 1, that is, −0.407, is computed as follows. The coefficient on Female in the underlying logit regression is equal to −0.542. The corresponding predictive margins, that is, the probabilities for each gender of graduating in Economics, are 0.04258 for males and 0.02525 for females. Subtracting the former from the latter and dividing by the former that is, (0.02525 − 0.04258)/0.04258 as from the definition of gender gap, yields −0.40653, as reported in the table after rounding. The level of statistical significance is computed with reference to the null hypothesis of gender parity.

[18] For instance, both *Liceo scientifico* and *Istituto tecnico* are classified as high math, but only the latter opens the possibility of entering the labor market directly upon completion, while keeping open the choice to continue with college—which in turn represents the main prospect for the former.

[19] Results are not reported for brevity.

[20] For continuous variables, that is, High School Grade and the Macro Indicators, we compute margins respectively at the values 60, 80, and 100 for the former and at the 25th, 50th and 75th percentiles for the latter.

[21] To capture the mediating effect of High School Math, in Table A4 we first regress High School Math on Female and all controls: Model 1 shows that as expected High School Math is strongly correlated with gender. Next, we regress the probability of graduating in a given field on all controls except High School Math, and compare results with the full specification. The increase in the gap in Model 2b relative to Model 2a confirms that gender is directly and indirectly—through high school choice—affecting the probability of graduating in Economics. Similar results apply to Business, STEM and, with opposite signs, Humanities (Models 3–5).

[22] Multinomial specifications involving combinations of the above sub-fields lead to similar results.

[23] The importance of high school type for STEM is shown by Granato (2023) over AlmaLaurea data.

[24] Appendix B replicates regressions in Tables 1 and 2 for a sample of second degree level (i.e., master) graduates, that is, the population of students who graduated from a two-year program at the master level, accessible after obtaining a first level degree.

[25] In Appendix C we present complementary results based on the Oaxaca (1973) and Blinder (1973) decomposition method.

[26] In both cases, father's education has a three times stronger influence on the respective gender gaps than mother's education. Our results for STEM confirm those by Chise et al. (2021) over AlmaLaurea data.

[27] Previous experimental tracks—namely, *Piano Nazionale per l'Informatica* (PNR) and *Progetto Brocca*, introduced in the 1980s and 1990s respectively—also involved curricula with additional hours of math, but they were implemented only sparsely (Giacardi & Scoth, 2014; Tomasi, 2012). By contrast, the Gelmini Reform took effect simultaneously in the entire country. As a result, in the vast majority of traditionally low math schools the number of weekly hours of math in the first year went from two to three, while it remained at five, for instance, in traditionally high math schools such as *Liceo scientifico* (MIUR, 2011).

[28] It is crucial to identify pre- and post-reform students by the year of enrollment rather than the year of graduation, because graduation dates in the Italian system are less closely linked to enrollment dates than in other systems. Specifically, the last cohort of pre-reform students, that is, those completing their third year in 2016–2017, can regularly complete their degree up to the spring of 2018. Likewise, the first cohort of post-reform students completing their third year in 2017–2018 can complete their degree up to the spring of 2019. Therefore, in 2018 the sample includes both pre- and post-reform three-year degree graduates, while post-reform graduates from five- or six-year (single cycle) degree programs are not included in the sample. Furthermore, it is quite common for students to complete their degree with a delay, sometimes of several years, as *fuori corso*.

[29] Meghir and Palme (2005) apply a DD to the analysis of a school reform. A DDD is applied by Piopiunik (2014).

[30] Since they are likely to be selected, we also exclude from the sample the tiny number of graduates that enrolled in 2017 and 2018. They amount to 627 and 76, compared to 63,603 in 2016.

[31] Results remain nearly identical in further variants of Equation (2) that also include a linear enrollment year trend and/or region of residence at graduation fixed effects. The latter are meant to capture education policies that may be implemented at such level.

[32] As in Table 4, results are similar in variants of Equation (3) that also include a linear trend and/or region of residence fixed effects.

[33] Within a DD analysis of a German reform aimed at increasing math intensity, Gorlitz and Gravert (2018) and Biewen and Schwerter (2022) obtain similarly gendered results for STEM. The former find an increase in STEM enrollment for males but not females, while the latter find no effect on STEM enrollment for males and a decrease for females.

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Additional supporting information can be found online in the Supporting Information section at the end of this article.

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