Online Appendix

A Institutional Background

Co-education and Underrepresentation of Women in STEM in France

Mixed-Gender Schooling in France Mixed-gender schooling was introduced in the French educational system in the beginning of the 20th century. It started with a long process of harmonization of educational programs for female and male students, which was finally ratified in 1924 by the Bérard Decree. Mixed-schooling was then gradually promoted by several laws after World War II: first in 1959 and 1963 for secondary schooling, then in 1965 for elementary schools. Finally, in 1975, the Haby Law sanctioned co-education (or mixed-gender schooling) in all educational institutions in France. Part of the motivation for co-education was economic and material circumstances. For instance, until the beginning of the 20th century, mixed-gender schools were only allowed in case of material constraints, in remote and rural areas, where the number of children in the municipality was too small to divide classes in two. In 1915, because of a shortage of teachers due to the conscription, a decree was passed to allow boys and girls to attend the same elementary classes.

Higher education in France was never formally close to women, although the number of female students only rose in the second half of the 20th century. In 1971, women represented 50 % of students at the university (Ferrand, 2004). Mixed-gender schooling was then gradually introduced among elite graduate schools: in 1945, the Ecole Nationale d'Administration (ENA), was open to both female and male students in order to train the future high officials of the country. Engineering and business schools opened their recruitment to women during the 1970s and, by the end of the 1980s, the entire system was formally mixed. Finally, mixed-gender competition was also introduced to recruit teachers (especially the *agrégation*, which is the examination required to teach in secondary schooling) between 1974 and 1976.

Under-representation of Women in STEM Co-education historically went hand-in-hand with gender differentiation in choices of fields of study. Though women now represent 55 % of students in higher education in France, they are still largely under-represented among STEM graduates: in 2020, women outnumbered men in medicine, health program and biology (accounting for respectively 65,6 % and 63,5 % of students in these fields), but only represented 28,9 % of students enrolled in engineering programs. This unbalance is even more striking among the most selective schools: in 2016, women represented only 31 % of students enrolled in science preparatory classes, less than 30 % of students enrolled in engineering schools, and only 21 % of students among the top 10 % most selective engineering schools (Bonneau et al., 2021). These gender differences in choices of fields of study, and more generally in attitudes towards math-intensive sciences, are present early on in students' trajectory (Perronnet, 2021). Nonetheless, they cannot be entirely explained by differences in academic performance. Women outperform their male counterpart at every step of the educational system: they obtain better grades at school, are far more likely to obtain their high school examination (*baccalauréat*), and are more likely to graduate from higher education (DEPP, 2022). For instance, Bonneau et al. (2021) show, using Blinder-Oaxaca decomposition, that given their academic performances, women should have higher enrolment rates to engineering schools than men. A large literature in economics and sociology has tried to explain these difference by the role of gender stereotypes. Recent studies have shown that stereotypes associating mathematics with masculinity is stronger in more egalitarian and developed countries, suggesting that, rather than being suppressed, gender stereotypes are reshaped, leading to more horizontal forms of social differentiation (Charles and Bradley, 2002; Charles and Grusky, 2005; Charles and Bradley, 2009; Sikora and Pokropek, 2012; Breda et al., 2020).

B Data

Table B1: Data Collection for the ENS d'Ulm Mathematics Entrance Examination

	Jury	List of					Written Grades of		Oral Grades of
Years	Composition	Candidates	Qualified	Wait-listed	Admitted	Enrolled	Candidates	Qualified	Qualified
1985 - 1984	✓	✓	✓	✓	✓	✓	✓	✓	✓
1983	✓		✓	✓	✓	✓			
1982	✓	✓	✓	✓	✓	✓			
1981			✓	✓		✓			
1980				✓	✓	✓			
1979	✓	✓	✓	✓		✓	✓	✓	
1978		✓	✓	✓	✓	✓	✓	✓	
1977 - 1976			✓	✓	✓	✓			
1975	✓		✓	✓	✓	✓			
1974			✓	✓	✓	✓			
1973				✓	✓	✓			
1972			✓						
1969 - 1971			✓	✓	✓	✓			

Table B2: Data Collection for the ENS de Sèvres Mathematics Entrance Examination

Years	Jury Composition	List of Candidates	List of Qualified	List of Wait-listed	List of Admitted	List of Enrolled	Written Grades of Candidates	Written Grades of Qualified	Oral Grades of Qualified
1985 - 1969	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table B3: Data Collection for the ENS de Paris Mathematics Entrance Examination

Years	Jury Composition	List of Candidates	List of Qualified	List of Wait-listed	List of Admitted	List of Enrolled	Written Grades of Candidates	Written Grades of Qualified	Oral Grades of Qualified
2009		✓	✓	✓	✓	✓	✓	✓	✓
2005 - 2008	✓	✓	✓	✓	✓	✓	✓	✓	✓
2005 - 2007		✓	✓	✓	✓	✓	✓	✓	✓
2003 - 2004	✓	✓	✓	✓	✓	✓	✓	✓	✓
2002	✓	✓ (partial)	✓	✓	✓ (partial)	✓	✓	✓	✓
2001		✓	✓	✓	✓	✓	✓	✓	✓
1995 - 2000	✓	✓	✓	✓	✓	✓	✓	✓	✓
1994	✓	✓	✓	✓	✓	✓	✓	✓	✓ (partial)
1993	✓	✓	✓	✓	✓	✓	✓	✓	✓
1992		✓	✓	✓	✓	✓	✓	✓	✓
1991	✓	✓	✓	✓	✓	✓	✓	✓	✓
1990		✓	✓	✓	✓	✓	✓	✓	✓
1989	✓		✓	✓	✓	✓		✓	✓
1987 - 1988		✓	✓	✓	✓	✓	✓	✓	✓
1986			✓	✓	✓	✓	✓	✓	

C Odds Ratios : Methodology

Odds ratio For a given group of individuals G (e.g.: female candidates), the odds ratio is the ratio between the probability to succeed (e.g.: admission to the ENS), and the probability of not succeeding :

$$\text{Odds ratio} = \frac{\tau_G}{(1-\tau_G)}, \tag{1}$$

where τ_G is the proportion of individuals from group G qui who succeeds (e.g. the proportion of female candidates admitted to the ENS).

Relative odds ratio The relative odds ratios between group A and B, is the ratio of the odds ratio of group A and the odds ratio of group B

$$\text{ODDS}_{A/B} = \frac{\tau_A/(1-\tau_A)}{\tau_B/(1-\tau_B)}, \tag{2}$$

where τ_A is the proportion of individuals from group A who succeeds and τ_B is the same proportion for group B.

The odds ratios can also be rewritten as:

$$\text{ODDS}_{A/B} = \frac{ad}{bc}, \tag{3}$$

Where: a is the number of female candidates who succeed, b is the number of female candidates did not, c is the number of male candidates who succeed and d the number of male candidates who did not.

Confidence Intervals The aim is to assess whether the value of the odds ratio is statistically different from 1, which is the case of perfect equality between male and female candidates. The distribution of odds ratio is skewed, so it is not possible to directly calculate confidence interval for the statistics. However, the log of the odds ratio is symmetrically distributed, and the standard error of the this statistics is given by

$$se(log(ODDS_{A/B}) = \sqrt{\frac{1}{a}+\frac{1}{b}+\frac{1}{c}+\frac{1}{d}}, \tag{4}$$

We first compute confidence interval at the 95 % confidence level for the log odds ratio, which is exactly equivalent to a logistic regression model. We then use the exponential of the upper and lower bound to recover the confidence interval for the odds ratio. Since the odds ratios are not distributed symmetrically, confidence intervals are not necessarily centered.

D Jurys

Table D4 presents the gender decomposition of the jurys of the ENS de Sèvres and the ENS d'Ulm for the sciences subjects of the mathematics entrance exam, for the years we could recover from the archives. Prior to the merger, the ENS d'Ulm jurys were composed of 100% male professors for the available years. The ENS de Sèvres jurys included some female professors, ranging from 0 % in 1985 to 40 % in 1975 and 1983. After the merger, the share of female professors in the jurys quickly dropped at 0 %.

Table D4: Jurys of Mathematics Entrance Exam in Sciences Subjects

	ENS de Sèvres (women only)		**ENS d'Ulm (men only)**	
	number of female jury members	number of male jury members	number of female jury members	number of male jury members
1975	2	3	0	5
1979	1	4	0	5
1982	1	5	0	6
1983	2	3	0	5
1984	1	7	0	5
1985	0	7	0	7

	ENS de Paris (mixed-gender)	
	number of female jury members	number of male jury members
1986	1	5
1989	0	6
1991	0	7
1993	2	15

Source: Documentation sourced from the ENS archives. Before 1986, we only display the years for which we have both the ENS de Sèvres and the ENS d'Ulm jury members.
Lecture: In 1982, there were one female jury member and five male jury members at the ENS de Sèvres mathematics entrance exams in sciences subjects, while there were zero female jury member and five jury members at the ENS d'Ulm mathematics entrance exams in sciences subjects.
Notes: The sciences subjects are the two mathematics written exams, the physics written exam, the mathematics oral exam and the physics/chemistry oral exam.

Before 1984, the jurys for the mathematics entrance exams in sciences subjects in the ENS d'Ulm and the ENS de Sèvres were different. In 1975 and 1979, the jurys at the mathematics entrance exam in sciences subjects of the two ENS were completely different. In 1982, the jurys for the sciences written exams were different individuals for the two ENS but the jurys for the sciences oral exams were the same persons. In 1983, the jury members for the two ENS were different except for the mathematics oral exam.

However, we observe a strong overlap of the jurys in 1984 and 1985. In 1984, the jury of the ENS de Sèvres is composed of the same professors than the jury of the ENS d'Ulm with two extra professors (one for the first mathematics written exam and one for the physics/chemistry oral exam). In 1985, we observe the opposite: the jury of the ENS d'Ulm is composed of the same professors than the jury of the ENS de Sèvres. The jury in 1986 is composed of the same professors than the ones of the ENS de Sèvres in 1985 with an extra professor (one extra female professor for the physics written exam).

Given the missing data about jury composition for some years pre and post-merger, the missing information about the matching between students and examiners for the oral exams, and the low variability of the female professors in the jurys post-merger, we cannot investigate the potential role of the jury gender composition on female students' success rate at the ENS mathematics entrance exam.

E Format of the Exam and Weighting Scheme

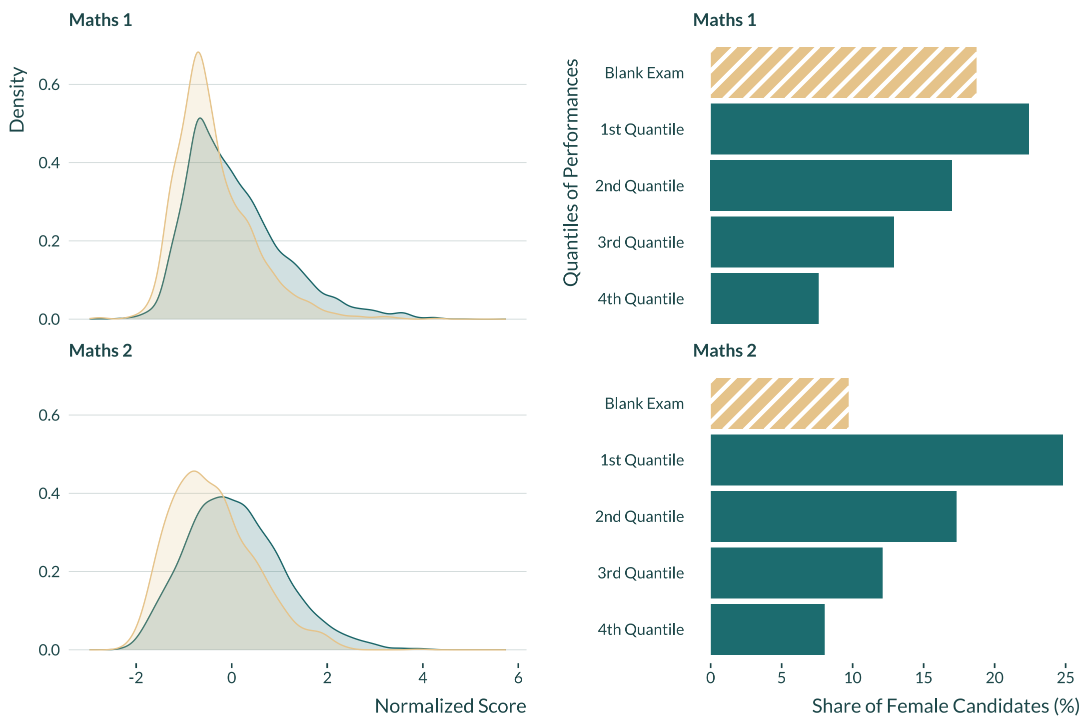
One potential explanation for the gender gap in performance at the entrance examination is the format of the exam. Recent literature in economics has raised significant concern on whether differences in performance by socioeconomic status or gender reflect inequities in the testing process itself, rather than differences in underlying skills (Miller and Stassun, 2014; Dobrescu et al., 2021; Duquennois, 2022). It has been notably shown that gender gaps in mathematics performance can be strongly influenced by the format of exams that students take (Griselda, 2022).

Combined with the weighting scheme applied to each subject, these factors could potentially affect the gender composition of qualified and admitted students. To explore this question, we simulate different weighting schemes and focus on two main aspects: the weights assigned to each mathematics subject (Maths 1 and Maths 2), and an analysis of the impact of the introduction of the common written examination for all ENS in 1994.

The Two Mathematics Subjects As mentioned above, the Maths 1 subject is considered to be one of the most challenging examinations in mathematics. It lasts 6 hours, which is an unusual format for this type of examination. Indeed, most mathematics written exam for entrance to STEM elite graduate school last 4 hours; students in preparatory programs are thus less trained for this exam. On the other hand, the Maths 2 subject is a more classical mathematics examination: it lasts 4 hours, and is closer in its difficulty and format to other examinations for entry into STEM elite graduate schools. We cannot argue that this specific subject in mathematics is irrelevant to select potential good researchers, which is one the core missions of the ENS Paris. However, we find almost no correlation between Math 1 test score and the probability to pursue an academic career in a French public university.

Figure E1 presents a comparison of the performances of male and female students at the two mathematics written exams. The left panel shows the density of normalised scores obtained in Math 1 and Math 2 by gender, while the right panel presents the share of female candidates by quartile of performance (including the share of female candidates who hand in a blank exam), for years 1986-2000. The first quantile represents the worst performers, while the fourth quantile represents the top performers.

Figure E1: Performance in Mathematics at the Written Exam, by Gender
1986-2000

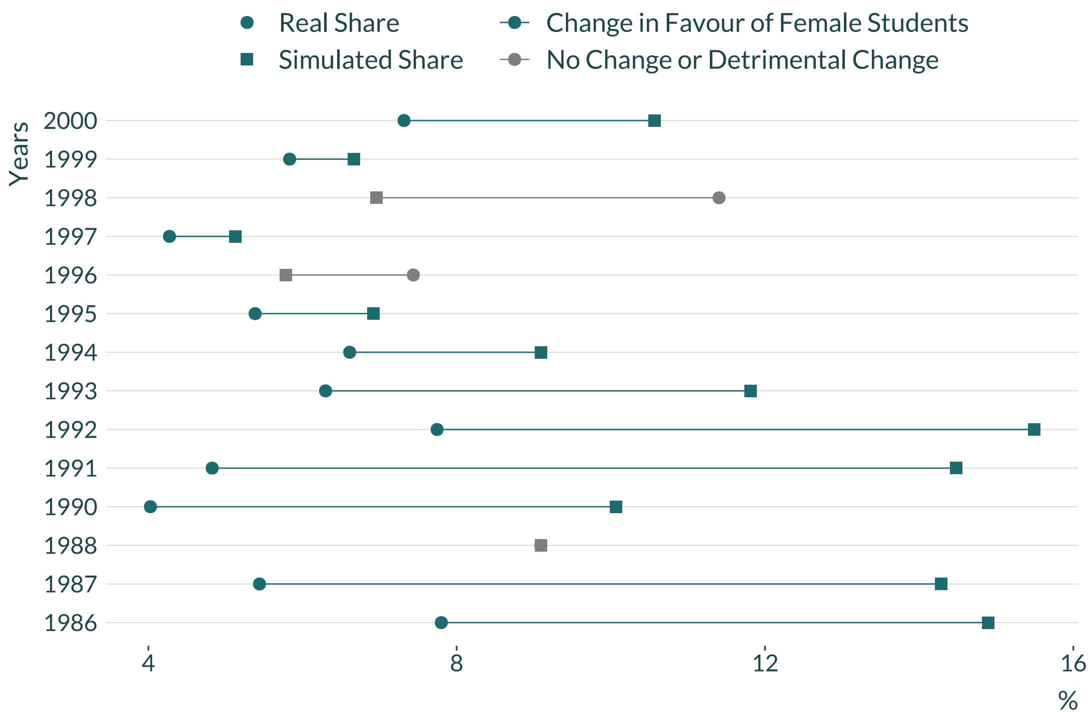


Source: Documentation sourced from the ENS archives.
Reading: In Maths 1, female students represent 19% of handed blank copies, while they represents only 10% of them in the Maths 2 written exam.

First, it does not seem that the two mathematics exams assess the same skills, as the distribution of scores are very different between Maths 1 and Maths 2. Both male and female candidates perform worse on average in Maths 1 than in Maths 2, with a higher kurtosis for the distribution of scores for female candidates. The two subjects are however very similar in the representation of female candidates in each quantile of performances, including at the highest level of performance (4th quantile). Interestingly, the proportion of female candidates who hand in a blank exam is almost twice as high in Maths 1 compared to Maths 2, which automatically prevent these candidates to get qualified. It seems that women get discouraged at a higher rate than male candidates by this specific exam. It has also been shown in other contexts that female students' written average tend to be dragged down by specific subjects, where male students clearly outperform them. For instance, in the case of competitive exams to administrative civil servant school, Meurs and Puhani (2019) show that women are disadvantaged by the "essay on general knowledge" at the written exam, though they are outperforming men on both "on the job" anonymous written and non-anonymous oral evaluations.

To see how much Math 1 matters in female candidates' chances to be qualified at the oral exam, we compute what would have been the total written score of every student without Math 1, from 1986 to 2000. To do so, we have to make the assumption that the elimination of Math 1 would not have changed the pool of candidates. Using this simulated total written score, we define a new pool of qualified students at the oral exam.

Figure E2: Real and Simulated Share of Female Candidates, Qualification Stage, 1986-2000



Source: Documentation sourced from the ENS archives.
Lecture: In 1986, the share of female qualified candidates was 7.8 %. It would have been 14.9 % if students would have been ranked without taken the Math 1 examination into account.

Figure E2 displays the real share (circle) and simulated share (square) of female candidates at the qualification stage. Years for which the simulated share of female candidates is higher than the real share are highlighted in green. On average, the simulated share is 3.4 percentage points higher than the real share of female candidates qualified at the oral exam (10.1 % against 6.7 %). There are 11 years out of 14 where the simulated share is actually higher than the real share. Eliminating Maths 1 could have a substantial impact on the share of women qualified to the exam; for 6 out of 14 years, it roughly doubles - even triples - the share of qualified female candidates.

Effect of the ENS Common Exam The introduction of a common ENS examination in 1994 represents another natural experiment we can exploit in our setting. Since 1994, the three ENS (Paris, Lyon and Saclay) have shared a common written examination. The majority of subjects are shared among all ENS; however, there are still some school-specific subjects, and each ENS is free to apply their own weights to compute the final average. Students only have one application to fulfill, and take all exams in the same week. Modalities of the written and oral exams also changed that year: the French and languages written exams are no longer part of the average written score, and are only accounted for in the average oral score for qualified students. A larger weight has also been given to these subjects.

The implementation of a joint exam led to a substantial increase in the number of candidates, almost doubling in 1994. However, this did not seem to impact the composition of the pool of candidates, as we do not observe any discontinuity in the share of female candidates (Figure **??**) or in distribution of preparatory programs after 1994 (Figure **??**).

The first striking effect of the common exam is the jump in the number of female candidates admitted to the ENS (Figure **??**). To investigate whether this change is due to the new coefficients, we simulate an alternative ranking for qualified candidates from 1987 to 1993, applying the weights of 1994. Table **??** (right panel) in appendix displays both the actual number and the simulated number of admitted female candidates each year. A change in the coefficients applied at the oral examination would have barely changed the number of admitted female candidates to the ENS before 1994. This suggests either a change in the ability of qualified candidates in the subsequent years, or that female candidates were favoured at the oral examination. The latter would not be surprising, as we found in the administration archives letters and exchanges expressing worries about the all-time low number of admitted female candidates in 1993, zero. This could also confirm to some extent the results found by Breda and Ly (2015) for latter periods, which shows that female candidates are favoured at the oral examination in field where they are under-represented.

The second fact is that the share of qualified female candidates did not increase after 1994 (Figure **??**). Table **??** (left panel) displays the real and simulated percentages of qualified female candidates from 1986 to 1993, when we only consider the subjects taken into account since 1994 (namely mathematics and physics). Overall, humanities helped boosting the share of qualified female candidates. However, as illustrated by the low number of admitted female candidates over this period, this was not enough to increase the proportion of qualified female candidates up to their share in the initial pool of candidates at the written exam.

Hence, the next section investigates whether female students were less inclined to take the exam after 1986, and whether female students turned away from this heightened mixed-gender competition.

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