Working Paper No. 230

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IBW – Institut für Betriebswirtschaftslehre

UNIVERSITÄT BERN

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Please cite as:
"Gender Norms, Occupational Choices, and the Innovation Gender Gap." Swiss Leading House "Economics of Education" Working Paper No. 230, 2024. By Andreas Fridolin Bühler, Patrick Lehnert and Uschi Backes-Gellner.

The Swiss Leading House on Economics of Education, Firm Behavior and Training Policies is a Research Program of the Swiss State Secretariat for Education, Research, and Innovation (SERI).

www.economics-of-education.ch

Gender Norms, Occupational Choices, and the Innovation Gender Gap†

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September 2024

Abstract: This paper analyzes how social gender norms affect the innovation gender gap, part of which stems from an underrepresentation of women in science, technology, engineering, and mathematics education. This underrepresentation is traceable to gender-biased educational and occupational choices. One determinant for such biased choices is social gender norms, which also directly affect the innovation gender gap. We disentangle the direct effect of social gender norms from their indirect effect via educational and occupational choices. Combining municipality-level voting data as a measure for social gender norms with patent data as a measure for innovation outcomes, we apply structural equation modeling. Our results show that more traditional gender norms are associated with a significantly lower number of patents filed by women and that the indirect effect via educational and occupational choices accounts for 5.5% of the total effect. These results are crucial for policymakers: while social gender norms are highly persistent and difficult to change in the short term, promoting greater gender equality in educational and occupational choices can be achieved more quickly and may therefore yield important short-term reductions in the innovation gender gap.

Keywords: Gender, Education, Occupational Choices, Innovation

† This study is partly funded by the Swiss State Secretariat for Education, Research, and Innovation (SERI) through its "Leading House VPET-ECON: A Research Center on the Economics of Education, Firm Behavior and Training Policies." We would like to thank Eric Bettinger, Simon Janssen, Keiko Yasukawa, Phillip Toner, seminar participants at the University of Zurich, and conference participants at DRUID24 in Nice for helpful comments. We thank the Swiss Federal Statistical Office for providing the labor market data.

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1. Introduction

Despite long-standing initiatives for improving gender equality in the labor market, women remain strongly underrepresented among inventors: in 2017, for example, the worldwide female percentage of patent inventors was still 12.7% (e.g., UK Intellectual Property Office, 2019). Even though this innovation gender gap is narrowing, Jung and Ejermo (2014) find it doing so at a slower pace than in other societal areas (e.g., education). Two main problems result from this innovation gender gap. First, the underrepresentation of women in innovation leads to an underrepresentation of women's needs and interests in innovation outcomes (e.g., Koning et al., 2021), thereby contributing to the reproduction of structural inequalities (e.g., Dahlin et al., 2023; Forman et al., 2019). Second, the innovation potential of half the workforce (i.e., women) remains largely untapped, potentially leading to reduced innovation outcomes overall. These problems are particularly salient in highly developed countries, which strongly rely on innovation for their competitiveness and for ensuring productivity and future wealth (e.g., Acemoglu & Restrepo, 2018; Howitt & Aghion, 1998).

Previous research has shown that education in science, technology, engineering and mathematics (STEM) fields is a crucial factor for innovation (e.g., Makkonen & Lin, 2012; Metcalfe, 2005). Not surprisingly, providing workers with the necessary skills for participating in innovation activities constitutes a key objective of education systems (Bloom et al., 2019), and researchers have been investigating the role of academic STEM education on innovation (e.g., Bianchi & Giorcelli, 2020; Toivanen & Väänänen, 2016; Winters, 2014). As STEM fields are usually male dominated, the underrepresentation of women in academic STEM education explains part of the innovation gender gap (e.g., Hunt et al., 2013). Moreover, a small but growing literature shows that not only workers with a university STEM education but also workers with vocational education and training (VET) foster innovation (e.g., Backes-Gellner, 1996; Backes-Gellner & Lehnert, 2021; Lewis, 2023; Rupietta & Backes-Gellner, 2019; Toner, 2010). Thus, in addition to their underrepresentation in academic STEM fields, their underrepresentation in VET STEM fields can further amplify women's underrepresentation among patent inventors. Moreover, recent research suggests that social gender norms are another important direct determinant of innovation. Qin et al. (2023) for example, show that more traditional gender norms are linked to gender inequalities in patenting.

In addition, research on educational and occupational choices has shown that social gender norms also critically affect educational or occupational choices and the representation of women in STEM fields (Kuhn & Wolter, 2023; Palffy et al., 2023b). Thus social gender norms may also indirectly affect innovation through their impact on educational or occupational choices. However, the extent to which social norms affect innovation directly or indirectly remains unclear. Even though social gender norms per se (direct effects) are persistent (Gruneau, 2022; Janssen et al., 2016; Kuhn & Wolter, 2023; Palffy et al., 2023b), educational interventions that reduce the bias in women's occupational choices may change gender biases in shorter term as previous research has shown (Delfino, 2021; Palffy et al., 2023a; Pietri et al., 2021) and thereby also indirectly affect innovation in the short term. Therefore, disentangling what percentage of the innovation gender gap induced by social gender norms is driven by a direct effect or by an indirect effect via occupational choices and may thus be influenced by educational interventions is highly important for innovation policy.

We analyze whether and, if so, to what extent social gender norms have a direct effect on innovation and an indirect effect through educational or occupational choices. To do so, we investigate how regional differences in social gender norms affect regional patenting. By estimating these relationships in a structural equation model (SEM), we are able to disentangle the direct effect of social gender norms on innovation from their indirect effect through educational or occupational choices.

In our analysis, we use data from Switzerland because they are ideal for our empirical analysis for three reasons. First, because of its frequent popular votes—which reveal large differences in social attitudes towards gender equality at disaggregated levels—we are able to reliably measure social gender norms across Swiss municipalities (Janssen et al., 2016; Kuhn & Wolter, 2023; Lalive & Stutzer, 2010; Palffy et al., 2023b). Second, Switzerland is among the most innovative countries (e.g., the World Intellectual Property Organization's Global Innovation Index) (see Dutta et al., 2021).[1] Third, because of its unique education system we are able to reliably measure occupational choices of individuals from age 15 on. Approximately 70% of Swiss adolescents choose a VET pathway in one of more than 200 occupations for upper secondary education (i.e., at around ages 15-16, in the last year of compulsory schooling); another roughly 20% choose a traditional academic education pathway for which we can identify their field of study.[2] Thus VET graduates constitute roughly 70% of the Swiss workforce, thereby making their occupational choices as important for innovation as the choices of college majors that have been the typical focus of innovation studies so far.

[1] Even though Switzerland is a highly innovative country, the female percentage of inventors is as low as 9% (Niggli & Rutzer, 2021).

[2] The remaining 10% of individuals does not acquire any post-compulsory education.

For our analysis, we combine four data sources. First, to measure gender norms, we use the municipality-level[3] voting outcomes of a constitutional referendum on gender equality issues. In doing so, we follow the measurement of regional social norms used by Janssen et al. (2016), Kuhn and Wolter (2023), Lalive and Stutzer (2010) Lalive and Stutzer (2010), and Palffy et al. (2023b). Second, to measure the percentage of women with either academic or VET STEM degrees[4] at the municipality level, we use the Swiss Labor Force Survey (SLFS). Third, to measure innovation outcomes, we use patent data from the European Patent Office's Worldwide Patent Statistical Database (PATSTAT).[5] We use the information on all patent applications with at least one inventor in Switzerland, including, among other items, the filing dates, the inventors' names, and their addresses. Fourth, to identify the gender of the inventors, we use Raffo's (2021) gender-name dictionary and apply it to the PATSTAT data.

To analyze the direct and indirect effects of social gender norms on the regional innovation output, we use women's patent quantity, i.e., the quantity of patent applications by women, per municipality and year as our outcome. We apply a structural equation modeling (SEM) framework, which allows us to simultaneously examine the direct and indirect effects of multiple variables on an outcome variable and thus disentangle direct from indirect effects. Our SEM results show that—as expected—social gender norms have both direct and indirect effects on innovation. The direct effect of a one percentage point stronger traditional gender norm on women's patent quantity is a reduction of 0.513%; the indirect effect is a reduction of 0.030%. Thus the indirect effect accounts for 5.5% of the total effect of social gender norms on women's patents, suggesting that occupational and educational choices substantially mediate the effect of gender norms on innovation. This finding underlines the role of occupational choices in the innovation gender gap. Moreover, when we use patent quality as indicated by patent citations as an outcome instead of patent quantity, the same pattern holds.

In further analyses, to ensure that women's patenting is not merely a substitution for men's patenting, we use overall patent quantity, i.e., the total number of patent applications, as

[3] In Switzerland, municipalities are the smallest administrative and political unit, functionally comparable to a U.S. county.

[4] In our analysis, we consider individuals with qualifications at the upper-secondary level (i.e., diplomas) and tertiary level (i.e., degrees). For the ease of reading, we use "degree" throughout the paper and not "either degree or diploma".

[5] We thank Dietmar Harhoff from the Max-Planck-Institute for Innovation and Competition in Munich for providing the patent data for this project.

an alternative outcome. We find that a larger percentage of women with a STEM degree also positively affects overall patent quantity. This finding clearly indicates that an increase of women in STEM fields does not just replace men's patents but leads to a net increase in innovation activities.

Our findings have important policy implications. As social gender norms have an indirect effect on innovation through STEM education, policy interventions aimed at reducing gender-biased educational or occupational choices can effectively narrow the innovation gender gap in the short term and increase the overall innovation level. Reducing gender-biased educational or occupational choices is thus not only important from an equity perspective but also for innovation policy.

2. Literature and Hypotheses

2.1 Social Norms and Innovation

Social gender norms are social norms[6] describing one set of typical "expected" behaviors for men and another for women. The strength of social norms varies regionally, meaning the cost of deviating is different across regions (i.e., the costs are higher when social norms are stronger). Empirical research has analyzed the effect of social gender norms on various economic outcomes. For example, studies find that when social gender norms are more traditional, the gender pay gap is larger (Janssen et al., 2016; Lalive & Stutzer, 2010) and the educational attainment of women is lower (Kosteas, 2013). Other studies examine women's labor force participation (Antecol, 2000; Fernández, 2013; Fernández & Fogli, 2009; Grewenig et al., 2020) or entrepreneurship (Feldmann et al., 2022; Tubadji et al., 2021). However, there is little evidence so far on the effects of social gender norms on innovation as an outcome variable. Qin et al. (2023)show that a stronger gender bias in cultural tightness (i.e., stronger traditional gender norms) is related to gender inequalities in patenting. Similarly, Bell et al. (2019) analyze the importance of inventors' personal backgrounds, finding that exposure to

[6] Social norms originate in social identity, which Akerlof and Kranton (2000) define as an individual's self-image and identification with a certain group. Therefore, this identity is often associated with different social categories and the ways in which a society tells people in those categories how they should behave. Deviating from such socially expected behavior comes at a cost (Akerlof & Kranton, 2000). Thus, individuals on average act in line with the expected behavior. These expectations are called "social norms" (Bertrand et al., 2020; Pearse & Connell, 2016; Smith et al., 2021).

inventors during childhood increases the probability of inventing for both men and women. They show that women who grow up in a location with more women inventors are also more likely to become inventors, suggesting that environment (of which social norms are part of) plays an important role. Additionally, given that an individual has a STEM degree or diploma, women are still less likely to engage in research and development activities (e.g., Hunt, 2016). Part of this effect can be attributed to social gender norms, leading to a low share of women in the patent-intensive STEM fields (e.g., Lubczyk & Moser, 2024).

As technological innovation is clearly a male-dominated field, we suggest that being an inventor is more likely an "expected" behavior for men, suggesting that social gender norms form an obstacle for women becoming inventors—and the stronger these norms, the fewer the women inventors. We therefore argue that social gender norms directly affect both innovation and educational choices, which leads us to the following hypotheses:

H1) The stronger the local traditional gender norms are, the larger is the a direct negative effect on innovation outcomes.

2.2 Social Norms and Occupational Choices

In addition, studies show that gender norms affect educational or occupational choices and, again, the stronger the norms, the more likely the choice of gender-typical occupations (e.g., Kuhn & Wolter, 2023; Palffy et al., 2023b). Specifically, adolescents are less likely to aspire for (Kuhn & Wolter, 2023) or choose (Palffy et al., 2023b) a gender-atypical VET occupation when living in a municipality with stronger traditional gender norms. Similar results are found for the choice of academic STEM programs (i.e., Humlum et al., 2012). As STEM fields are usually male-dominated, these gender-typical choices contribute to even larger gender gap in STEM fields (Humlum et al., 2012; Kuhn & Wolter, 2023; Osikominu et al., 2020; Palffy et al., 2023b; Zafar, 2013).

H2a) The stronger the local traditional gender norms are, the lower is the percentage of women with an academic STEM degree.

H2b) The stronger the local traditional gender norms are, the lower is the percentage of women with a VET STEM degree.

2.3 Education and Innovation

A large literature studies the determinants of innovation, with many of those studies viewing the education system as a crucial factor for innovation by generating the skills that are required to foster innovation (Makkonen & Lin, 2012; Metcalfe, 2005). Therefore, providing the workforce with the necessary skills for participating in innovation activities constitutes a key objective of education systems (Bloom et al., 2019).

As skills in the STEM fields are most important for innovation, many studies focus on STEM education (e.g., Bianchi & Giorcelli, 2020; Winters, 2014). For example, Bianchi and Giorcelli (2020), who exploit a policy change in Italy that led to an abrupt increase in the number of university STEM graduates, find that students receiving a STEM diploma are more likely to patent in STEM-oriented fields. Similarly, Winters (2014) finds that a regional increase in STEM graduates significantly increases regional patent intensity.

Another strand of the economics literature focuses on the establishment of new universities (i.e., traditional academic universities, which focus on basic research and recruit students from general education pathways such as Gymnasium or High Schools) and the effect of the subsequent increase in STEM graduates on regional innovation. For example, Toivanen and Väänänen (2016), who examine the introduction of technical universities in Finland, find that they led to an increase in both patent quantity and patent quality in the affected regions. Similar results have been shown for Italy (Cowan & Zinovyeva, 2013) and the United States (Andrews, 2023). Whereas most of the research on education and innovation in the past focused on academic tertiary education, a growing strand of more recent literature focuses on vocational education and training (VET) as an additional source of STEM education. Research on applied higher education institutions (i.e., universities of applied sciences,[7] which focus on applied research and recruit students from VET pathways) find that these institutions significantly boost regional innovation as well. (Lehnert et al., 2020) show that firms employ more research and development personnel after the introduction of universities of applied sciences, Pfister et al. (2021) show an increase in overall patenting quantity and quality, and Schlegel et al. (2022) show that the effect size depends on regional economic conditions such as labor market size and industry structures.

[7] Universities of applied sciences (UASs) are tertiary-level vocational institutions that grant bachelor's and master's degrees. Entry to these programs usually requires a VET diploma with a vocational baccalaureate and some practical work experience.

Another strand of literature shows that vocationally trained middle skilled workers (i.e., workers with upper-secondary VET diplomas) also make a significant contribution to innovation (Backes-Gellner, 1996; Lewis, 2023; Rupietta & Backes-Gellner, 2019; Toner, 2010), particularly in economies with a large percentage of well-trained vocationally trained workers (Toner, 2011). For example, Schultheiss and Backes-Gellner (2022) show that middle-skilled VET workers trained under updated occupational curricula that integrate new technologies help to speed up the diffusion of those technologies across firms because these workers provide all training firms with updated skills. This effect is particularly pronounced for firms that are not at the innovation frontier because they do not conduct their own research and development (often small and medium-sized firms). These findings suggest that VET is important for innovation not only through tertiary VET degrees but also through the middle-skilled workforce with upper-secondary degrees. Furthermore, Schultheiss et al. (2023) show that the establishment of UASs not only increases innovation through a higher number of graduates with a tertiary VET degree but also increases the likelihood of workers with a secondary VET degree to work in R&D related tasks. The reason is that UAS graduates build a bridge between graduates from academic tertiary institutions and upper-secondary VET graduates. Thus, the complementarity of the different types of academic and vocational skills provides an additional boost to regional innovation.

To conclude, previous literature shows that innovation is fostered by particular types of education. This applies to different types of education (i.e., academic vs. VET) and different levels of education (i.e., tertiary vs. upper-secondary). As women are largely underrepresented in STEM fields (Hunt et al., 2013; Kahn & Ginther, 2018; Niggli & Rutzer, 2021), we argue that the underrepresentation of women in STEM fields also leads to the underrepresentation of women in innovation activities. We therefore expect similar effects for both academic and VET degrees and state the following hypotheses:

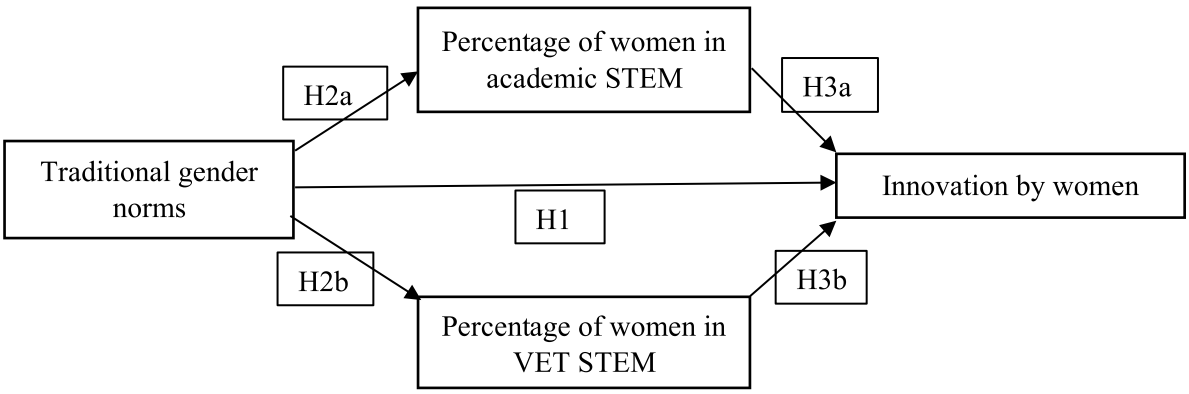
H3a: Higher percentages of women with an academic STEM degree have a positive effect on innovation outcomes.

H3b: Higher percentages of women with a VET STEM degree have a positive effect on innovation outcomes.

2.4 Combining the Effects of Education and Social Norms on Innovation

Overall, we hypothesize a direct negative relationship between more traditional gender norms and innovation and the percentage of women in STEM. We also expect that higher percentages of women in STEM will result in more innovation. In line with our three hypotheses, Figure 1 depicts the expected relationships between our variables. After estimating all these relationships, we will be able to establish the indirect effects of traditional gender norms on innovation by combining the estimates from hypotheses 2a and 3a, and 2b and 3b, respectively. Therefore, we can establish not only the direct effects but also the indirect effects of social gender norms on innovation.

Figure 1: Social Gender Norms, Education and Innovation Outcomes: Structural Model



Notes: Figure 1 models the hypothesized relationship between traditional gender norms and innovation by women. Each path represents a relationship that we estimate in our model. The percentage of women in academic STEM degrees and the percentage of women in VET STEM degrees are the mediators for modeling the indirect effect between social gender norms and women's patents.

3. Data

We construct our dataset by combining four main data sources. First, to measure social gender norms on the municipality level, we use the results from the 1981 constitutional referendum on gender equality. Second, to construct our measures for the municipality-level educational composition of the workforce, we use the Swiss Labour Force Survey (SLFS). Third, to construct our proxy for innovation as our dependent variable, we use patent data. Fourth, to identify the gender inventors in the patent data, we use Raffo's (2021) gender-name dictionary. We then aggregate the patent data on the municipality level.

3.1 Social Gender Norms

To measure social gender norms, we follow Lalive and Stutzer (2010), Janssen et al. (2016), Palffy et al. (2023b), and (Kuhn & Wolter, 2023), by using voting data from a constitutional referendum on gender equality. As voting outcomes on constitutional referenda are legally binding on a national level and therefore have real consequences for all, they provide a reliable proxy for individuals' true attitudes, free of the social desirability bias common in survey data (Janssen et al., 2016; Lalive & Stutzer, 2010). We use municipality-level voting data because the municipality constitutes the smallest administrative regional unit in Switzerland and thus the most fine-grained measurement that best represents the social norms in an individual's daily live and the heterogeneity across municipalities. Specifically, we use voting data from a 1981 constitutional amendment that guarantees the equality of women and men in all spheres of life. This constitutional amendment is particularly suitable for our analysis because it focused on gender equality per se, with no specific policies, so that voters would not be voting for or against the amendment on the basis of certain policies. Moreover, as the 1981 vote predates our observation period, we can avoid reverse causality issues.[8, 9] The required majority of voters and cantons[10] approved the amendment, the rate of approval for this amendment was very heterogeneous across municipalities, varying from 29% to 89% in our sample.

To build our measure of the strength of traditional social gender norms, we use this heterogeneity but use the inverse of the voting result. We thus measure the strength of traditional gender norms by the voter disapproval rate in the 1981 constitutional amendment. Our variable $TraditionalGenderNorms_m$ is measured by the disapproval rate of the constitutional amendment at the municipality level m. A disapproval rate closer to 1 denotes stronger traditional gender norms. A disapproval rate closer to 0 denotes weaker traditional gender norms, i.e., stronger preferences for equality between women and men.

[8] Studies have shown that social norms and their differences among municipalities are relatively stable over time (Cantoni et al. 2019; Janssen et al., 2016).

[9] For a more detailed discussion on the use of voting data as a proxy for social gender norms, see Lalive and Stutzer (2010), Janssen et al. (2016), Palffy et al. (2023), and Kuhn and Wolter (2023).

[10] Cantons are a Swiss political entity functionally comparable to U.S. states.

3.2 Occupational Choices

To measure the educational and occupational choices, we use the Swiss Labor Force Survey (SLFS) from 2007 through 2019. The SLFS constitutes a representative sample of the Swiss working population from age 15. The survey provides information on individuals' level of education (i.e., lower secondary, upper secondary, and tertiary), the type of education (i.e., VET and academic), and the occupational field of education (at the five-digit level according to the Swiss Standard Classification of Occupations, CH-ISCO-19[11]). From this information, we calculate the municipality STEM percentages. To do so, we apply two sample restrictions. First, we consider only individuals who are employed and who hold at least an upper secondary diploma.[12] To assess their level and type of education, we use their highest educational diploma or degree. To determine whether this degree is in a STEM field, we use Gutfleisch and Kogan's (2022) STEM definition and apply it to the observed CH-ISCO-19 occupation.

Second, we aggregate the data at the municipality-year level. For data protection, SLFS municipality information is available only for municipalities with more than 5,000 inhabitants. In total, therefore, we can observe educational or occupational choices only in the largest 297 of the 2148[13] municipalities in Switzerland. Importantly, however, these 297 municipalities account for 59% of the Swiss population.

For this sample, we calculate the percentage of women with STEM degrees within the academic workforce and the percentage of women with STEM degrees within the VET workforce. Specifically, we calculate the percentage of women with an academic STEM degree ($PercWomenAcademicSTEM$) per year y and municipality m as the number of women with an academic STEM degree $F_{y,m}^{Ac,STEM}$ relative to all observed individuals with an academic degree (regardless of gender and STEM/non-STEM). $F_{y,m}^{Ac}$ denotes the number of women with an academic degree, and $M_{y,m}^{Ac}$ denotes the number of men with an academic degree. Likewise,

[11] The first four digits of CH-ISCO-19 are identical to the International Standard Classification of Occupations (ISCO-08) by the International Labor Organization (ILO). The fifth digit accounts for the peculiarities of the Swiss labor market.

[12] Corresponds to the International Standard Classification of Education (ISCED) level 3 and higher. We do not include individuals with only compulsory education (i.e., a lower secondary diploma at ISCED Level 2), because this level of schooling is part of the mandatory schooling system, during which students do not choose any occupations, types, or levels.

[13] Given the trend towards municipality mergers, we have updated all data to the municipality stock as of 2022.

we calculate the percentage of women with a VET STEM degree ($PercWomenVETSTEM$) per year y and municipality m as the number of women with a VET STEM degree $F_{y,m}^{VET,STEM}$ relative to all observed individuals with a VET degree (regardless of gender and STEM/non-STEM). $F_{y,m}^{VET}$ denotes the number of women with a VET degree and $M_{y,m}^{VET}$ denotes the number of men with a VET degree. For example, if we observe 100 vocationally educated individuals in a municipality in one year and ten are women with a VET STEM degree, the respective value of $PercWomenVETSTEM_{y,m}$ is 10%.

$$PercWomenAcademicSTEM_{y,m} = \frac{F_{y,m}^{Ac,STEM}}{F_{y,m}^{Ac} + M_{y,m}^{Ac}} \tag{1}$$

$$PercWomenVETSTEM_{y,m} = \frac{F_{y,m}^{VET,STEM}}{F_{y,m}^{VET} + M_{y,m}^{VET}} \tag{2}$$

3.3 Innovation Outcomes

To measure innovation activity, we use patent data from the PATSTAT Worldwide Patent Statistical Database (October 2023 version). This database provides comprehensive information on patent applications worldwide and is publicly available at the European Patent Office (EPO). We use the information on all patents filed at the EPO with at least one inventor from Switzerland.

We use annual municipality-level patent quantity as an established measure for innovation (e.g., Hall & Harhoff, 2012; Trajtenberg, 1990). We further differentiate this measure by the inventors' gender. Therefore, to construct this measure, we proceed in three steps. First, to indicate the year of invention, we use the priority year of the patent filing. Second, to localize the municipality of an invention, we geocode the inventor's address information available in the EPO data.[14] As a patent can have more than one inventor, we use fractional weights to calculate the quantity of the patent applications per municipality.[15]

[14] For geocoding, we use the ArcGIS World Geocoding Service and update its result with information from de Rassenfosse et al.'s (2019) inventor geolocation database for any unidentified geolocations.

[15] For example, if a patent lists three inventors—one from municipality A, one from municipality B, and one from another country—the patent counts as one-third of a patent application in municipality A and one-third in municipality B. The remaining fraction from the out-of-country inventor does not enter our analyses.

Third, to construct our measure of women's patent quantity, we need identify the inventors' gender. To do so, we use Raffo's (2021) gender-name dictionary (for methodological information, see Lax Martinez et al., 2016; Lax Martínez et al., 2021) and apply it to the patent data. To improve precision, we apply the German dictionary to the German-speaking municipalities, the French dictionary to the French-speaking municipalities and the Italian dictionary to the Italian-speaking municipalities of Switzerland. We then apply the worldwide dictionary to all names that have not been attributed at this stage. Overall, we are able to assign a gender to 99.58%[16] of the entries. This set of information enables us to calculate the quantity of patent applications by gender at the municipality level.[17]

Table 1: Descriptive Statistics

Municipality Level Variables	mean	sd	min	max
Total patent quantity (per year and municipality)	9.495	25.950	0	391.837
Women's patent quantity (per year and municipality)	0.817	3.360	0	56.397
Traditional Gender Norms (disapproval rate in the 1981 constitutional referendum)	0.400	0.120	0.115	0.715
Percentage Women Academic STEM	0.100	0.139	0	1
Percentage Women VET STEM	0.056	0.048	0	0.429
Percentage Men Academic STEM	0.276	0.218	0	1
Percentage Men VET STEM	0.264	0.097	0	0.75

Notes: Authors' calculations of the descriptive statistics. Data based on PATSTAT patent data, voting data from the Swiss Federal Statistical Office and the SLFS 2007-2019. N=3,861 year by municipality observations. (297 Municipalities). Reading example: A municipality produces on average 9.495 patents per year, 0.817 of these patents are women's patents. The average disapproval rate in the 1981 referendum was 0.400 = 40%. In the workforce with a VET degree, 5.6% of individuals were women holding a STEM degree and 26.4% were men holding a STEM degree (the remaining 68% in the VET workforce holds a degree in a non-STEM field).

The final patent sample that we use to calculate our innovation outcomes contains information on 64,524 patents. This sample includes all patents with at least one inventor to

[16] No attribution of gender occurs in the following three cases: a firm is listed as an inventor, a name does not appear in any of the gender-name dictionaries, or a name is listed only with the inventor's initial letter or is completely missing.

[17] To reduce the skewness of the patent data, we transform the number of patents. As our data contains observations with zero-patent values, we apply the inverse hyperbolic sine transformation. We run a robustness test with logged values (Figure A1 in the Appendix) and a robustness test in which we use the patenting rate (i.e., the representation of the number of patents relative to 10,000 individuals in the workforce) (see Figure A2 in the Appendix). Our main results remain robust to these alternative specifications.

whom we can assign both a Swiss municipality and the gender. Moreover, it is restricted to patent applications filed between 2007 (the first year in the SLFS data) and 2019 (to allow for a time lag of three years for citations as our patent quality indicator).

3.4 Control Variables

To account for the size of the local labor market we include the logged number of the local workers. Additionally, to account for men's contribution to patenting, we control for STEM percentages among men ($PercMaleAcademicSTEM$ and $PercMaleVETSTEM$). In combination with our corresponding explanatory variables for STEM percentages among women (see Section 3.2), men's STEM percentages are also a proxy for STEM-focused industries. Furthermore, we control for local labor market characteristics by following Schlegel et al. (2022). We do so by including[18] control variables for (1) the level of education, i.e., the percentage of tertiary educated people in a municipality; (2) the unemployment rates in the percentage of the people in a municipality; (3) the percentage of non-Swiss citizens in a municipality; and (4) the age structure, i.e., the percentage of individuals between 20 to 64 and above 64, respectively. We also include firm structure, which is the number of firms and the high-tech intensity as the percentage of employees in high-tech industries.[19] Moreover, to account for time trends in patenting, we include year fixed effects.

[18] In the estimations with occupational choices as outcome (i.e., Female Academic STEM and Female VET STEM), we do not use control variables that are either not relevant (i.e., the number of firms, the size of the workforce, and year fixed effects) or directly related to education (i.e., Male Academic STEM, Male VET STEM, and the percentage of tertiary degrees).

[19] For high-tech intensity, we follow the Swiss Federal Statistical Office (FSO, 2024) definition of high-tech industries (at the 2-digit level according to the NOGA-08 general classification of economic activities) to calculate the percentage of high-tech employment at the municipality level. The following industries are aggregated to the high-tech sector: manufacture of chemicals and chemical products; manufacture of basic pharmaceutical products and pharmaceutical preparations; manufacture of computer, electronic and optical products; manufacture of electrical equipment; manufacture of machinery and equipment; manufacture of motor vehicles, trailers and semi-trailers.

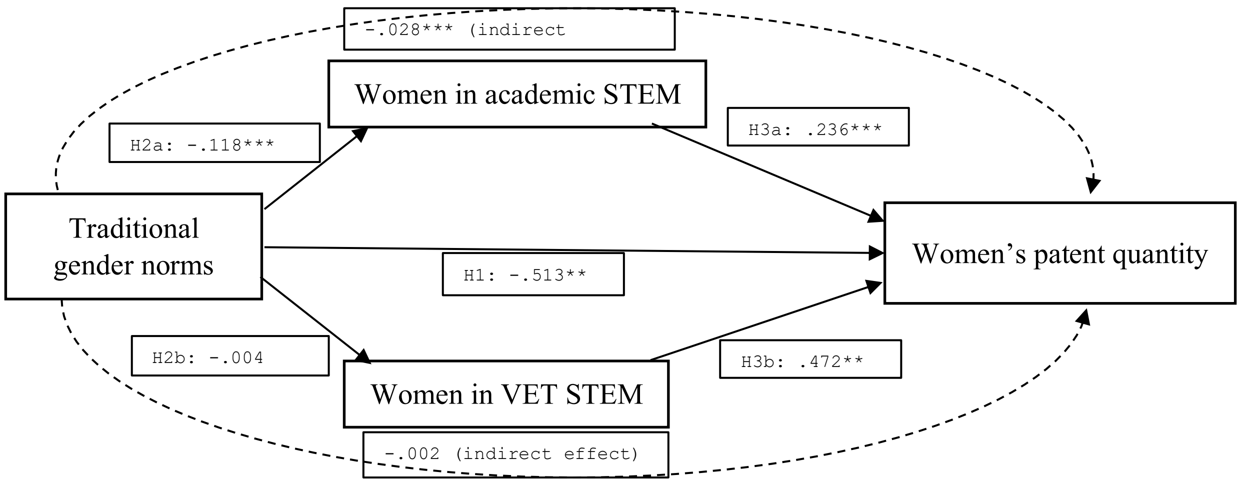
4. Results

To test the hypothesized relationships between social gender norms, occupational choices, and patent quantity, we adopt a structural equation modeling (SEM) approach. We do so because SEM allows us to examine the direct and indirect effects of multiple variables on the outcome variables simultaneously (Gunzler et al., 2013; Sobel, 1987; Wang & Sobel, 2013). Specifically, we build the model according to the hypotheses that we derived from the literature in Section 2. We use a generalized SEM and cluster standard errors at the municipality level.

4.1 Main Results

Figure 2 summarizes our results, with Table 2 reporting the coefficients, standard errors, and p-values of the structural relationships. The results reveal a negative direct effect of more traditional social gender norms on women's patent quantity, confirming hypothesis 1 (i.e., a one percentage point stronger traditional gender norm directly decreases women's patent quantity by 0.513%). Simultaneously, stronger traditional gender norms also affect the percentage of women with academic STEM degrees, confirming hypothesis 2a. The effect on VET STEM degrees is small and insignificant. However, both academic and VET STEM degrees positively affect women's patent quantity, confirming hypotheses 3a and 3b that educational and occupational choices are determinants of gender-biased innovation outcomes.

Figure 2: Main direct and indirect effects of traditional gender norms on women's patents



Notes: Data based on PATSTAT patent data, voting data from the Swiss Federal Statistical Office and the SLFS 2007-2019. N=3,861 year by municipality observations. (297 Municipalities). Solid arrows depict direct effect. Dotted lines depict indirect effects. Standard errors clustered at the municipality level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 2: Results of structural model

Path between variables (direct effects)		Estimates		
From	**To**	**β**	**se**	**p-value**
Traditional Gender Norms	→ Women's patent quantity	-0.513**	0.203	0.012
Women with academic STEM degrees	→ Women's patent quantity	0.236***	0.070	0.001
Women with VET STEM degrees	→ Women's patent quantity	0.472**	0.217	0.030
Social Gender Norms	→ Women with academic STEM degrees	-0.118***	0.027	0.000
Social Gender Norms	→ Women with VET STEM degrees	-0.004	0.010	0.680

Notes: Data based on PATSTAT patent data, voting data from the Swiss Federal Statistical Office and the SLFS 2007-2019. N=3,861 year by municipality observations. (297 Municipalities). Standard errors clustered at the municipality level. * p < 0.10, ** p < 0.05, *** p < 0.01.

After having established all direct effects in our model, we calculate the indirect effect of stronger traditional gender norms on women's patents via occupational and educational choices. Table 3 reveals that stronger traditional gender norms also have a negative effect on women's patents through their effect on educational and occupational choices. The indirect effect of a one percentage point stronger traditional gender norm is a decrease in women's patents by 0.03%. When distinguishing between academic education and VET, we find that most of the indirect effect arises through occupational choices in academic education.

Table 3: Indirect effects

	Estimates		
Indirect relationship	**β**	**se**	**p-value**
Traditional Gender Norms → Women with ac. STEM degrees→ Women's patent quantity	-0.028***	0.010	0.007
Traditional Gender Norms → Women with VET STEM degrees → Women's patent quantity	-0.002	0.005	0.676
Total indirect effect from Traditional Gender Norms to Women's patent quantity	-0.030***	0.011	0.009

Notes: Data based on PATSTAT patent data, voting data from the Swiss Federal Statistical Office and the SLFS 2007-2019. N=3,861 year by municipality observations. (297 Municipalities). Standard errors clustered at the municipality level. * p < 0.10, ** p < 0.05, *** p < 0.01.

These results suggest that educational and occupational choices partially mediate the effect of gender norms on innovation, underlining the role of occupational choices in innovation activities and reducing the gender innovation gap. Overall, the total effect a one percentage point stronger traditional gender norms is a decrease 0.543% in women's patents, i.e., the direct effect of 0.513% plus the indirect effect of 0.030%. Consequently, the indirect effect accounts for 5.5% of the total effect of gender norms on women's patents (0.030/(0.513+0.030)). A decrease of 10 percentage points in the strength of traditional gender norms (i.e., in the percentage of voters not voting for gender equality) is thus associated with an increase in women's patents by 5.43%. When we compare the highest disapproval rate (71.5%) with the lowest disapproval rate (11.5%) in our sample, the estimated difference in women's patents is 32.58% ((71.5-11.5)*0.543)).

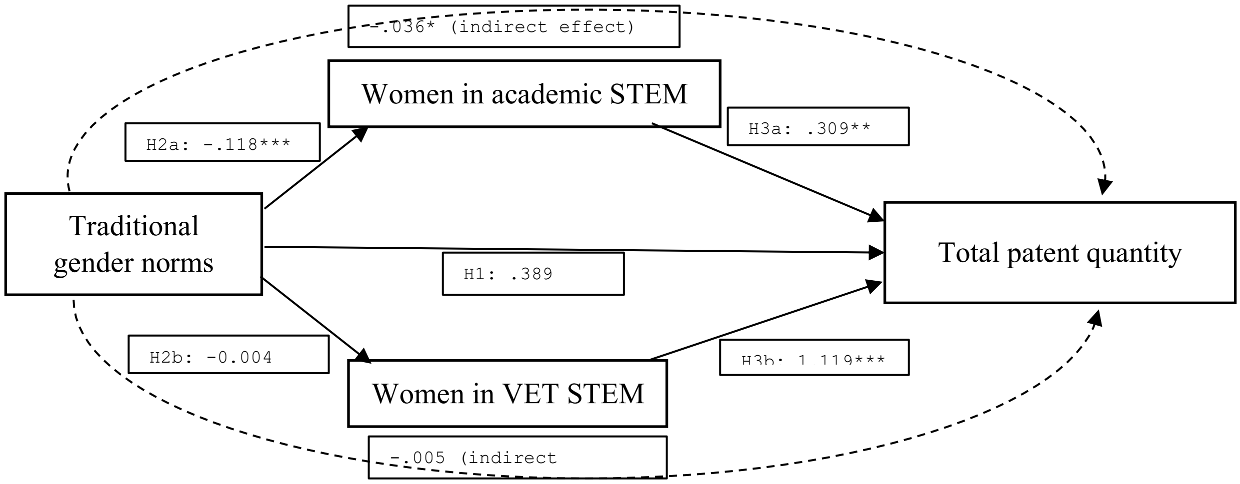
4.2 Further Analyses

To investigate whether an increase in women's patenting also increases the overall number of patents or potentially merely replaces men's patenting, we provide further analyses that use the total number of patents as an alternative outcome measure. Moreover, to analyze whether the increase in patent quantity comes at the cost of reduced patent quality, we include quality measures for innovation.

4.2.1 Effect on the Total Number of Patents

To analyze whether more traditional social norms also have a direct or indirect effect on overall patent quantity, we use the total number of patents per year and municipality ($total\ patent\ quantity$) as an outcome. Figure 3 shows that a larger percentage of women in STEM (both academic and VET) also increases the total number of patents, not only the number of women's patents. Thus an increase of the percentage of women in STEM does not lead to a replacement of men's patents by women's patents. Tables 4 and 5 additionally depict the standard errors and p-values. Table 4 depicts the results of the direct relationships in the model, showing that overall patenting activities increase with weaker traditional gender norms through more women with STEM degrees and that occupational choices of STEM degrees explain most of this increase. Table 5 shows that the indirect effect of traditional social gender norms on total patent quantity is significantly negative and thus similar to the indirect effect on women's patent quantity.

Figure 3: Results of direct and indirect effects of social gender norms on total patents



Notes: Data based on PATSTAT patent data, voting data from the Swiss Federal Statistical Office and the SLFS 2007-2019. N=3,861 year by municipality observations. (297 Municipalities). Solid arrows depict direct effect. Dotted lines depict indirect effects. Standard errors clustered at the municipality level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 4: Results of structural model on total patents

Path between variables (direct effects)		**Estimates**		
From	**To**	**β**	**se**	**p-value**
Traditional Gender Norms	→ Total patent quantity	0.389	0.438	0.375
Women with academic STEM degrees	→ Total patent quantity	0.309**	0.154	0.045
Women with VET STEM degrees	→ Total patent quantity	1.119***	0.431	0.009
Traditional Gender Norms	→ Women with academic STEM degrees	-0.118***	0.027	0.000
Traditional Gender Norms	→ Women with VET STEM degrees	-0.004	0.010	0.680

Notes: Data based on PATSTAT patent data, voting data from the Swiss Federal Statistical Office and the SLFS 2007-2019. N=3,861 year by municipality observations. (297 Municipalities). Standard errors clustered at the municipality level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Indirect effects on total patents

	Estimates		
Indirect relationship	**β**	**se**	**p-value**
Tratitional Gender Norms → Women with ac. STEM degrees→ Total Patent quantity	-0.036*	0.021	0.091
Traditional Gender Norms → Women with VET STEM degrees → Total Patent quantity	-0.005	0.011	0.678
Total indirect effect from Traditional Gender Norms to Total Patent quantity	-0.041*	0.024	0.084

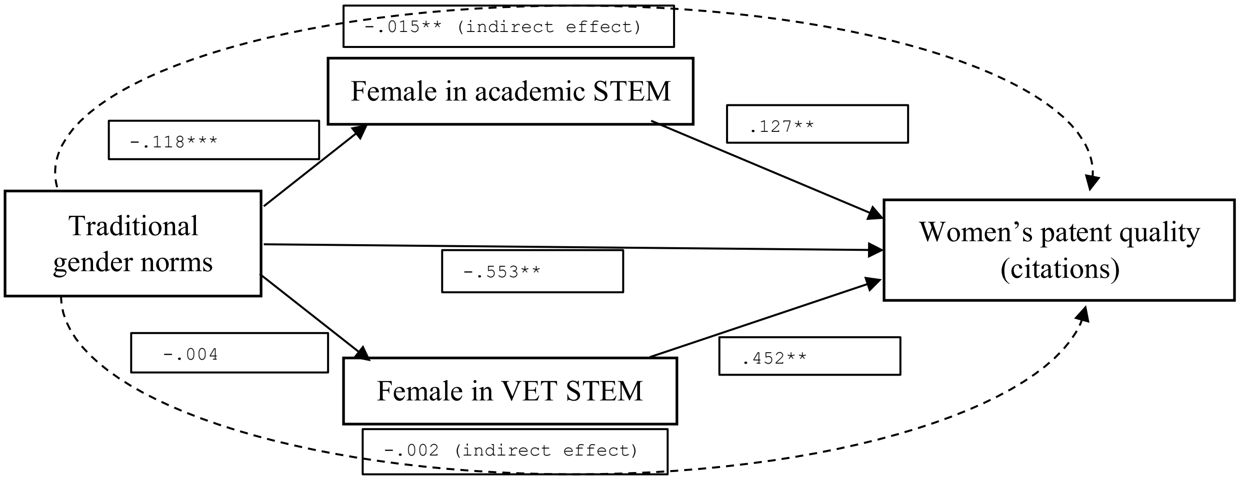
Notes: Data based on PATSTAT patent data, voting data from the Swiss Federal Statistical Office and the SLFS 2007-2019. N=3,861 year by municipality observations. (297 Municipalities). Standard errors clustered at the municipality level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

4.2.2 Patent Quality Measures as Additional Outcome Variables

To analyze whether the increase in patent quantity comes at the cost of reduced patent quality, we include three established quality indicators as another proxy for innovation (e.g., Pfister et al., 2021; Squicciarini et al., 2013). First, we use citations, i.e., the number of patent citations three years after publication. Second, we use the patent family size, i.e., the number of patents filed in different countries, related to each other by protecting the same invention. Third, we use claims, i.e., the number of priority claims per patent. For all three indicators, we use the fractionated average per municipality and year. Specifically, we fractionate the quality measure of each patent by the number of inventors. We then attribute each fraction to the municipality of the respective inventor and aggregate the quality measure at the year-municipality level. In addition, as in our main specifications, we estimate our model for women's patent quality in a first step and for the overall patent quality in a second step.

As with patent quantity, we find similar results for patent quality. Figure 4 reports the results with the average number of citations per women's patents as the outcome. They show that less traditional social gender norms increase the quality of women's patents, so the additional quantity in women's patents that we find in Section 4.1 does not come at the cost of lower quality as measured by the number of citations. The results are similar for the other quality measures (i.e., the patent family size and the number of claims, results reported in Figures A3 and A4 in the appendix). Thus, if gender norms become less traditional, it does not only increase the quantity of women's patents but also of their quality. The effect results from a strong direct effect as well as from a substantial indirect effect through occupational choices.

Figure 4: Main direct and indirect effects of traditional gender norms on citations of women's patents



Notes: Data based on PATSTAT patent data, voting data from the Swiss Federal Statistical Office and the SLFS 2007-2019. N=3,861 year by municipality observations. (297 Municipalities). Solid arrows depict direct effect. Dotted arrows depict indirect effects. Standard errors clustered at the municipality level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5. Conclusion

In this paper, we analyze whether and, if so, to what extent differences in social gender norms have an effect on regional innovation outcomes. Particularly, we disentangle the direct effect from the indirect effect through educational and occupational choices. We use regional voting outcomes as a highly reliable measure for social gender norms, workforce percentages by gender with different types of educational degrees as a measure for educational and occupational choices, and (women's) patent applications as a measure for gender-biased patenting and innovation.

Applying SEM to municipality-level data from Switzerland, we find that in municipalities with stronger traditional gender norms, the quantity of women's patents is lower. Specifically, a one percentage point stronger traditional gender norm directly decreases women's patent quantity by 0.513%. Moreover, we find that the indirect effect of a one percentage point stronger traditional gender norm is a decrease in women's patents by 0.03%. Thus traditional social gender norms increase the gender innovation gap, with 5.5% of this effect arising through educational and occupational choices. This indirect effect size is substantial considering the many other potential channels through which social gender norms may affect innovation activities, such as the likelihood and intensity of engaging in innovation activities after choosing a STEM occupation or education.

In a further analysis, we assess whether women's patenting might only replace men's patenting. To do so, we analyze the total number of patents as an alternative outcome, finding that a larger percentage of women with a STEM degree is also positively related to overall patenting activities. Given that we observe a net increase in overall patenting activities when the percentage of women in STEM rises, our finding indicates that substitution effects do not drive our results. Furthermore, when we use patent quality indicators as an outcome, we find that the increase in patent quantity does not come at the cost of reduced patent quality. On the contrary, less traditional gender norms and more women in STEM increase not only the quantity but also the quality of women's patents.

Our study contributes to the literature on social gender norms, and education and innovation in three ways. First, our results confirm previous findings on the strong connection between STEM education and innovation, for both academic education and VET. Second, and in line with Qin et al. (2023) we demonstrate that regional differences in social gender norms directly affect regional innovation measured in women's patent quantity and quality. Third, our paper is the first to disentangle the direct effects of social gender norms on innovation from the indirect effects that go through educational and occupational choices.

Our findings show that a substantial part of the social gender norm effect on innovation arises indirectly through occupational choices of women (i.e., because they less frequently choose STEM fields when social norms are more traditional). The findings underline the role of educational and occupational choices for innovation, and suggest that policy interventions aimed at promoting gender equality in education are not only important in and of themselves but will also be effective in narrowing the innovation gender gap. This insight is important because social gender norms tend to be stable over time, making changing them in the short term difficult. In contrast, educational and occupational choices have a much higher potential for short-term changes. Our results thus contribute to a broader understanding of the innovation gender gap and offer insights into the value of policy interventions aimed at promoting gender equality in education and innovation.

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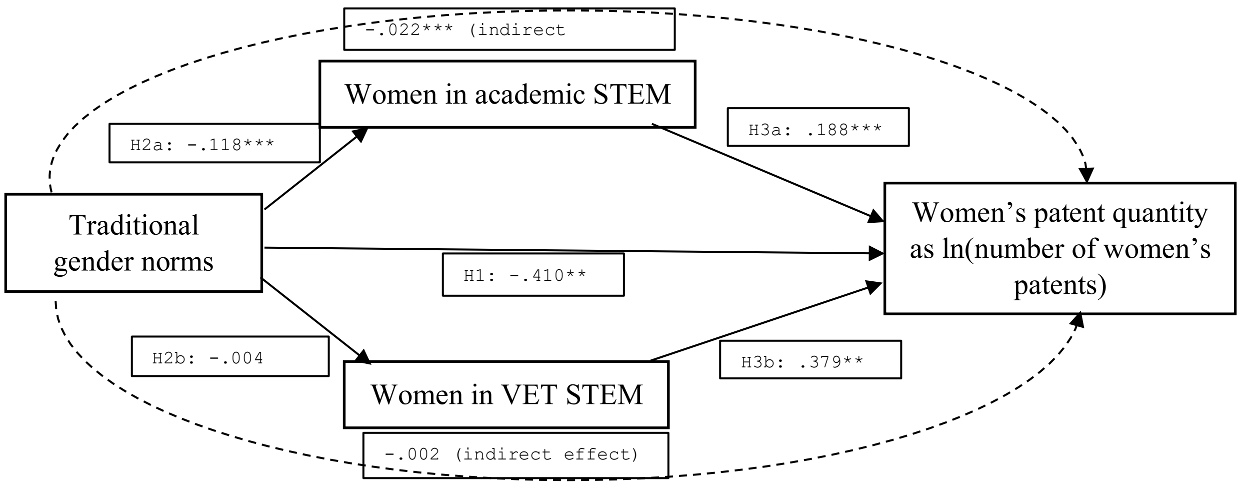
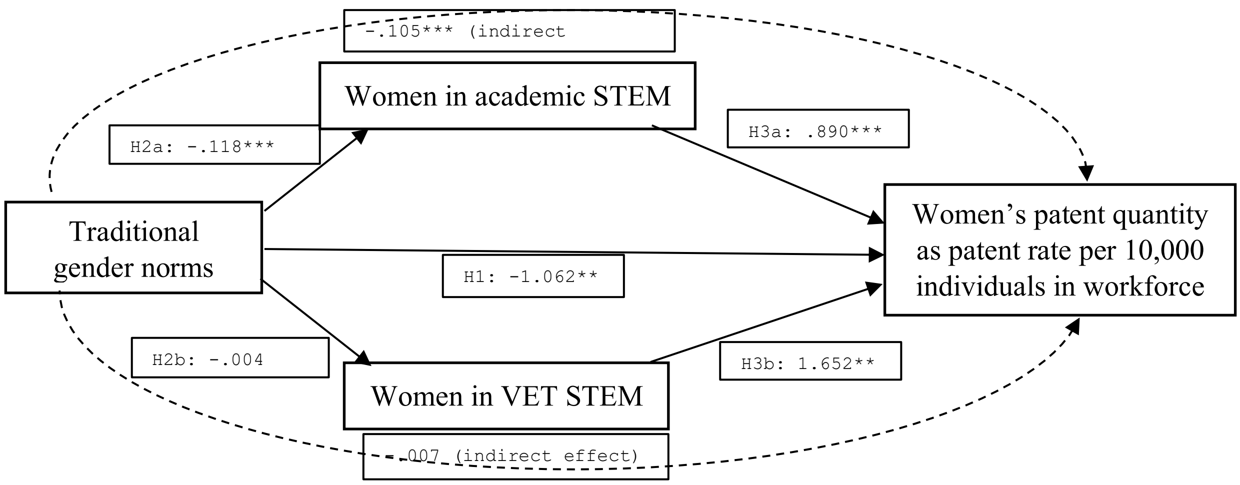
Appendix

Figure A1: Results with ln(women's patents)



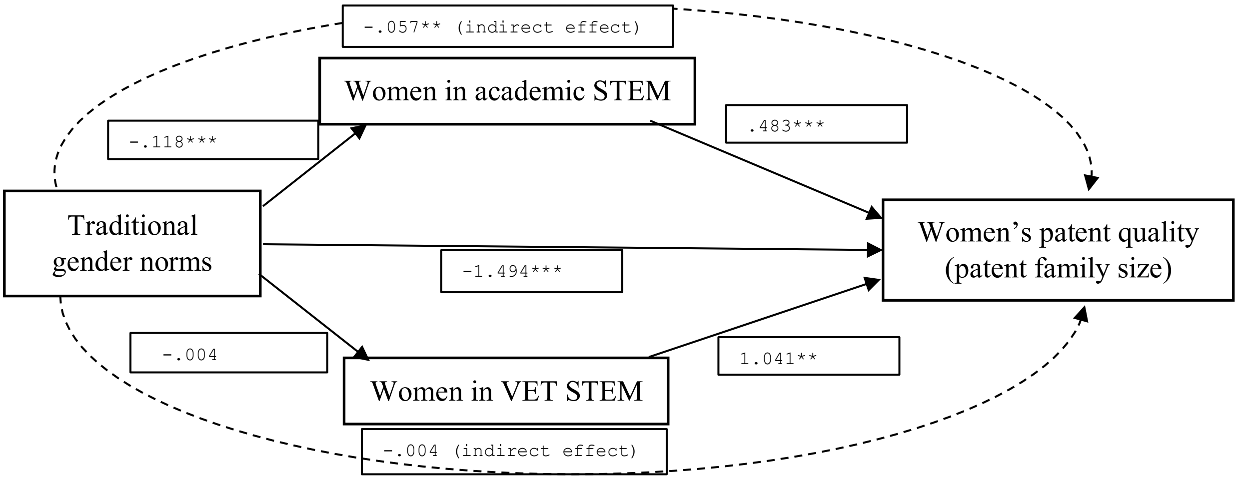
Notes: Data based on PATSTAT patent data, voting data from the Swiss Federal Statistical Office and the SLFS 2007-2019. N=3,861 year by municipality observations. (297 Municipalities). Solid arrows depict direct effect. Dotted lines depict indirect effects. Standard errors clustered at the municipality level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Interpretation example: A one percentage point stronger traditional social norm is associated with a 0.41% decrease in the number of women's patents.

Figure A2: Results with women's patent rate



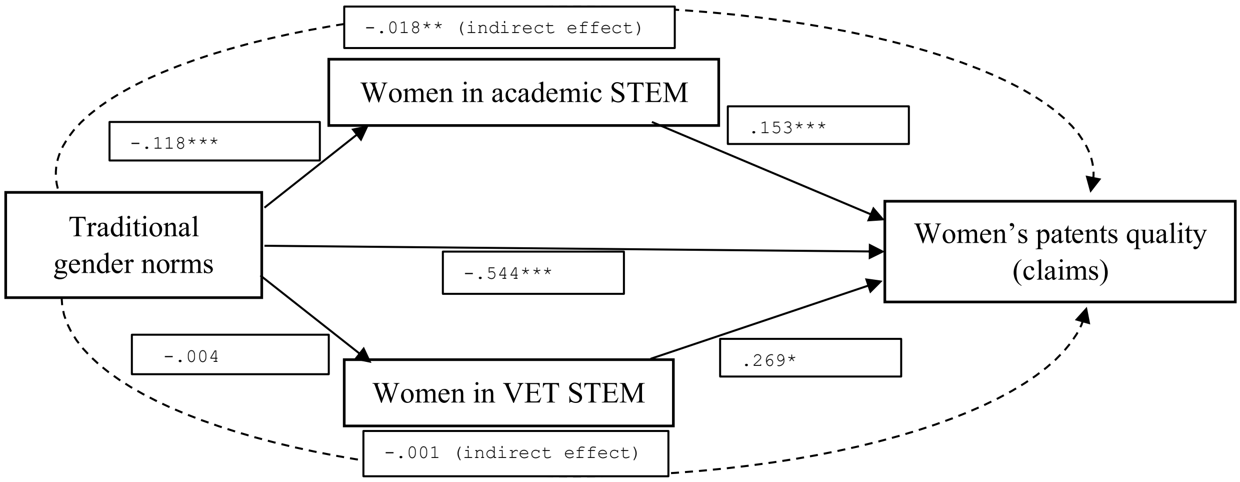
Notes: Data based on PATSTAT patent data, voting data from the Swiss Federal Statistical Office and the SLFS 2007-2019. N=3,861 year by municipality observations. (297 Municipalities). Solid arrows depict direct effect. Dotted lines depict indirect effects. Standard errors clustered at the municipality level. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$. Interpretation example: A one percentage point stronger traditional social norm is associated with a direct decrease of 0.0106 women's patents per workforce of 10,000 individuals.

Figure A3: Main direct and indirect effects of traditional gender norms on family size of women's patents



Notes: Data based on PATSTAT patent data, voting data from the Swiss Federal Statistical Office and the SLFS 2007-2019. N=3,861 year by municipality observations. (297 Municipalities). Solid arrows depict direct effect. Dotted arrows depict indirect effects. Standard errors clustered at the municipality level. * p < 0.10, ** p < 0.05, *** p < 0.01.

Figure A4: Main direct and indirect effects of traditional gender norms on the number of patent claims of women's patents



Notes: Data based on PATSTAT patent data, voting data from the Swiss Federal Statistical Office and the SLFS 2007-2019. N=3,861 year by municipality observations. (297 Municipalities). Solid arrows depict direct effect. Dotted arrows depict indirect effects. Standard errors clustered at the municipality level. * p < 0.10, ** p < 0.05, *** p < 0.01.