Reinforcing the STEM pipeline in vocational-technical high schools: The effect of female teachers.

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Abstract

Although secondary Vocational-Technical Education (VTE) is highly prevalent in low-income settings in the developing world, this sector remains understudied in the Economics of Education literature. Situated in the Chilean context, this study examines the effect of exposure to a female VTE teacher on STEM pipeline persistence from secondary to post-secondary level. We find that having at least one female teacher in secondary STEM-VTE programs increases overall enrollment in STEM higher education programs by 2.1 percentage points, primarily driven by women choosing postsecondary VTE diplomas in STEM fields. The effect of female VTE teachers in enrollment in these diplomas reaches 4.0 percentage points, equivalent to an 18% reduction in the observed gender gap. We argue that these female teachers acting as role models have the potential to mitigate the traditional barriers for women to persist in the STEM pipeline, thereby contributing to closing the STEM gender gap.

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1 Introduction

The underrepresentation of women in Science, Technology, Engineering, and Mathematics (STEM) fields is a persistent and well-discussed issue in educational research (Blackburn, 2017). Evidence shows that girls and women face unique barriers, including stereotype threats and implicit bias, in what is considered a long march toward a STEM career. This long march that starts in high school, continues in higher education, and ends with a degree and career in STEM has been characterized as the STEM pipeline: the single pipeline or pathway that students must follow to enter STEM careers (Clark Blickenstaff, 2005). Key transition points along the STEM pipeline are where students "leak out" of or decide to leave the path toward a STEM career (Maltese & Cooper, 2017).

While conventional high school academic courses in mathematics and sciences have long been seen as the primary route into STEM coursework, there is growing recognition that applied STEM Vocational-Technical Education (STEM-VTE) programs can also play an essential role in increasing student engagement and promoting advanced STEM studies (Gottfried & Bozick 2016; Gottfried & Plasman 2018). However, despite the potential of these programs to provide practical skills and prepare students for STEM careers, gender imbalance, and inequality remain pervasive in secondary VTE (OECD, 2020), limiting opportunities for women to enter and succeed in STEM fields (UNESCO, 2020; Sevilla, 2021). Furthermore, with male-dominated teaching staff and a lack of female role models, women in applied STEM-VTE programs are often left without the support and encouragement they need to persist in the STEM pipeline (UNESCO, 2020).

Recent research highlights the significant impact of female teachers in low-income settings or environments where young women are a distinct minority (Card et al., 2022). Secondary VTE often attracts a disproportionate number of students from low-income backgrounds due to its historical emphasis on practical skills and immediate workforce entry (Donner & Schneider, 2019). However, examining the impact of female teachers in applied STEM programs in secondary VTE is missing in the teacher gender effect literature. Situated in Chile, our paper aims to address this gap by examining female gender match effects on student persistence in the STEM pipeline between secondary and post-secondary levels. More specifically, we investigate whether being taught by a female teacher in secondary STEM-VTE programs enhances the probability of female students enrolling in STEM higher education programs, either with a bachelor's degree or a VTE diploma.

In Chile and several other Latin American countries, more than one-third of students opt for secondary VTE, a feasible path to higher education rather than a direct route to the labor market (Sevilla, 2017). Among the diverse programs offered in this educational sector, applied STEM programs, including electricity, metalworking, information technology, and chemistry, attract about 40% of the total enrollment in secondary VTE. These programs are male-dominated, with female attendance accounting for only 15% of the student body (Mineduc, 2020). However, this underrepresentation of female students is not only a recruitment issue but also affects retention rates. While 46% of male graduates from STEM-VTE programs pursue higher education programs in STEM fields, only 23% of their female counterparts do so (Sevilla, 2021). By examining school factors, such as the secondary VTE teacher gender, this paper aims to contribute evidence that informs public policy on supporting disadvantaged female students in the STEM pipeline during the critical transition from high school to higher education.

We use longitudinal administrative records that track nine cohorts of students from secondary STEM-VTE programs to higher education from 2007 to 2018. These data link students to their secondary teachers, allowing us to estimate female gender match effects in subjects encompassing STEM-VTE programs. Employing linear probability models, our analyses rely on the variability of having at least one female teacher within the same school and the same STEM-VTE program. In other words, we assume that the variation in exposure to at least one female teacher within a school and program is quasi-random across and within years. This assumption relies on the absence of correlation between this variation and unobserved variables that influence the presence of female teachers in high school and a student's enrollment in post-secondary STEM programs. Since in Chile, all students in a specific secondary VTE program cannot choose the teachers they are assigned to; we do not have to be concerned about students selecting sections within their program based on their preferences for teacher gender.

Our results indicate that female students benefit from having at least one female teacher in STEM-VTE programs, positively affecting their persistence in the STEM pipeline during the transition to higher education. Overall, we find a student-teacher female gender match effect of 2.1 percentage points on STEM enrollment in higher education. This effect is equivalent to a 9.6 % increase in the probability of enrolling in these fields and is statistically significant at a 95% confidence level. However, our result also indicates that having a female teacher in STEM-VTE has a slightly negative impact on female enrolment in STEM bachelor's degrees. A plausible explanation is that the female STEM-VTE teacher and female student match tends to channel students who were not going to enroll in higher education and some women who were going to enroll in STEM bachelor degrees toward VTE diplomas in STEM fields. Indeed, being taught by a STEM-VTE female teacher rather than a male teacher increases in 4.0 percentage points the probability of enrolling in VTE diplomas, a more specialized and practical STEM higher education kind of program. This effect is equivalent to an 18% reduction in the gender gap observed in the enrollment of STEM-VTE diplomas among graduates from secondary STEM-VTE programs in 2018. The estimated impacts of student-teacher female gender match on enrollment in STEM-VTE diplomas remain robust when controlling for confounding factors through various tests, including adding a program-school time trend, program-year fixed effects, and placebo experiments.

The existing literature highlights three main explanations for the positive impact of female teachers on female students' educational prospects: teacher bias, classroom environments, and the role model effect. Some argued that female teachers would be more biased in favor of female students than male teachers by devoting more effort or attention (Jones & Dindia, 2004) or even grading them more favorably (Lavy & Sand, 2018). A long literature has also shown that female teachers would positively impact the performance of female students through their ability to create female-friendlier learning environments (Dee, 2007; Price, 2010; Sansone, 2017; Bottia, 2015). The role model effect explanation, rather than focusing on teacher behavior, revolves around how female students react to teachers of the same gender. Mainly in male-dominated STEM fields, young women would feel inspired and motivated by the presence of a female teacher, reinforcing their STEM-related identity and fostering confidence in their ability to succeed in these fields, despite potential challenges (Oyserman, 2007; Elmore & Oyserman, 2012). As counter-stereotypical role models, female teachers would protect against the harmful effects of the stereotype threat that causes young women to disidentify with the STEM fields and ultimately drop out of them (Marx & Roman, 2002). Therefore, if more female teachers taught STEM courses, female students could potentially strengthen their identification with these fields and best progress through the STEM pipeline (Solanki & Xu, 2018).

At the secondary level, STEM-VTE programs are directly linked to occupational identities in blue-collar STEM trades in the labor market (Niemeyer & Colley, 2015). This connection leads to female students perceiving gender stereotypes and discrimination in these trades as the primary barrier to persisting in their studies (Sevilla et al., 2019). Thus, in these programs, female teachers who previously worked in STEM trades and tech-related subjects, referred to as STEM-VTE teachers in this study, are unique as salient role models. They are the only ones who can play a crucial role in helping female students reduce the stereotypical views associated with STEM trades and inspire them to persist in STEM careers. We further posit that, given the scarcity of these female teachers in STEM-VTE programs, their role model effects must be strong enough to be independent of teacher-student classroom interactions and must be observed across STEM classroom sizes, benefiting female students in both small and large classes (Card, 2022; Maured et al., 2023).

While our data do not allow for a direct investigation of the mechanisms underlying the positive impact of female teachers in STEM-VTE programs, our findings provide evidence that refutes alternative explanations beyond the role model effect. Firstly, we consistently observe no significant effects of female teachers on male enrollment in STEM programs across all our model specifications, dismissing the notion of gender bias in teacher effort or attention allocation. Secondly, our robustness check using placebo treatments show that non-STEM-VTE female teachers do not significantly influence female students' persistence in the STEM pipeline, supporting the notion that the observed effect is specific to STEM-VTE teachers and not a result of a generally more female-friendly classroom environment created by any female teacher. Lastly, our findings demonstrate that the female gender match effect persists regardless of class size, indicating that it is not dependent on direct and frequent interactions between students and teachers. Also, descriptive data suggest that the observed positive effects of female VTE teachers are not driven by gender differences in their qualifications or experience levels in teaching in VTE or industry.

Our paper is related to the expanding body of research exploring the impact of female gender matching on STEM outcomes. Several studies have shown that having a female teacher in primary or secondary schools matters for female students' performance in math and science. (Muralidharan & Sheth, 2016; Lee et al., 2019; Paredes, 2014; Gong et al., 2018). Notably, these positive effects are often observed in low-income settings, suggesting that the role model effect of female teachers may be context-specific (Card et al., 2022). In addition, there is extensive evidence that during the college years, female teachers positively impact grade performance (Carrell et al., 2010; Griffith, 2010; Griffith & Main, 2021), major choice (Bettinger & Long, 2005), and graduating with a STEM degree (Carrell et al., 2010) of female students. Furthermore, recent research shows that having a female professor in math and science courses during the first year of college can significantly influence the career paths of high-ability female students, boosting their likelihood of pursuing STEM careers and obtaining a master's degree in STEM fields (Mansour et al., 2022).

Although the literature on how female teachers impact STEM outcomes in school and higher education is robust, there is less research on their effect on the transition between school and STEM higher education. This is an important research gap, especially considering that high school years greatly influence students' later educational choices (Legewie & DiPrete, 2014). Current studies look at the gender composition of teaching faculty in STEM-related courses instead of the specific student-instructor gender match (Bottia et al., 2015; Dulce-Salcedo et al., 2022; Stearns et al., 2016). Overall, their result suggests that the proportion of female teachers has a powerful effect on female students' likelihood of enrolling in STEM programs. At the same time, male students are unaffected by the gender composition of high school faculty in STEM-related courses. Some authors attribute the positive impact of female teachers on female students to their ability to create a supportive and inclusive learning environment (Bottia et al., 2015).

We contribute twofold to the literature by providing evidence of the positive impact of female gender matching in secondary STEM-VTE programs on enrollment in STEM higher education, particularly in VTE diplomas programs. First, to the best of our knowledge, our study is the first to examine the effect of teachers' gender on STEM outcomes in a non-traditional academic setting, such as vocational-technical high schools. This setting is particularly significant but often overlooked, considering that nearly half of the STEM workforce comprises mechanics, construction managers, electricians, and information technology support technicians, which demand VTE qualifications (Caprile et al., 2015). Thus, generating evidence to inform public policy on how to support female students in the STEM-VTE pipeline between secondary and postsecondary levels is crucial beyond the context of vocational-technical high schools as low-income settings. Second, in contrast to previous studies focusing on the transition between high school and STEM higher education (Bottia et al., 2015; Dulce-Salcedo et al., 2022; Stearns et al., 2016), we examine the impact of female gender matching in STEM-VTE classrooms, rather than solely considering the gender composition of teaching faculty in STEM-related courses. By focusing on the STEM classroom, where various aspects of female students' STEM identity come into play, we can better capture the role model effect of female teachers. This effect is crucial as it has the potential to shape and sustain a STEM-related identity, instilling confidence in the attainability of a future in these fields, even in the face of challenges (Oyserman, 2007; Elmore & Oyserman, 2012).

The remainder of this paper is structured as follows. First, we offer a comprehensive overview of the Chilean educational system. Next, we outline the data and methods employed in our analysis. Subsequently, we present the findings from our analyses. Finally, we engage in a discussion of the outcomes and draw broad conclusions from the study.

2 Institutional background

In Chile, compulsory schooling extends until the completion of secondary school (12th grade). Primary education encompasses eight grades, typically starting at age 6. Secondary education includes four grades starting at age 14 and has a general core of two years (grades 9th and 10th) (ISCED 2), then formally splits into VTE and academic education (grades 11 and 12) (ISCED 3). VTE is offered by public, private subsidized, and corporative high schools, which tend to enroll more students from low socioeconomic backgrounds than academic schools. In 2018, approximately 79% of students from the lowest socioeconomic group pursued VTE, while the remaining 21% opted for academic education (Mineduc, 2020).

Secondary VTE programs aim to develop technical and foundational skills, equipping students for both initial employment and higher education. The teaching staff in VTE can be broadly classified into two categories: general teachers responsible for teaching core and foundational subjects and VTE teachers who specialize in technical subjects. Unlike general teachers, VTE teachers often commence teaching without formal pedagogical training, instead relying on their practical industry experience. For these teachers, there are two-year part-time vocational pedagogical programs in which VTE teaching pedagogy and curriculum are addressed on a general level. However, only 37% of in-service secondary VTE teachers hold a teaching diploma, while the remaining 63% did not have any pedagogical training. School assignments for general and VTE teachers are determined locally, adhering to national regulations.

VTE curricula are nationally determined and organized into study programs categorized under five broad fields: administration, applied STEM, personal services, agricultural, and maritime. Predominantly, applied STEM programs in economic sectors such as electricity, metalworking, information technology and chemistry involve courses that provide students with STEM-related skills opportunities by including practical vocational experiences and hands-on learning. These applied STEM programs concentrate about 40% of the total student population in secondary VTE and are male-dominated, with female enrollments constituting only 17% of this population (Mineduc, 2020). Like student trends, female teachers in these programs make up only 12%of the VTE teaching staff.

There are three types of programs at the post-secondary level: bachelor's degrees, non-degree professional diplomas, and technical-professional diplomas. Only bachelor degree programs (ISCED 6) are delivered exclusively by universities, requiring a mandatory entrance examination test based on preceding study in secondary academic subjects. Non-degree professional and technical programs, known as VTE diplomas (ISCED 5), are predominantly offered by post-secondary vocational institutions with an inclusive admissions policy and comparatively lower tuition fees than universities. Graduates from secondary VTE are eligible for enrollment in any post-secondary program, including bachelor's degrees. Nonetheless, the academically selective admission policies for universities result in a disproportionate enrollment of these students in VTE diploma programs in contrast to students from secondary academic education. Reports indicate that, in 2017, close to 70% of secondary VTE students who pursue higher education enrolled in VTE diplomas offered by post-secondary VTE institutions, while only 25% of students from academic backgrounds opted for the same path (Mineduc, 2020).

3 Data

We created a database from different administrative records sources from the Chilean Ministry of Education. This data yields information on the characteristics of students enrolled in STEM-VTE programs, the high schools they attended, and their teachers in general and technical subjects. Specifically, we used merged data comprising information from all 11th-grade student cohorts between 2007 and 2018 that were assessed by the 10th-grade SIMCE standardized test (nine cohorts: 2007, 2009, 2011, 2013-2018). We follow each student cohort for two years in high school (11th and 12th grades) and two years afterward to capture enrollment in post-secondary STEM programs at universities or post-secondary vocational institutions.

The initial sample consisted of 239,485 students enrolled in STEM-VTE programs across the nine cohorts, with only 12.90% being females. These students attended 563 different vocational-technical high schools. We excluded data from 40,067 students (16.7% of the initial sample) due to the lack of 10th-grade standardized test scores, resulting in a final sample of 199,418 students (12.35% females). This data omission is a limitation of our study, as it is not random and mostly affects students who repeated 11th grade and did not take the SIMCE test in 10th grade. Table 1 presents a comprehensive sample description, encompassing schools and students across the examined cohorts. Among the total sample of students in STEM-VTE programs, only 36,832 students (18.46% females) from 296 schools were taught by at least one female VTE teacher during the 11th or 12th grades. Table 6 in the Appendix provides further insights into the characteristics of these female teachers compared to male VTE teachers in applied STEM programs. The data reveal that female teachers, unlike their male counterparts, have less experience teaching in VTE (column 2) and tend to enter the teaching profession at a younger age with less industry experience (column 3). However, there is no statistically significant difference between female and male teachers possessing a teaching diploma.

Table 1: Sample Description of Schools and Students

	VTE schools offering Applied-STEM programs			VTE schools offering Applied-STEM programs with female teachers		
Cohort	Number of schools	Number of students	Percentage of females	Number of schools	Number of students	Percentage of females
2007	354	25,276	10.12	98	4,807	9.28
2009	362	24,080	9.94	97	4,218	13.37
2011	377	22,796	9.86	110	3,923	15.01
2013	414	21,231	11.39	117	3,807	18.12
2014	432	22,477	13.27	122	4,203	21.98
2015	436	19,453	13.15	122	3,551	23.29
2016	451	21,677	14.78	123	4,067	24.42
2017	475	21,246	14.45	128	4,111	21.28
2018	488	21,182	15.10	116	4,145	21.47
Total	563	199,418	12.35	296	36,832	18.46

VTE schools offering Applied-STEM programs with female teachers are defined as schools with at least one female teacher. .

Table 2 displays the percentages of female and male students enrolled in all higher education and in STEM higher education programs whitin the first two years after finishing high school. The table presents enrollment data for all STEM programs and distinguishes between bachelor's degrees and VTE diplomas. We define STEM programs as those that fall under the following ISCED categories: natural sciences and mathematics, information and communication technology, and engineering, manufacturing, and construction. For female and male students, there is an increasing trend in all higher education and STEM higher education enrollment across the cohorts examined. However, while females outperform males in overall enrollment, their enrollment in STEM fields lags significantly behind. On average, only 21.9% of females persist in the STEM pipeline during the transition to higher education, while 41.7% of male students do so. When examining STEM enrollments by program type, VTE diplomas emerge as the preferred pathway to higher education in STEM fields for secondary VTE students. Unfortunately, gender disparities in STEM enrollment in these diplomas are more pronounced than in STEM bachelor's degrees (1.98 times versus 1.49 times).

Table 2: Secondary STEM-VTE students enrolled in Higher Education (%)

	All Higher Education		STEM Higher Education		STEM Bachelor Degree		STEM VTE Diploma	
Cohort	Female	Male	Female	Male	Female	Male	Female	Male
2007	39.94	37.53	14.73	29.44	2.11	3.61	12.62	25.82
2009	47.91	42.16	19.38	34.01	2.30	3.77	17.08	30.25
2011	51.94	47.85	24.61	38.59	2.80	4.24	21.81	34.34
2013	59.53	52.61	24.43	42.65	3.02	4.60	21.41	38.06
2014	62.52	55.69	22.53	44.65	4.69	5.67	17.83	38.99
2015	66.61	59.26	21.89	47.24	4.34	6.28	17.55	40.96
2016	68.01	59.41	22.28	47.65	3.68	6.11	18.60	41.54
2017	67.54	60.35	23.54	48.56	3.87	6.79	19.67	41.77
2018	64.93	58.38	22.79	47.22	3.50	5.74	19.29	41.48
Total	59.57	51.90	21.85	41.66	3.43	5.11	18.42	36.55

Bachelor's degrees (ISCED 6) are university majors. VTE diplomas (ISCED 5) are non-degree professional and technical programs, predominantly offered by post-secondary vocational institutions.

The percentages of secondary STEM-VTE students' enrollment in STEM higher education programs based on whether they had at least one female teacher during the 11th or 12th grades are presented in table 3. Data reveals that, on average, the enrollment proportion of female students in these programs is 5.8 percent higher when exposed to at least one female teacher compared to their counterparts who did not have such exposure (26.1% vs. 20.3%). The positive difference linked to this exposition extends to both bachelor's degree and VTE diploma programs when we further analyze female enrollment by the type of STEM program.

Overall, these descriptive statistics provide an initial insight into the potential influence of female teachers in increasing female enrollment in higher education STEM programs.

Table 3: Enrollment in Higher Education STEM Programs for female students exposed and non-exposed to female STEM-VTE teacher (%)

Cohort	Exposed to Female Teacher			Non-exposed to Female Teacher		
	All STEM	Bachelor Degree	VTE Diploma	All STEM	Bachelor Degree	VTE Diploma
2007	24.89	3.14	21.75	12.59	1.89	10.70
2009	22.87	2.13	20.74	18.31	2.35	15.96
2011	30.22	3.90	26.32	22.62	2.41	20.21
2013	27.54	4.64	22.90	23.19	2.37	20.82
2014	26.19	6.28	19.91	20.88	3.98	16.90
2015	25.27	6.41	18.86	20.28	3.35	16.93
2016	24.07	5.14	18.93	21.48	3.03	18.45
2017	25.37	4.69	20.69	22.81	3.55	19.26
2018	28.31	4.83	23.48	20.66	2.99	17.67
Total	26.07	4.81	21.26	20.25	2.90	17.34

Bachelor's degrees (ISCED 6) are university majors. VTE diplomas (ISCED 5) are non-degree professional and technical programs, predominantly offered by post-secondary vocational institutions. Exposure to a female teacher refers to students from STEM-VTE high schools that were taught by at least one female teacher.

4 Identification Strategy

We aim to estimate the effect of female gender match in STEM-VTE classrooms on enrollment in STEM higher education programs. For this purpose, we exploit the variability of having at least one female VTE teacher within the same school and the same STEM-VTE program. In particular, we use two sources of identifying variation: first, the within-program-school variation on treatment in a particular year. This means that for a specific year, some students of the same program in the same school have a female teacher, while others do not. Our second source of variation stems from the variability across cohorts, specifically from the fact that the teacher composition can change over time, resulting in variations in the gender of the assigned teacher for a student within a particular program-school. Thus, our treatment unit is program-school combinations, totaling 5,311 in our sample. To analyze variability in these units, Table 6 in the Online Appendix offers a broad overview of how they can be classified based on transitions by the presence of female teachers over the examined period. The variability arises from the 48% of the treatment units that comprise those program-school combinations that initially lacked a female teacher but later switched to have at least one (5.99%), those with initial female teachers that later switched to having only male teachers (5.42%), and those that experienced fluctuations in having female teachers over time (36.5%). The remaining 52% of the treatment units correspond to program-school combinations that either always had female teachers (0.64%) or never had female teachers (51.42%), thereby not being a source of variation.

We use linear probability models to examine whether the variability in the "treatment", defined as the exposure to at least one female VTE teacher in secondary STEM-VTE programs in 11th or 12th grade, is systematically related to changes in STEM higher education enrollment. We run estimations for all STEM higher education programs and distinguish between STEM-VTE diplomas and STEM bachelor's degrees. The model specification used is as follows:

$$STEM\ enrollment_{ispy} = \beta_1 Female\ teacher_{ispy} + \beta_2 Male_{ispy} + \beta_3 Male_{ispy} \times Female\ teacher_{ispy} + X_{ispy} + \gamma_{sp} + \delta_y + \epsilon_{ispy} \quad (1)$$

Where $STEMenrollment_{ispy}$ is a binary variable that takes the value of 1 if student i that attended an applied-STEM program p in VTE high school s in year y is enrolled in STEM higher education (all, bachelor's degree or VTE diploma) within the first two years after finishing high school. $Female\ teacher_{ispy}$, our variable of interest, is a binary variable that captures if the student i had at least one STEM-VTE female teacher in 11th or 12th grades. $Male_{ispy}$ is a binary variable for male students, so the base category is female students. X_{ispy} is a vector of student-level controls that includes the average GPA in 9th and 10th grades measured in standard deviations, mathematics and language standardized test scores[1], parental education, students' expectations of accessing higher education, age, and dummy variables that indicate if any of these controls are missing. Since previous studies have shown that peer composition is an important determinant of student outcomes (Sacerdote, 2011), the control vector also includes the percentage of female peers for student i's in STEM-VTE classrooms and its interaction with the gender of the student. Finally, we add program-school fixed effects to make comparisons within school STEM programs and year fixed-effect and cluster errors by school-program-year to account for year-specific shocks that may influence STEM higher education enrollment.

The causal effect of our treatment on enrollment in a STEM higher education program relies on the identification assumption that the within-school-program variation of female VTE teacher presence is quasi-random and not correlated with unobserved variables that affect both the presence of these female teachers for student i in a specific VTE-STEM program p in high school and the student's enrollment in STEM higher education. Note that in the Chilean educational system, all students in a specific secondary VTE program cannot choose the teachers they are assigned to. This eliminates concerns about students selecting subjects based on their preferences for teacher gender. Consequently, from the student's perspective, the presence of female VTE teachers can be seen as exogenous within a specific program-school combination.

[1] The mathematics and language test scores come from the National Standardized Test called SIMCE, which all students should take at 10th grade, which is before the treatment.

To ensure the robustness of our findings, we employ several strategies. First, we incorporate a time trend into the model to account for any temporal changes that may influence the outcomes. Second, we include program-year fixed effects to control for any systematic variations across different programs and years that could affect the results. Furthermore, we employ several placebo tests, including examining the effects of STEM-VTE teachers on all enrollment and non-STEM-VTE teachers on STEM enrollment.

Additionally, we explore the heterogeneity of effects by considering the interaction of the treatment with various factors, including standardized Math test scores as measures of student ability, classroom gender composition, and classroom size.

5 Results

5.1 Main Results

Table 4 presents results from the linear probability model described in equation 1 for estimating the impact of the student-teacher female gender match on STEM higher education enrollment. The table reports the estimated impact with and without controls for three outcomes: all STEM programs, STEM-VTE Diploma, and STEM Bachelor's Degree. Results indicate that exposure to at least one female STEM-VTE teacher increases the likelihood of enrolling in STEM higher education by 2.1 percentage points (p.p.) compared to female students not exposed to female teachers in STEM-VTE classrooms.[2] This effect is equivalent to a 9.6% increase in the probability of enrolling in STEM higher education, and it is statistically significant at a 95% confidence level for the specification with controls (column 2). Separately analysis for VTE diplomas and bachelor's degrees reveals contrasting effects of the student-teacher female gender match. The exposition of at least one female VTE teacher in secondary STEM-VTE programs is associated with a 3.9 p.p. increase in the probability of enrolling in VTE diplomas. This increase is statistically significant and robust to excluding control variables (columns 3 and 4). In contrast, student-teacher female gender match diminishes the chances of enrolling in a STEM bachelor's degree by 1.8 p.p, suggesting that the increase in STEM-VTE diploma enrollment is driven not only by female students transitioning from non-STEM to STEM-VTE diploma enrollment, but also some female students originally intending to pursue STEM bachelor's degrees opting for STEM-VTE diplomas instead.

The results further suggest that the impact of having at least one of these female teachers during the 11th or 12th grades is negligible and statistically insignificant for male students, except for STEM bachelor's degree enrollment. However, even in this case, the effect is smaller than that observed for female students and exhibits an opposite direction.

[2]Errors the are clustered at the school-year-program level. These results are robust to alternative clustering. Table B1 in the Appendix shows the estimation of our main results clustering at the school level to address correlation across years.

Table 4: Main Results

	All		VTE Diploma		Bachelor Degree	
	(1)	(2)	(3)	(4)	(5)	(6)
Male	0.219**	0.210**	0.198**	0.190**	0.021**	0.020**
	(0.004)	(0.006)	(0.004)	(0.006)	(0.002)	(0.002)
Female STEM-VTE Teacher	0.018+	0.021*	0.037**	0.039**	-0.018**	-0.018**
	(0.010)	(0.010)	(0.010)	(0.010)	(0.004)	(0.004)
Male x Female STEM-VTE Teacher	-0.020*	-0.021*	-0.043**	-0.043**	0.023**	0.023**
	(0.010)	(0.010)	(0.009)	(0.009)	(0.004)	(0.004)
Observations	199,403	199,403	199,403	199,403	199,403	199,403
Controls	No	Yes	No	Yes	No	Yes
Mean Outcome for Women	0.219	0.219	0.184	0.184	0.034	0.034
Effect for Men	-0.001	0.000	-0.006	-0.005	0.005	0.005
P-Value of Effect for Men	0.814	0.934	0.317	0.439	0.034	0.018

All specifications have School-Program and Year fixed effects. Errors are clustered at the school-year-program level. All outcomes consider enrollment in STEM programs. Standard errors in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

5.2 Robustness Checks

Our main results suggest that female VTE teachers in secondary STEM-VTE programs can partially offset the gender gap in STEM higher education enrollment without adversely impacting male students. The causal interpretation of our estimates relies on the assumption that the variation in the presence of a female teacher within a school-program is quasi-random and unrelated to unobservable factors influencing the presence of at least one female VTE teacher for student i in program p during high school and the subsequent enrollment of student i in STEM higher education. To assess the validity of this assumption, we conducted several robustness checks, including time trends, stricter fixed effects, and placebo tests.

5.2.1 *Time Trend*

In our first robustness check, we account for some potential confounding factors by controlling for unobserved characteristics that may be correlated with changes in the presence of female VTE teachers. To achieve this, we include program-school time trends (γ_{sp}) in our main model, as specified in Equation 2. An example of this threat would be the arrival of a principal who pushes to hire more female teachers in STEM-VTE programs and tries to get female students to enroll in STEM higher education at higher rates. Another example is female students self-selecting into STEM-VTE programs where the presence of female VTE teachers is increasing. Whatever factor leads to an increase in the presence of female VTE teachers (e.g., a welcoming school environment for young female teachers) could also increase students' chances of STEM higher education enrollment, which makes it an unobserved variable that biases our results. For both cases, the unobserved variable would increase (or decrease) with the presence of female VTE teachers. Hence, by including a program-school-specific time trend, we control for the unobserved characteristics that are linearly increasing or decreasing in time, using the deviations of the presence of female VTE teachers from the program-school time trends as our identifying variation. If the unobserved characteristics that are linearly changing in time are not meaningfully biasing our results, we would not see relevant changes in the coefficient of interest, β_1.

$$STEM\ enrollment_{ispy} = \beta_1 Female\ teacher_{ispy} + \beta_2 Male_{ispy} + \beta_3 Male_{ispy} \times Female\ teacher_{ispy} + \theta_{sp} year + X_{ispy} + \gamma_{sp} + \delta_y + \epsilon_{ispy} \quad (2)$$

Table 5 presents the estimated effects obtained by including a time trend in our main model, with and without controls. We find that the effects for all STEM maintain the same direction and similar magnitude, although they lose some statistical significance. For the outcomes that differentiate by type of STEM program enrollment, the treatment coefficients remain statistically significant at a 99% confidence and of similar magnitude for both STEM-VTE diplomas and STEM bachelor's degrees. This stability of the coefficient of interest supports the notion that controlling for unobserved school-level variables that linearly vary over time does not alter our conclusions regarding the impact of the student-teacher female gender match on STEM higher education enrollment.

Table 5: Robustness Check - Time Trend

	All		VTE Diploma		Bachelor Degree	
	(1)	(2)	(3)	(4)	(5)	(6)
Male	0.219**	0.209**	0.198**	0.190**	0.021**	0.019**
	(0.004)	(0.006)	(0.004)	(0.006)	(0.002)	(0.003)
Female STEM-VTE Teacher	0.012	0.017+	0.034**	0.037**	-0.022**	-0.020**
	(0.010)	(0.010)	(0.010)	(0.010)	(0.004)	(0.004)
Male x Female STEM-VTE Teacher	-0.019*	-0.022*	-0.043**	-0.045**	0.024**	0.023**
	(0.010)	(0.009)	(0.009)	(0.009)	(0.004)	(0.004)
Observations	199,418	199,418	199,418	199,418	199,418	199,418
Controls	No	Yes	No	Yes	No	Yes
Mean Outcome for Women	0.219	0.219	0.184	0.184	0.034	0.034
Effect for Men	-0.007	-0.005	-0.009	-0.008	0.002	0.003
P-Value of Effect for Men	0.280	0.455	0.148	0.213	0.318	0.160

All specifications have School-Program and Year fixed effects and a School-Program-specific time trend. Errors are clustered at the school-year-program level. All outcomes consider enrollment in STEM programs. Standard errors in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

5.2.2 *Additional Fixed Effects*

To further strengthen the robustness of our results, we introduce additional fixed effects in our main model to deal with some unobservable variables that remain fixed across different program-school combinations and may be correlated with both the treatment (presence of female VTE teachers) and the outcome (STEM enrollment in higher education). As shown in Equation 3, the general model specification for these robustness checks includes

α_g as a fixed effect that aims to control for unobservable characteristics that remain constant within group g.

$$STEM\ enrollment_{ispy} = \beta_1 Female\ teacher_{ispy} + \beta_2 Male_{ispy} + \beta_3 Male_{ispy} \times Female\ teacher_{ispy} + X_{ispy} + \gamma_{sp} + \delta_y + \alpha_g + \epsilon_{ispy} \quad (3)$$

Using Equation 3, we first incorporate a program-year fixed effect to control for unobservable characteristics that remain constant within each program and year across different schools. This helps capture program-specific trends, such as the growing popularity or increasing demand for computer science programs over time. By including this fixed effect, we aim to account for the potential influences of these trends on both female STEM enrollment and the presence of female teachers. Table 6 presents the estimations of our main model, including a program-year fixed effect. Notably, the coefficient for Female STEM-VTE Teacher remains statistically significant in all specifications. For STEM-VTE diplomas, the student-teacher female gender match effect remains significant at a 99% confidence level, increasing from 0.039 to 0.041. The consistency of the coefficients when incorporating a program-year fixed effect suggests that our main results are robust to controlling for program-specific unobservable factors that could potentially bias our findings.

Table 6: Robustness Check - Including Program-Year Fixed Effect

	All		VTE Diploma		Bachelor Degree	
	(1)	(2)	(3)	(4)	(5)	(6)
Male	0.219**	0.211**	0.198**	0.191**	0.021**	0.020**
	(0.004)	(0.006)	(0.004)	(0.006)	(0.002)	(0.002)
Female STEM-VTE Teacher	0.020*	0.023*	0.038**	0.041**	-0.019**	-0.018**
	(0.010)	(0.010)	(0.010)	(0.010)	(0.004)	(0.004)
Male x Female STEM-VTE Teacher	-0.021*	-0.022*	-0.045**	-0.046**	0.023**	0.023**
	(0.010)	(0.009)	(0.009)	(0.009)	(0.004)	(0.004)
Observations	199,403	199,403	199,403	199,403	199,403	199,403
Controls	No	Yes	No	Yes	No	Yes
Mean Outcome for Women	0.219	0.219	0.184	0.184	0.034	0.034
Effect for Men	-0.002	0.001	-0.007	-0.005	0.005	0.005
P-Value of Effect for Men	0.774	0.921	0.288	0.423	0.031	0.012

All specifications have School-Program, Year-Program and Year fixed effects. Errors are clustered at the school-year-program level. All outcomes consider enrollment in STEM programs. Standard errors in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

In our second fixed effect robustness check, we include a program-province-gender fixed effect in Equation 3 to account for variations in social beliefs about STEM careers and gender across different geographical locations. This allows us to capture any unobservable factors related to certain regions being more progressive in specific programs, leading to an increased presence of female STEM teachers and higher female enrollment in STEM higher education. For the Chilean context, an example would be the varying beliefs about women's participation in the mining sector in different regions. In the province of Antofagasta, the country's main copper-producing region, the familiarity and prominence of the mining industry may lead to more progressive views on women's involvement in mining compared to other provinces or regions. Including a program-province-gender fixed effect helps account for these unobservable beliefs and their impact on female students' interest and enrollment in STEM programs related to mining.

Table 7 shows the results of our estimates when introducing this additional, more restrictive fixed effect. The sign of the effect of the female gender match on VTE Diploma and Bachelor Degree STEM enrollment remains similar to our main estimations. However, it is important to note that the effect for VTE Diploma enrollment loses some statistical significance due to a moderate decrease in the size of the coefficient, yielding a p-value of 0.053 for the specification that includes controls. In consequence, the aggregated effect across all STEM higher education programs also decreases in size, losing its statistical significance. Although the aggregated enrollment result loses significance in the mentioned specification, the effects on both VTE Diploma and Bachelor Degree remain significant and consistently aligned. Based on this observation, we argue that the overall impact on enrollment remains of interest.

Table 7: Robustness Check - Including a Program-Province-Gender Fixed Effect

	All		VTE Diploma		Bachelor Degree	
	(1)	(2)	(3)	(4)	(5)	(6)
Female STEM-VTE Teacher	0.008	0.009	0.017+	0.020+	-0.010*	-0.011**
	(0.011)	(0.011)	(0.010)	(0.010)	(0.004)	(0.004)
Male x Female STEM-VTE Teacher	-0.007	-0.006	-0.020*	-0.020*	0.013**	0.014**
	(0.011)	(0.010)	(0.010)	(0.010)	(0.004)	(0.004)
Observations	195,563	195,563	195,563	195,563	195,563	195,563
Controls	No	Yes	No	Yes	No	Yes
Mean Outcome for Women	0.219	0.219	0.184	0.184	0.034	0.034
Effect for Men	0.001	0.003	-0.002	-0.001	0.003	0.004
P-Value of Effect for Men	0.906	0.625	0.706	0.907	0.162	0.099

All specifications have School-Program, Program-Province-Gender and Year fixed effects. Errors are clustered at the school-year-program level. The small difference in the number of observations is due to the fact that we do not have Province information for schools that were closed before 2014. All outcomes consider enrollment in STEM programs. Standard errors in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

5.2.3 *Placebo Tests*

We conducted a series of placebo tests to assess the robustness of our findings. These tests involved examining alternative definitions of the treatment and outcome variables to determine if the effects observed in our main analysis persist when the treatment should theoretically have no impact on the outcome, according to the role model explanation of the positive impact of female teachers on female students' educational outcomes.

Our first placebo test checks whether the positive effect of female STEM-VTE teachers is specific to STEM enrollment. To assess this, we examine overall enrollment in higher education programs as a placebo outcome, which includes both STEM and non-STEM programs. Our theoretical postulation suggests that female teachers serve as role models in STEM-VTE programs for female students who typically lack access to such role models. Therefore, we expect the effect of female STEM-VTE teachers to be concentrated in the areas where they can serve as valid role models: the subjects they teach. We should not observe an effect of female STEM-VTE teachers on general enrollment since their role model potential is specific to STEM fields. The results of our estimation, shown in Table 8, indicate that the female gender match effect is not statistically significant at a 90 or 95% confidence level for any of the outcomes examined. Additionally, the magnitude of the effect coefficients is practically zero, providing further support for the notion that the positive impact of female STEM-VTE teachers on enrollment exists solely in the fields where these teachers can act as role models

Table 8: Placebo Test - Outcome as All Higher Education Enrollment (STEM and non-STEM)

	All		VTE Diploma		Bachelor Degree	
	(1)	(2)	(3)	(4)	(5)	(6)
Male	-0.042**	-0.026**	0.008+	0.013*	-0.051**	-0.038**
	(0.004)	(0.006)	(0.005)	(0.006)	(0.003)	(0.004)
Female STEM-VTE Teacher	-0.002	-0.004	0.002	0.002	-0.004	-0.006
	(0.009)	(0.009)	(0.010)	(0.010)	(0.007)	(0.006)
Male x Female STEM-VTE Teacher	0.005	0.008	-0.005	-0.004	0.010	0.012*
	(0.009)	(0.008)	(0.010)	(0.010)	(0.006)	(0.006)
Observations	199,403	199,403	199,403	199,403	199,403	199,403
Controls	No	Yes	No	Yes	No	Yes
Mean Outcome for Women	0.596	0.596	0.433	0.433	0.163	0.163
Effect for Men	0.003	0.004	-0.003	-0.002	0.006	0.006
P-Value of Effect for Men	0.649	0.431	0.594	0.724	0.052	0.028

Treatment is all higher education enrollment. All specifications have School-Program and Year fixed effects. Errors are clustered at the school-year-program level. All outcomes consider enrollment in STEM programs. Standard errors in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Our second placebo test aims to check whether the observed effect is not solely attributed to a gender match between female STEM-VTE teachers and students but extends to any female STEM teachers. Previous studies (Bottia et al., 2015; Dulce-Salcedo et al., 2022; Stearns et al., 2016) have indicated that the proportion of high school female math and science teachers influences young women's inclination to pursue STEM majors. Therefore, the mechanism we observe may be attributed to the presence of a female teacher in a STEM academic subject, rather than specifically having a female role model from the industrial sector in which the student is interested. Given that we have the information on STEM teachers' gender in our data set, we show the results of estimating our main model with treatment defined as having a female teacher in math and science in Table 9. The alternative treatments have an effect close to zero on VTE, Bachelor, and overall enrollment, and it is not statistically significant at the 95% confidence level. This suggests that the impact we are detecting is specific to STEM-VTE Female teachers and not all STEM academic teachers.

Table 9: Placebo Test - All Female Academic STEM Teachers as Treatment

	All		VTE Diploma		Bachelor Degree	
	(1)	(2)	(3)	(4)	(5)	(6)
Male	0.214**	0.209**	0.189**	0.186**	0.025**	0.023**
	(0.006)	(0.008)	(0.006)	(0.007)	(0.002)	(0.003)
Female STEM-VTE Teacher	-0.009	-0.006	-0.003	-0.003	-0.005+	-0.003
	(0.007)	(0.007)	(0.007)	(0.007)	(0.003)	(0.003)
Male x Female STEM-VTE Teacher	-0.000	-0.003	-0.003	-0.004	0.003	0.002
	(0.008)	(0.008)	(0.007)	(0.007)	(0.003)	(0.003)
Observations	199,403	199,403	199,403	199,403	199,403	199,403
Controls	No	Yes	No	Yes	No	Yes
Mean Outcome for Women	0.219	0.219	0.184	0.184	0.034	0.034
Effect for Men	-0.009	-0.008	-0.007	-0.007	-0.002	-0.001
P-Value of Effect for Men	0.015	0.015	0.048	0.043	0.229	0.313

Treatment is female math and science teachers. All specifications have School-Program and Year fixed effects. Errors are clustered at the school-year-program level. All outcomes consider enrollment in STEM programs. Standard errors in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Our third placebo test follows a similar logic and checks if the effect we detect is not about having VTE-STEM female teachers as role models but from the fact that having any female teacher provides a welcoming environment for female students, regardless of being examples of successful professionals in industrial STEM occupations. If this explanation was correct, we would observe a significant positive effect of having female teachers in other subjects that are not science, math, or STEM industrial courses. We present the placebo estimates of our original specification with treatment defined as having female teachers in other subjects in Table 10. If this treatment were effective, it would indicate that what we estimate as a “role model effect” is driven not by having an industrial STEM role model but by a better learning environment fostered by female teachers. The coefficients for this placebo treatment are not statistically significant, and their magnitude is much smaller than the main effect. This supports the idea that the effect of the STEM-VTE female teachers is due to them reinforcing examples of STEM-VTE professionals and not only by a better learning environment due to having a female instructor.

Table 10: Placebo Test - All Other Female Teachers as Treatment

	All		VTE Diploma		Bachelor Degree	
	(1)	(2)	(3)	(4)	(5)	(6)
Male	0.230**	0.222**	0.184**	0.180**	0.046*	0.041*
	(0.033)	(0.033)	(0.030)	(0.030)	(0.020)	(0.021)
Female STEM-VTE Teacher	0.009	0.008	-0.000	-0.001	0.009	0.009
	(0.032)	(0.032)	(0.028)	(0.028)	(0.019)	(0.019)
Male x Female STEM-VTE Teacher	-0.017	-0.015	0.003	0.003	-0.019	-0.018
	(0.034)	(0.033)	(0.030)	(0.030)	(0.020)	(0.021)
Observations	199,403	199,403	199,403	199,403	199,403	199,403
Controls	No	Yes	No	Yes	No	Yes
Mean Outcome for Women	0.219	0.219	0.184	0.184	0.034	0.034
Effect for Men	-0.008	-0.007	0.002	0.002	-0.010	-0.009
P-Value of Effect for Men	0.596	0.582	0.875	0.897	0.132	0.147

Treatment is other female teachers. All specifications have School-Program and Year fixed effects. Errors are clustered at the school-year-program level. All outcomes consider enrollment in STEM programs. Standard errors in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Finally, we present a placebo test using the future presence of female STEM-VTE teachers as the treatment. The reasoning is that the presence of female STEM-VTE teachers three years into the future should not affect a current student's STEM higher education enrollment. Therefore, if our assumptions hold and the model yields the true effect of the treatment on the outcome, we should not observe a significant effect of future treatment on the outcome. Furthermore, it is reasonable that the future and the current presence of female STEM-VTE teachers share some causes that are potential confounders in the analysis. An example of such a confounder could be changing social beliefs about a program that increases the number of women that go into STEM-VTE teaching in that program and the number of female students enrolling in higher education STEM. Hence, a possible relationship between future and present treatment driven by such unobservables would threaten the causal interpretation of our results and be captured by the proposed placebo treatment. Table 11 shows the results of estimating our main model defining the treatment as the presence of at least one female STEM-VTE teacher for that same program in that same school three years into the future. The coefficients of the effect of the treatment are close to zero and not statistically significant at a 95% confidence level for any of our outcomes. The estimates suggest that our results are not biased by omitting contextual unobserved variables that could influence the presence of female STEM-VTE teachers in a program in a school consistently throughout the years.

Table 11: Placebo Test - Future Presence of Female STEM-VTE Teacher as Treatment

	All		VTE Diploma		Bachelor Degree	
	(1)	(2)	(3)	(4)	(5)	(6)
Male	0.198**	0.189**	0.180**	0.176**	0.018**	0.013**
	(0.007)	(0.008)	(0.006)	(0.008)	(0.003)	(0.003)
Female STEM-VTE Teacher	-0.010	-0.003	-0.001	0.003	-0.009+	-0.006
	(0.013)	(0.013)	(0.012)	(0.013)	(0.005)	(0.005)
Male x Female STEM-VTE Teacher	0.001	-0.005	-0.015	-0.018	0.016**	0.012*
	(0.011)	(0.011)	(0.011)	(0.011)	(0.005)	(0.005)
Observations	110,032	110,032	110,032	110,032	110,032	110,032
Controls	No	Yes	No	Yes	No	Yes
Mean Outcome for Women	0.219	0.219	0.184	0.184	0.034	0.034
Effect for Men	-0.008	-0.008	-0.015	-0.015	0.007	0.006
P-Value of Effect for Men	0.363	0.357	0.080	0.097	0.011	0.028

The treatment corresponds to the presence of a STEM-VTE teacher 3 years into the future. All specifications have School-Program and Year fixed effects. Errors are clustered at the school-year-program level. All outcomes consider enrollment in STEM programs. Standard errors in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

5.3 Heterogeneity Effects

Given that STEM-VTE diplomas are the most taken path to STEM higher education for secondary VTE students, we now investigate the heterogeneity of our treatment specifically for this outcome. Drawing from previous research on the effects of female teachers on STEM outcomes, we analyze three sources of heterogeneity: class size, classroom gender composition, and student ability. This examination may be useful to shed light on plausible mechanisms through which female VTE teachers influence the persistence of female students in the STEM-VTE pipeline. Additionally, it can help identify subgroups of female students that would particularly benefit from having female teachers in their STEM-VTE classrooms. To accomplish this, we incorporate the heterogeneity variable into our main model and interact it with the treatment, as specified in Equation 4. The coefficient β_7 indicates whether our treatment effect differs for students with varying levels of the analyzed heterogeneity variable.

$$STEM\ enrollment_{ispy} = \beta_1 Male_{ispy} + \beta_2 Het_{ispy} + \beta_3 Female\ teacher_{ispy} + \beta_4 Male_{ispy} \times Het_{ispy} + \beta_5 Het_{ispy} \times Female\ teacher_{ispy} + \beta_6 Male_{ispy} \times Female\ teacher_{ispy} + \beta_7 Male_{ispy} \times Het_{ispy} \times Female\ teacher_{ispy} + X_{ispy} + \gamma_s + \delta_y + \epsilon_{ispy} \quad (4)$$

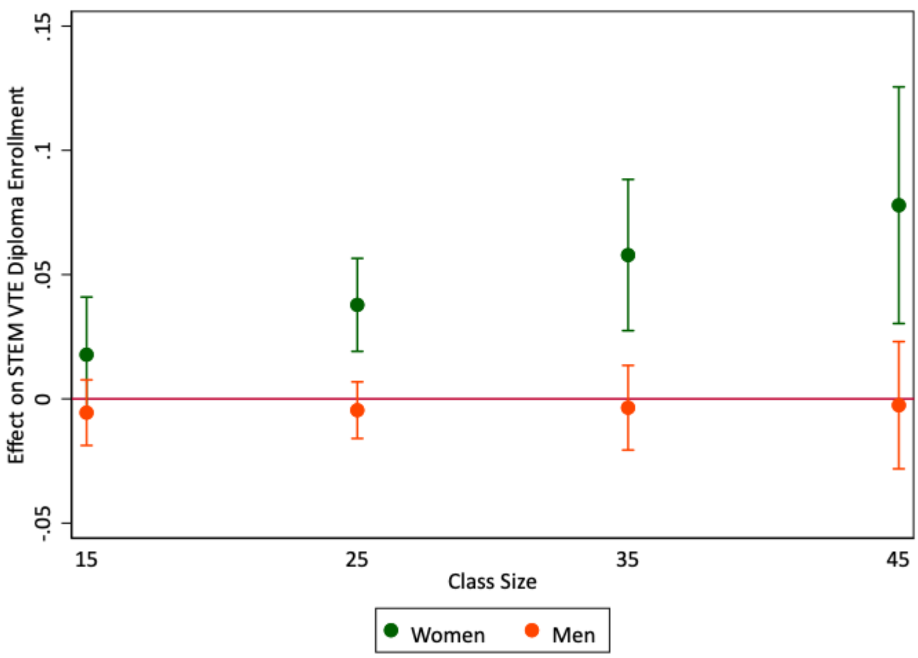
Table 12 presents the estimations of Equation 4 using class size as the heterogeneity variable, while Figure 1 illustrates the effect size of the student-teacher female gender match effect across different class sizes. The coefficient for the interaction between Female STEM-VTE teachers and class size is positive and statistically significant, indicating that the female gender match effect is more extensive for students in larger classes. This finding challenges the previous evidence, as suggested by Maurer et al. (2023), which attributes the effect solely to increased and more direct interaction between teachers and students in smaller class settings. Instead, our findings indicate that female STEM-VTE teachers benefit female students in both small and large classes in terms of their enrollment in STEM higher education programs.

Table 12: Heterogeneity Effects by Classroom Size

	VTE Diploma	
	(1)	(2)
Female STEM-VTE Teacher	-0.011	-0.012
	(0.024)	(0.024)
Female STEM-VTE Teacher x Class Size	0.002+	0.002*
	(0.001)	(0.001)
Observations	199,403	199,403
Controls	No	Yes
Mean Outcome for Women	0.184	0.184
Effect for Men	-0.005	-0.007
P-Value of Effect for Men	0.684	0.571

All specifications have School-Program and Year fixed effects. Errors are clustered at the school-year-program level. All outcomes consider enrollment in STEM programs. Standard errors in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Figure 1: Heterogeneity Effects by Classroom Size



Another variable that may affect female students' exposure to STEM-VTE female teachers is the gender composition of the classroom. Some author suggests that the presence of female teachers can encourage young women to engage with their female classmates, potentially influencing their academic performance and choice of major (Canaan & Mouganie, 2023). This aligns with findings indicating that women's decisions to pursue and continue in STEM fields can be influenced by the gender composition of their peers (Sacerdote, 2011). Table. 13 present the result of the gender composition of STEM-VTE classrooms as a source of heterogeneity of female teacher effect on STEM-VTE diplomas enrollment. The estimates are small and statistically insignificant, indicating that the effect does not vary according to the composition of students' classrooms.

Table 13: Heterogeneity Effects by Classroom Gender Composition

	VTE Diploma	
	(1)	(2)
Female STEM-VTE Teacher	0.037*	0.046**
	(0.016)	(0.015)
Female STEM-VTE Teacher x Female Peers Perc	0.002	-0.026
	(0.044)	(0.044)
Observations	199,403	199,403
Controls	No	Yes
Mean Outcome for Women	0.184	0.184
Effect for Men	-0.012	-0.020
P-Value of Effect for Men	0.677	0.499

All specifications have School-Program and Year fixed effects. Errors are clustered at the school-year-program level. All outcomes consider enrollment in STEM programs. Standard errors in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

Prior studies have indicated that the effects of teacher gender are more pronounced for highly skilled female students, as measured by SAT math scores (Carrell et al., 2010; Solanki Xu, 2018). We follow this line of inquiry and explore the heterogeneity of the effects of having a female STEM-VTE teacher considering their math standardized test scores. Table 14 presents the test results for heterogeneity of effects based on math standardized test scores. However, the interaction between having at least one female VTE teacher and students' standardized math scores is small and not statistically significant. Therefore, we do not observe differential effects for female students with higher math scores in our study.

Table 14: Heterogeneity Effects by Mathematics Score

	VTE Diploma	
	(1)	(2)
Female STEM-VTE Teacher	0.039**	0.041**
	(0.010)	(0.010)
Female STEM-VTE Teacher x Math Score (SD)	0.009	0.010
	(0.007)	(0.007)
Observations	199,403	199,403
Controls	No	Yes
Mean Outcome for Women	0.184	0.184
Effect for Men	-0.015	-0.013
P-Value of Effect for Men	0.071	0.099

All specifications have School-Program and Year fixed effects. Errors are clustered at the school-year-program level. All outcomes consider enrollment in STEM programs. Standard errors in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

6 Conclusion

The attrition of young women in the STEM pipeline, particularly from secondary to post-secondary education, is a concerning trend, particularly in low-income environments. This is worrisome because research shows that pursuing a STEM major leads to better early career outcomes, regardless of students' socioeconomic status (Wolniak & Engberg, 2019; Sullivan et al., 2018). Our paper finds that female students in applied-STEM programs in vocational-technical high schools benefit from having at least one female VTE teacher, enhancing their opportunities to pursue STEM fields at the post-secondary level. We observe that this effect is driven by female students' increase in their VTE diploma enrollment, at least partly due to female students originally intending to pursue STEM bachelor's degrees instead of opting for STEM-VTE diplomas. Other potential sources for this increase may stem from female students with at least one female VTE teacher transitioning from non-STEM to STEM diplomas or transitioning from not enrolling in higher education to enrolling in a STEM post-secondary diploma. This trend aligns with the prevailing belief held within vocational-technical high schools that VTE diplomas, rather than bachelor's degrees offered by universities, are the most direct and effective entry point to higher education for their students. (Lopez et al., 2018).

Research has shown that gender imbalance in STEM-related VTE programs fosters educational environments plagued with gender stereotypes, discouraging women from persisting in their career paths (Bridges et al., 2020; Makarova et al., 2016; Smith, 2013). In the Chilean context, it has been argued that existing discourses and micro-practices within STEM-VTE classrooms perpetuate and amplify gender stereotypes, reinforcing the notion that STEM careers are predominantly male-oriented (Sevilla & Carvajal, 2020). A recent study also suggests that enrolling in a VTE STEM-focused program while still in secondary school has limited positive effects on female post-secondary VTE-STEM career development, as it can boost their self-efficacy but may not affect their career expectations (Sevilla & Rengel, 2022). Our findings support the notion that female VTE teachers in applied STEM fields, serving as role models, have the potential to mitigate gender stereotypes and elevate career expectations of female students, maintaining them in the STEM pipeline.

Addressing the gender imbalance in STEM education and careers involves two distinct challenges. One is increasing the retention of women who are already pursuing STEM fields. The second is increasing the recruitment of women into the STEM pipeline. While some authors suggest that female role models assist in both of these efforts, others posit that same-gender role models are more effective for women who are already in STEM fields (Drury et al., 2011). This is because female role models protect women who are highly identified with STEM against the harmful effects of gender-negative stereotypes (Marx Roman, 2002). Our findings align with this theoretical postulate, as female students in secondary STEM-VTE programs, who are already identified with STEM fields, are more likely to persist in the STEM pipeline by enrolling in STEM-VTE diplomas when they have a female teacher rather than a male teacher.

While the exact mechanisms are challenging to disentangle empirically, we have provided several pieces of evidence suggesting that at least part of our main effects are driven by female VTE teachers acting as role models to female students in secondary STEM-VTE programs. First, the non-significant effects of female teachers on male enrollment in STEM programs dismiss the notion of gender bias in favor of women. Likewise, the non-significant effect of non-STEM-VTE female teachers on female student STEM enrollment, allows us to discard other channels through which these female teachers can affect female students, such as being more comfortable talking to a female rather than a male teacher or the more positive school atmosphere that any female teachers can create. Lastly, our role model interpretation is reinforced by the fact that the student-teacher gender match effect persists regardless of class size, which discards that female teachers impact their students solely through increased direct interaction that would be more prevalent in smaller classes. Also, descriptive data suggest that the observed positive effects of female VTE teachers are not driven by gender differences in their qualifications or experience levels in teaching in VTE or industry.

Despite the evidence we present about how VTE female teachers increase female students' enrollment in STEM-VTE diplomas, our work has some limitations. From an empirical perspective, although we ran several robustness checks, our analysis remains quasi-experimental. In other words, our causal claim still hinges on the assumption that the variation in exposure to STEM-VTE female teachers within program-school is quasi-random. A possible extension of our work would be a similar analysis in a context where STEM-VTE female teachers are randomly assigned to students in applied STEM high school programs.

Another set of limitations refers to the type of outcomes analyzed. VTE aims to favor meaningful transitions to the labor market in tandem with preparing students for higher studies. Our paper does not deal with labor market outcomes as it only considers the persistence in the STEM pipeline in terms of enrolling in STEM higher education programs. Female teachers in STEM-VTE programs can also impact labor market outcomes, pushing young women to pursue STEM jobs with better labor prospects. However, we did not capture this highly relevant dimension for VTE schools since access to the labor market is still the main goal for a significant fraction of their students (Mineduc, 2020). Besides, we only focus on enrollment in STEM higher education programs, overlooking persistence and graduation. Most recent papers on female teachers examine lifelong impacts such as working in a STEM occupation, receiving a STEM master's degree, having higher family incomes, and increasing longevity (Card et al., 2022; Mansour et al., 2022). More research on female teachers' impact on VTE schools is needed to examine these long terms outcomes.

We conclude by emphasizing the importance of providing young women, particularly those from low-income settings, with early opportunities to enter and persist in STEM-related educational paths. Our study looked at school factors such as teachers' gender during the critical transition from high school to higher education, providing strong evidence of the positive impact that female teachers have on boosting female enrollment in STEM-VTE diplomas. Therefore, we advocate for expanding our efforts to recruit more female professionals in the STEM fields as teachers that can serve as role models in vocational-technical high schools.

Declaration

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Appendix A: Descriptive Statistics

Table A1: STEM-VTE Teacher Characteristics

	Years of experience as VTE teacher	Starting age as teacher	Teaching Diploma
Female	-1.942***	-3.561***	-0.00466
	(0.303)	(0.253)	(0.0108)
Observations	4,912	4,912	4,912
Controls	Yes	Yes	Yes

Controls include geographic regions and years.

Column 3 adds years of experience in the educational system as a control.

Standard errors in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$

Table A2: Descriptive Statistics of the control variables by STEM and gender

	Enrolled in STEM			Enrolled in Non-STEM		
Variables	Women	Men	Diff	Women	Men	Diff
High School GPA	0.50	0.37	0.128**	0.33	0.20	0.122**
Standardized Lecture Test Score	0.38	0.19	0.188**	0.16	-0.09	0.254**
Standardized Mathematics Test Score	0.19	0.33	-0.139**	-0.17	-0.09	-0.078**
Father's Education	8.60	8.77	-0.176**	8.19	7.73	0.459**
Mather's Education	8.68	8.84	-0.160*	8.19	7.77	0.428**
Expectations of enrolling in higher education	0.67	0.64	0.034**	0.59	0.46	0.130**
Age	16.25	16.29	-0.037**	16.37	16.43	-0.055**

Standard errors in parentheses

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

Table A3: STEM-VTE School-Programs transitions by the presence of female teachers

	Treatment Units	
	N	%
Always had female teacher	34	0.64
Never had female teacher	2,731	51.42
Switch to female teachers	318	5.99
Switch to all male teachers	288	5.42
Switch on and off	1,940	36.53
Total	5,311	100

Appendix B: Cluster Errors at the School Level

Table B1: Main Results - Error Clustering at the School Level

	All		VTE Diploma		Bachelor Degree	
	(1)	(2)	(3)	(4)	(5)	(6)
Male	0.219**	0.210**	0.198**	0.190**	0.021**	0.020**
	(0.007)	(0.008)	(0.006)	(0.008)	(0.002)	(0.003)
Female STEM-VTE Teacher	0.018	0.021	0.037*	0.039*	-0.018**	-0.018**
	(0.016)	(0.015)	(0.015)	(0.015)	(0.007)	(0.006)
Male x Female STEM-VTE Teacher	-0.020	-0.021	-0.043**	-0.043**	0.023**	0.023**
	(0.016)	(0.015)	(0.016)	(0.015)	(0.008)	(0.007)
Observations	199,403	199,403	199,403	199,403	199,403	199,403
Controls	No	Yes	No	Yes	No	Yes
Mean Outcome for Women	0.219	0.219	0.184	0.184	0.034	0.034
Effect for Men	-0.001	0.000	-0.006	-0.005	0.005	0.005
P-Value of Effect for Men	0.881	0.956	0.495	0.591	0.133	0.065

All specifications have School-Program and Year fixed effects. Errors are clustered at the school level. All outcomes consider enrollment in STEM programs. Standard errors in parentheses. + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$.

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