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LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00

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Youssouf Merouani & Faustine Perrin

DEPARTMENT OF ECONOMIC HISTORY, LUND UNIVERSITY

Women Inventors:

On the Origins of the Gender Patenting Gap

Youssouf Merouani[♠]

Faustine Perrin[♠]

Abstract

The gender patenting gap is well-established and is wide. Despite important progress made over the past decades, the gap remains. Why are women underrepresented in patenting activities? What are the roots of the gender patenting gap? How did the gap evolve since the 'modern' patenting system was established? Our knowledge of women's contribution to innovative activities in the past is extremely scarce. We build an original dataset covering the entirety of French patents to investigate the extent to which women patented relative to men in France during the long nineteenth century and explores the factors behind the historical gender patenting gap. We find that despite the absence of scientific and technical education opportunities for women and the presence of institutional barriers, women, including those who were married, took an active part in the innovation process. The empirical analysis conducted in the paper suggests that explanations of the origins and persistence of the gender patenting gap have to be found outside of the patent system itself.

Keywords: Patent • Innovation • Gender • Women • Nineteenth Century • France
JEL Codes: J16, N33, O30

[♠] Department of Economic History, Lund University. Contact information: youssouf.merouani@ekh.lu.se, faustine.perrin@ekh.lu.se .
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1. Introduction

The expanding research on the evolution of women's position in society has contributed to dispel persistent myths about how much they contributed to the economic prosperity of developed and developing economies. Scholars have addressed the role of gender and women's economic activities on economic development (e.g. Boserup, 1970; Goldin, 1990), showing the importance of human capital as key component for the development process (e.g. Diebolt and Perrin, 2013; Baten and de Pleijt, 2021). Although a rich literature has documented the importance of technical and scientific knowledge in the emergence and adoption of innovative industrial technology fostering the industrialization process (Mokyr, 2010; Squicciarini, and Voigtländer, 2015; Mokyr, Sarid, van der Beek, 2019, among others)[2], we lack knowledge on how much women may have contributed to the process (Merouani and Perrin, 2022).

Using a sample drawn from patent and exhibition records for France during the first half of the nineteenth century, Khan (2016) showed that entrepreneurship and innovation was not only done by the elites in society but also by middle-class women. During this era women were unable to acquire formal schooling, and it was not until the second half of the nineteenth century that changes in French legislation permitted the establishment of a wider state educational system open to both sexes (Perrin, 2013). Furthermore, while the legal status of women in France was more equal than most other countries in Europe, married women still faced more restrictions than widowed or unmarried women (Hart, 1997; Lewis, 1980).

In this paper, we investigate the participation of women in innovative activities and question the extent to which women participated to the innovation process relative to men during the nineteenth century, period characterized by a crucial phase of industrialization and economic development in France. Patents provide tangible historical records of technological and scientific advancements, and by their very nature, are closely tied to industrial processes. Patents are not just inventions; they reflect the intent to commercialize and protect innovative ideas. The modern patent system was adopted in France in 1791. The patent system captures a broad spectrum of innovations, from minor improvements to existing technologies to groundbreaking inventions. The patent files are standardized and provide rich and detailed information about the invention and the inventor(s). Although patents do not capture the full complexity of innovation during the nineteenth century, they offer a rich, detailed, and broad

[2] See Moser (2013).

source of information that can provide invaluable insights into the era of technological and economic developments.

Relying on the richness of the patent data, we build an original dataset covering the entirety of French patents granted to women and men from the implementation of the modern patent system in France in 1791 to the turn of the twentieth century. Despite the absence of scientific and technical education for women and institutional barriers, we find that women took an active part in the innovation process. Paradoxically, despite the legal restrictions established by the Civil Code, married women occur more frequently in our patent data than widows and unmarried women. While the structural changes in human capital investment occurring in the second half of the nineteenth century may have contributed to foster the ability for women to innovate and invent, we uncover the existence of an extremely stable gender patenting[3] from the 1840s onward. The exploration of differences in women's and men's patenting behavior reveals that women's and men's patenting activities were not that dissimilar but there exists a glass ceiling that women do not manage to overcome. The empirical analysis suggests that explanations of the origins and persistence of the gender patenting gap have to be found outside of the patent system itself.

This paper has significance for our understanding of women lives in the past, but it has also wider implications, notably as a preliminary and necessary step toward better understanding and explaining the factors behind the gender patenting gap. This research ultimately aims to enhance our understanding of the mechanisms behind the development process in particular the links between upper-tail human capital and economic development.

The paper is organized as follows. Section 2 provides a state-of the-art of the literature on women patenting and the gender patenting gap. Section 3 describes the evolution of women patenting activities relative to men in France during the long nineteenth century. Section 4 discusses the sources and data used in the paper. Section 5 presents our empirical strategy. Section 6 presents and discusses our main findings. Section 7 briefly open the discussion about France in a comparative perspective with the United States.

[3] We define this gap as the disparity in the number of patents granted to women compared to those granted to men.

2. Women Patenting and the Gender Patenting Gap

This section first provided an overview of recent research about women inventors in the modern context and is followed by a more specific discussion of previous research conducted on the topic from a historical perspective.

2.1. Women Patenting – Modern Context

Today in Europe, about one in seven (16%) patents have at least one woman among the inventors. A few decades ago, the ratio was still close to one in 50 patents (around 2%). The literature consistently reports the existence of a wide gender gap in patenting, with women obtaining patents at a lower rate than men (McMillan, 2009; Jung and Ejermo, 2014; Jensen et al., 2018; Bell et al., 2019; Heikkilä, 2019; among others) and discusses the lower technological impact of women's patents (Bikard and Fernandez-Mateo, 2022), particularly in academic settings (Rosser, 2009; Seguimoto et al., 2015; Giui et al., 2020).

Studies relying on modern data have quantified the extent of the gender disparity in patenting and investigated the root causes of the gap. Hunt et al. (2012) have highlighted the underrepresentation of women in patent-intensive sectors and explain that the gender patenting gap reflects a broader gender gap existing in science and engineering. Similarly, Sugimoto et al. (2015) analyzed global patent data, revealing that the gender gap in patenting is not isolated to specific regions, hinting at pervasive structural and societal barriers. Whittington and Smith-Doerr (2008) argue that institutional settings, notably in academia, play a decisive role in influencing patenting behaviors. Universities and research institutions that encompass diversity and inclusive policies experience a lesser gender disparity in patent applications. Ding et al. (2006) suggest that disparities in academic rank and productivity between genders influence patenting behavior. The hierarchical structure of academia, coupled with systemic biases, could disproportionately affect women.

Networking plays an integral role in innovation and patenting. Women's limited access to male-dominated networks has also been shown to adversely affect their patenting prospects (Murray and Graham, 2007; Mauleón and Bordons, 2010). The effects of the gender patenting gap extend beyond academia and research. This gap amplifies economic inequalities, with women in STEM fields facing stunted career growth (Cook and Kongcharoen, 2010), and deprives the market of diverse innovations (Koning et al., 2021), inhibiting economic growth and potential breakthroughs in various domains.

2.2. Women Patenting – Historical Context

The historical literature examining women's participation in innovative activities is markedly limited. Although the broader context of the time often limited women's rights and roles, some women nonetheless managed to secure patents for their inventions in the nineteenth century and made significant contributions to various fields of science and technology. Yet, many women's contributions went unrecognized. Either their inventions were attributed to men, or they were not credited due to prevailing gender biases (Merouani and Perrin, 2023).

Most of the literature encompassing for a historical perspective focuses on the role of women inventors in the United States. Oldenziel (1999) offers a glimpse into the past and underscores the oft-underestimated contributions women made, especially in domestic and textile inventions. Societal norms and institutional barriers affected the participation of women in innovative activities and the recognition and patenting of their inventions (Pilato, 2000).

Khan (2005) has shown that the U.S. patent system was relatively open and accessible compared to European systems, such as the French and British systems which were more expensive (higher fees) and required more complex procedures. This accessibility benefitted women and individuals without formal education or significant financial resources (Khan, 2020). Women's patenting activity experienced a notable increase during the 19th century. Khan's work indicated that while women accounted for only 0.3% of all patentees between 1790 and 1895, the proportion grew over time. By the end of the 19th century, the percentage had increased to around 2%. Women's inventions during this period spanned a wide range of sectors. While many were related to domestic and traditional "female" roles (such as clothing or kitchen devices), women also patented in non-traditional areas like tools, machines, and chemical processes (Merouani and Perrin, 2023).

Married women in the US faced legal obstacles since, in many jurisdictions, they could not legally own property, including patents, in their own names. Despite these barriers, many married women were still able to patent by using legal workarounds or by collaborating with male family members. Khan (2020) emphasizes the importance of economic incentives in encouraging innovation. Women were more likely to patent in States with better economic opportunities and in areas where they could benefit from market returns on their innovations. While women were underrepresented in patent records, those who did secure patents were as commercially successful as their male counterparts, indicating that the quality of their inventions was on par with those of men (Khan, 2000). The number of women patentees grew faster in the late 19th and early 20th centuries, particularly after institutional changes that provided more rights to women, such as property rights reforms and improved access to technical education.

In the French context, Khan (2016) has shown that, during the first half of the nineteenth century, middle-class women were extensively engaged in entrepreneurship and innovation and in nontraditional market activities, notably because of their association with family firms. Focusing on the turn to the twentieth century, Chanteux (2009) argues that women inventors had to be autonomous, technically knowledgeable, but also socially active. Merouani and Perrin (2023) have broadened the investigation of women's involvement in innovative activities by creating a comprehensive database that compiles information on all patents issued to both men and women in France throughout the nineteenth century. Beyond presenting the evolution of the patent system and legal frameworks surrounding patent activities, the authors discuss the existence of biases and challenges encountered in the study of women innovative activities.[4] Interestingly, the authors find that despite the legal restrictions established by the Civil Code in 1804, married women patented almost as frequently as widows and unmarried women.

3. Women Patenting Activities – France, 1791-1900

One of the central themes of this study is the examination of the persistence of the gender patenting gap throughout the period from 1791 to 1900 in France. Analyzing the historical evolution of this gender disparity in patenting activities provides valuable insights into the changing dynamics of innovation and entrepreneurship over the course of a century.

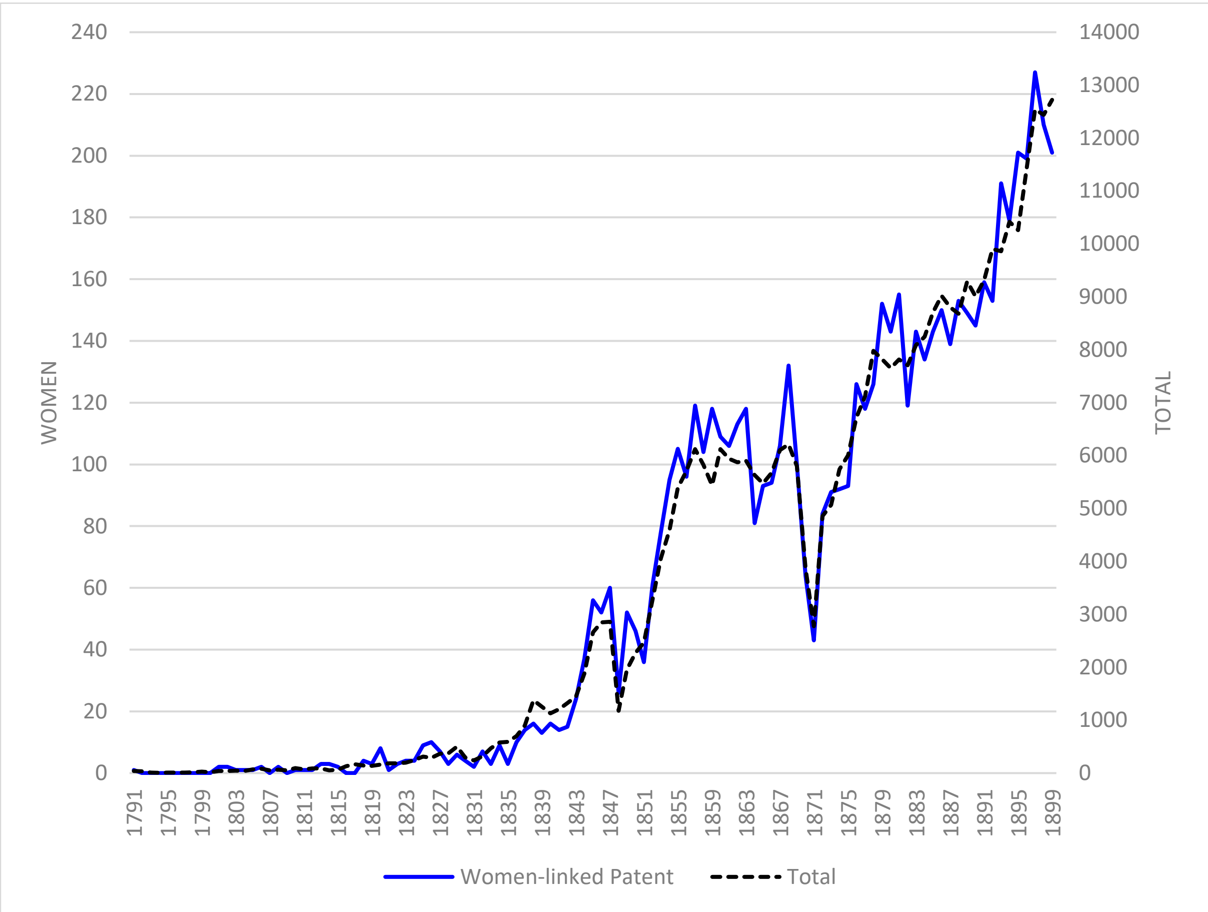
3.1. Women Patentees

Figure 1 presents the evolution of patenting activities in France from 1791 to 1900. The left axis displays the count for women-linked patents and the right axis charts the total counts of patents. The figure shows a significant growth in patenting activities throughout this period. Even though the absolute number of patents linked to women is substantially lower than the total count, the upward trend of women-associated patents is noteworthy and reflects the increasing participation of women in patenting and innovation during this period.

[4] See also Chanteux (2023).

Figure 1 reflects the existence of three main distinctive phases. In the early years of our study, spanning from 1791 to the 1830s, the number of patents remains relatively modest. Despite the underrepresentation of women among patent applicants, it is remarkable to note their participation in innovation and patenting activities, especially when considering the societal constraints they faced. During this era, marital status frequently played a pivotal role; married women, in particular, encountered numerous legal obstacles. Regardless, married women patented to a similar extent than single women and widows (see Merouani and Perrin, 2023).

Figure 1: Women-linked Patents, 1791-1900



Sources: See data section below.

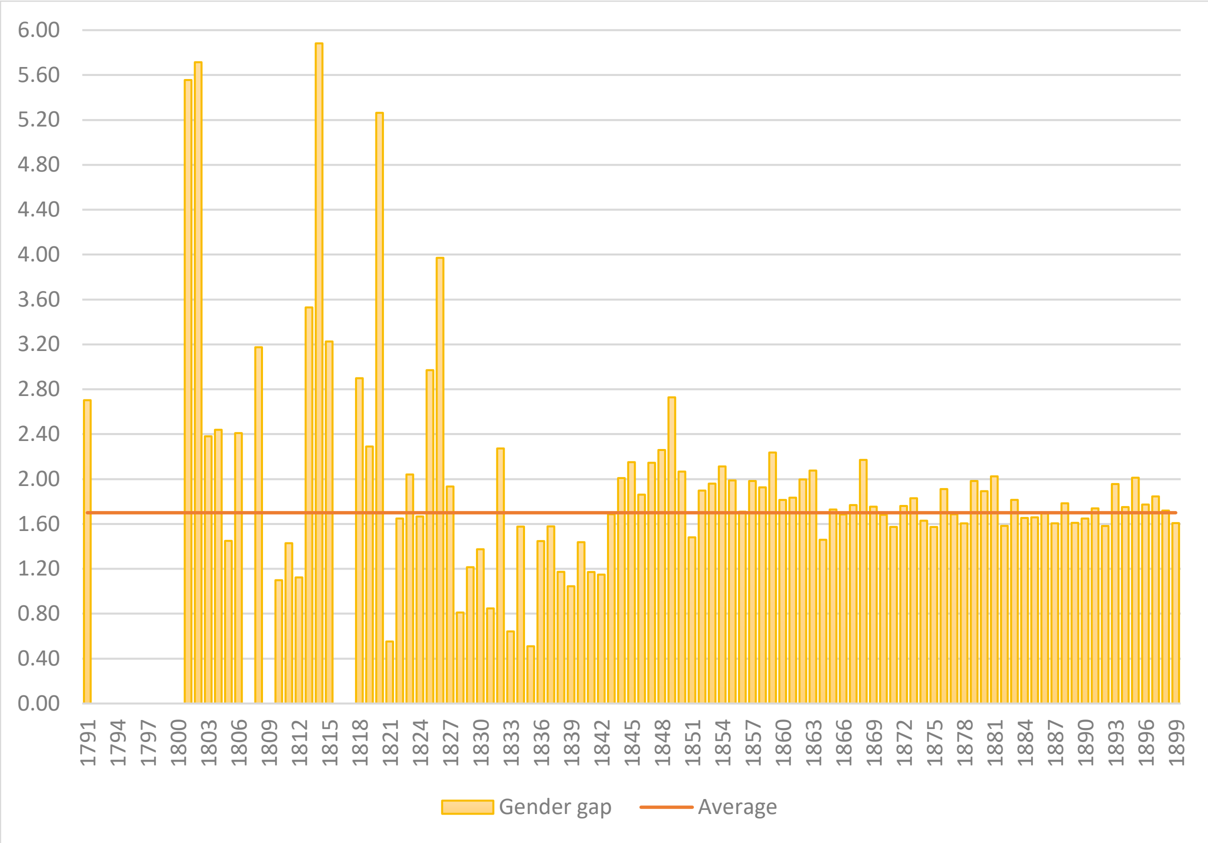
As we move into the mid-nineteenth century, spanning from the 1840s to the 1880s, we observe transitional shifts in the patenting landscape reflected by a noticeable uptick in the number of total patents and women-linked patents. Emerging signs of change, such as social and economic transformations, the spread of industrialization and urbanization likely influenced patenting trends. The pace of the rise increases during the latter part of the nineteenth century. Both curves exhibit sharper growth in patenting after the 1880s. The total patents' growth rate increased up to reach 130,000 patents granted in 1900; among which 220 being granted to at least one woman. Several factors might have contributed to this shift, including changes in legal frameworks, improved access to education, and the increasing recognition of women's contributions to innovation.

Similarly, to Marovich (1999) who explored the trends in women's inventive activities during wartime in the United States and found that wars typically had a negative impact on women's patenting rates, our data suggest that women were strongly affected by wars and conflicts. Interestingly, external shocks, including the French Revolution of 1848 and the Franco-Prussian War of 1870, appear to have had similarly adverse effects on patenting activities for both women and men (see Figure 1).

3.2. Persistence of the Gender Patenting Gap

Despite the progress and increase in patenting activities for women, the gender patenting gap remained pronounced and extremely stable. Figure 2 depicts the gender patenting gap over the period 1791-1900. A peak is observed in 1814, a year in which almost 6% of the patents were linked to at least one woman. This period showcases a higher percentage and substantial variability in female patenting activities. However, from the 1840s onward, there is an extreme stability in the gender patenting gap, with roughly 1.70% of the patents consistently being linked to at least one female inventor.

Figure 2: Gender Patenting Gap, 1791-1900



Sources: See data section below.

Even though educational opportunities for women saw considerable expansion during the second half of the nineteenth century (Perrin, 2013), their participation in patenting activities relative to men remained strikingly stable. The sustained gender patenting gap throughout the study period can be ascribed to a blend of intertwined factors. Legal barriers, such as restrictive marital property laws, and prevailing societal norms, coupled with cultural influences, likely impeded women from owning and enforcing patents independently. Furthermore, women's limited exposure to fields conducive to innovation, their restricted access to influential networks and associations, and the deeply ingrained gender roles that often funnel women towards domestic obligations rather than entrepreneurial endeavors, may have collectively played a part in this disparity.

3.3. Testable Hypotheses

Several factors come into play to determine the gender dynamics of patenting activities. One pivotal factor to consider is marital status. Historically, societal norms and expectations have often limited married women's professional and entrepreneurial endeavors. We hypothesize that women's involvement in patented inventions decreases upon marriage. This observation is rooted in the potential constraints that marriage might pose, such as household responsibilities and societal expectations, which could deter married women from actively participation in the invention process to a greater extent than single women and widows do (hypothesis 1).

Another consideration is access to financial resources. Women often lacked the financial resources to develop their inventions. The unequal access to resources necessary to engage in innovative activities and patenting is likely to have negatively affected the probability for women to patent. Accordingly, the duration of patents, 5 years against 10 or 15 years patents, can hampered women likelihood to patent due to resource constraints (hypothesis 2). Team dynamics may also play a pivotal role in patenting participation. Previous research using modern data has emphasized the importance of networks and collaborations in enhancing women's participation in patenting (Sifontes and Morales, 2020). We can test the persistence of this phenomenon by looking at the probability for women to be involved in patented inventions when working within teams of inventors (hypothesis 3).

The nature of the patented invention, particularly the sector (classification) of activity, is also crucial. We hypothesize that women have a higher probability to patent in female-oriented sectors. This is not to stereotype certain sectors as being inherently "female-oriented", but rather to highlight that women might have unique insights or expertise in specific areas, leading to increased involvement (hypothesis 4). Lastly, women's educational and occupational background undoubtedly influences their propensity to patent. Our hypothesis here is that women endowed with significant endowment in human capital are more likely to contribute to patented inventions. This is grounded in the understanding that education and professional experience can provide the requisite skills for women to innovate and navigate the often complex world of patenting (hypothesis 5).

4. Database of French Patents

4.1. Sources and Description

The data used in this study are gathered from various sources. Our primary source of information is the French National Institute of Intellectual Property (INPI). The Institute provide a comprehensive set of information covering patents granted in France between 1791 and 1900. Despite the richness of these data, they suffer from a number of limitations, particularly concerning patents from the latter half of the 19th century (INPI, 2011). In order to overcome these limitations and ensure the accuracy of our database, we collected information from additional sources.

To supplement and correct the original dataset, we delved into the original historical documents of patent applications whenever they were available. Additionally, we consulted sources like “Les Bulletin des Lois”, which is a series of reports published by the French state documenting state affairs, new laws, and detailed patent information (République Française, 1793). These sources provide a wealth of information, including patent lengths, inventor(s) address, and detailed descriptions. By using these sources, we were able to not only correct any inaccuracies in the primary sources but also verify and enrich the database. Furthermore, we cross-referenced and checked patent information by consulting the *Catalogue des Brevets d'Invention*, industry magazines, and reports from World fairs that took place in France during the relevant period. This approach allowed us to ensure the completeness and accuracy of our data for the entire century.

Our database contains detailed information on over 390,000 patents, including 6,864 patents associated with female depositors. The dataset includes patent records gathering information about application dates, patent durations (ranging from 5, 10, to 15 years), comprehensive written descriptions of the inventions, sector classifications (divided into 20 sectors), and information about the depositors. Regarding the depositors, we have access to a hierarchical set of names that enables us to distinguish between the first applicant, second applicant, and so on. Additionally, the dataset contains information such as marital status for women, occupation descriptions or titles, and geographic origins, providing further context about the depositors. Some records in the dataset also contain additional relevant details, such as information on legal issues related to the patent, which sheds light on challenges and barriers faced by some of the inventors during this period.

4.2. Data Enhancement Process

An important aspect of our data handling process involved rigorous standardization and correction methods. Given the historical nature of the patents we analyzed, it was not uncommon to encounter discrepancies in the information. To address this, we employed a range of semi-automatic clustering techniques, including Fingerprinting, to rectify inconsistencies in names and other data sections. These methods allowed us to systematically correct errors, whether they were systematic or random, to ensure the integrity of our data.

Additionally, we innovatively expanded the dataset by introducing new variables, namely gender, HISCO (Historical International Standard Classification of Occupations), and patent classification. For gender classification, we employed a multifaceted approach. We developed a procedure that involved identifying patent depositors through honorific titles, kinship terms, linguistic gender markers, and first names. As this classification was crucial for our gender-based analysis of patenting activities, including insights into the marital status of women depositors, we were particularly cautious in the use of programmatic techniques for assigning gender to the depositors. Instead, once we identified a patent depositor as potentially a woman, we conducted manual checks to ensure accuracy.

In our HISCO coding procedure, we used a streamlined methodology that combined advanced natural language processing (NLP) and machine learning techniques to map inventor profession descriptions to a dataset of French historical occupations and their corresponding HISCO codes. Initially, we preprocessed the relevant datasets, including patent professions and historical HISCO classifications, using techniques such as text normalization and duplicate removal. A key component of our methodology was the use of a Sentence Transformer model, specifically designed for multilingual contexts, to convert textual profession descriptions into numerical embeddings. These embeddings captured the semantic essence of each profession, enabling us to accurately match job titles and occupation descriptions of the inventors with the occupations in the HISCO database. We then implemented a Nearest Neighbors algorithm, leveraging cosine similarity, to identify the closest HISCO code for each profession. This iterative process ensured the highest possible accuracy by adjusting the input string length to find the best match. The outcome of this procedure was a refined dataset where each contemporary profession was paired with its corresponding HISCO code, along with a similarity score indicating the closeness of the match. We achieved an impressive 97% accuracy across the entire database.

This method exemplifies the integration of linguistic methods in machine learning to refine and extend our database. We used a somewhat similar approach to classify patents into 20 distinct sectors. The original data acquired from the INPI portal only provided patent classifications for approximately one-third of the patents, covering patents until the early 1850s. To include patents from the second half of the century, we employed CamemBERT, a state-of-the-art model for French Natural Language Processing (Martin et al., 2020), to classify over 300,000 patents into 20 distinct sectors. To avoid overfitting to the data, we retrained the CamemBERT model using a combination of real and synthetic patent descriptions. Despite computational limitations, we achieved an accuracy of approximately

80%. However, it is important to note that patent categorization is a complex task, as inventions often challenge the boundaries of industrial categories even for trained professionals (Meyer, 2022). Overall, our model performed quite well, and in the majority of cases, it matched or outperformed human classification under the constraints of time and data volume.

5. Empirical Analysis – Women-linked Patents

In this section, we assess the impact of various factors on women's participation in patenting activities. We first present our empirical strategy and then we discuss our results.

5.1. Model Specification

We use a probit regression model to investigate the underlying relationship between the probability for a patent to be linked to a women inventor and a set of specific characteristics associated with the patent. The structure of our dependent variable y is binary. Specifically, it takes the value of 1 if the patent is associated with a female inventor, and 0 otherwise. Our probit model can be expressed as:

$$Pr(Y_i = 1) = \Phi(\beta_0 + \beta_1 Year1844_i + \beta_2 PatentLength_i + \beta_3 TeamSize_i + \sum_{j=1}^{J} \beta_{4j}\, Sector_{ji} + \sum_{k=1}^{K} \beta_{5k}\, Education_{ki} + \varepsilon_i)$$

Where:

- Y_i is the probability of the dependent variable taking the value 1 for the patent i given the values of the independent variables.
- $\Phi()$ is the cumulative distribution function of the standard normal distribution.
- β_0 represents the intercept term.
- β_1, β_2, β_3, β_4, and β_5 are the coefficients associated with the independent variables.
- ε_i represents the error term for the patent i.

We employ the maximum likelihood estimation approach to estimate our model. This method identifies the coefficient values of β that optimize the likelihood function. This function gauges the probability of y taking the value of 1 given a specified set of parameter values.

We successively introduce independent variables in our probit model (Table 2). We first control for the year of the implementation of the 1844 reform to capture the potential effect of the reform on women's participation in patenting activities (Column 1). The variable year 1844 is a dummy variable, which takes the value 1 for the patent applications submitted post-1844, 0 otherwise. We include a dummy variable to control for the effect of the patent lengths. Specifically, the variable takes the value 1 for 5-year patents; 0 for 10-year and 15-year patents. The certificates of addition are excluded from the analysis to focus on the primary patent types. The variable number of inventors involved in the patent application process is a continuous variable. The number of inventors is included to assess the impact of collaborative efforts on women's participation in patenting (Column 2). Next, we introduce the variable sector. This categorical variable encompasses 20 different sectors (or industries). This variable accounts for sector-specific variations in patenting activities and their influence on women's participation (Column 3). Finally, we use a proxy to capture the level of education. Our variable education is a categorical variable derived from occupation. It categorizes applicants into different education levels or qualifications (Column 4). The descriptive statistics are presented in Table 1.

Table 1: Descriptive Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Female linked	389680	.018	.132	0	1
Patent 5 years	389680	.021	.143	0	1
Patent 10 years	389680	.016	.127	0	1
Patent 15 years	389680	.765	.424	0	1
Number certificat addition	389680	.677	1.534	0	27
Number inventors	389680	1.154	.419	1	12
Agriculture	389680	.044	.204	0	1
Food processing	389680	.039	.192	0	1
Railways	389680	.094	.292	0	1
Textiles	389680	.091	.288	0	1
Machinery	389680	.062	.242	0	1
Marine navigation	389680	.018	.134	0	1
Construction	389680	.022	.148	0	1
Mining	389680	.024	.153	0	1
Domestic economy	389680	.077	.266	0	1
Road transport	389680	.054	.227	0	1
Weaponry	389680	.021	.142	0	1
Precision instrument	389680	.069	.253	0	1
Ceramics	389680	.024	.152	0	1
Chemistry	389680	.118	.323	0	1
Lighting heating	389680	.078	.269	0	1
Clothing	389680	.046	.209	0	1
Industrial arts	389680	.048	.215	0	1
Office articles	389680	.025	.158	0	1
Medicine hygiene	389680	.015	.123	0	1
Paris articles	389680	.03	.169	0	1
Higher education	143949	.021	.145	0	1
Secondary education	143949	.412	.492	0	1
Schooled	143949	.14	.347	0	1
Farmers	143949	.316	.465	0	1
Lower schooled	143949	.079	.27	0	1
Unschooled	143949	.031	.173	0	1
Married	6147	.456	.498	0	1
Single	6147	.269	.444	0	1
Widow	6147	.274	.446	0	1

5.2. Results

The results of the probit model provide insights into the determinants of women's participation in patenting activities in France during the 1791-1900 period. Specifically, we assess the impact of the 1844 reform, patent length, team size, sector, and level of education (proxy based on occupation) on the likelihood of a patent being linked to a woman.

Given that the probit model is non-linear in nature, the signs of the coefficients indicate the direction of the relationship, but the coefficients are not directly interpretable as marginal effects on the dependent variable.[5] We transform the coefficient using the delta method to interpret the coefficients as average marginal effects. The marginal effects reflect the change in the probability of our dependent variable (female-linked patent) given a one unit change in our independent variables. Table 2 presents the results of our probit regression analysis. The independent variables are introduced successively as presented in section 5.1 (Columns 1-4).

The new patent law that was adopted in 1844 increased the patent tax from 300 livres tournois in 1791 for five-year patents to 500 francs; and from 800 livres tournois to 1,000 francs for ten-year patents, payable by annuity of 100 francs – under penalty of forfeiture if the patentee allows a term to pass without paying it (see Article 4). Galvez-Behar (2019) argues that this new possibility to spread the payment of the tax promoted a democratization of patenting by enabling artisans or small entrepreneurs to patent by decreasing its actual cost. For every model, the coefficient for the year of the 1844 reform is positive and significant, suggesting that the implementation of the reform increased the likelihood of a patent being female-linked by 0.7 percentage points at the 0.1% significance level (Columns 2 and 3).

When controlling for the duration of the patent, 5 years against 10 or 15 years patents, to test whether resources constraints could hamper women likelihood to patent (hypothesis 2), we find positive and significant coefficients. This result indicates a higher probability by 0.8% (column 2) for 5-year patent to be linked to women inventors, which likely reflects the greater financial constraints faced by women (in particular before the implementation of the 1844 reform). Women patenting activities may have been limited because of a lower access to capital, which was necessary to acquire a patent.

Similarly, the number of inventors is positive and highly significant, across all specifications. The size of the teams increases the likelihood of a patent to be female-linked, with a marginal effect ranging from 0.5 to 0.7 percentage points. This means that an increase by one inventor is associated with an increase in the probability of a patent to be female-linked by 0.6 percentage points on average.

The coefficients for sectors show how the probability of a female-linked patent varies across different industrial sectors, compared to Chemistry (column 3). Different sectors seem to have varying effects on the likelihood of a patent being female-linked. For instance, Agriculture, Railways, Weaponry, and Mining consistently exhibit negative coefficients across all models, suggesting that patents in these sectors are less likely to be female-linked.

[5] The results of the probit regression are available in Table A in Appendix. Table B presents the results obtained using a logistic regression based on the specification of Column 3.

Conversely, Textile, Clothing, Industrial Arts, Office Articles, Medicine and Hygiene, and Paris articles have positive and significant coefficients across all models, indicating a higher probability to find female-linked patents relative to other sectors in comparison to Chemistry.

The coefficients for levels of education where the reference category, Farm, is situated between primary and secondary education present a non-linear relationship (column 4). Higher education, Unschooled, and Schooled exhibit a positive coefficient, indicating that these levels of educational attainment are associated with an increased likelihood of a patent being female-linked (relative to farm). The Secondary education category however presents a negative coefficient, suggesting that this level of schooling decrease the probability of a patent being female-linked. Overall, this result suggests the existence of a U-shape in the probability for women to innovate relative to men. We identify the existence of two types of women inventors: on the one hand skilled women inventors who have high education and develop tools or techniques based on their knowledge; and on the other hand, women who have developed inventions based on their experience, via the process of learning by doing. In contrast, women with secondary level education may often find themselves in clerical roles and are therefore less likely to be inventors.

Overall, most effects are extremely small, ranging from -0.021 to 0.024 (see Figure A in Appendix). This indicates that for most characteristics the marginal effect on the likelihood for a patent to be associated with a female inventor is relatively small. The marginal effects suggest a negligible effect of most characteristics on the probability for a patent to be linked to a woman inventor.

Table 2: Probit Model – Marginal Effects

Dependent variable	**Female-linked patent**							
	(1)		(2)		(3)		(4)	
	dy/dx	St.Err.	dy/dx	St.Err.	dy/dx	St.Err.	dy/dx	St.Err.
Year 1844	0.003*	(0.001)	0.007***	(0.002)	0.007***	(0.002)	0.004**	(0.001)
Patent 5-year			0.008***	(0.002)	0.005**	(0.002)	0.003	(0.001)
Number of inventors			0.005***	(0.000)	0.006***	(0.000)	0.007***	(0.000)
Sectors								
Agriculture					-0.009***	(0.001)	-0.006***	(0.020)
Food processing					-0.008***	(0.002)	-0.003	(0.002)
Railways					-0.017***	(0.001)	-0.09***	(0.002)
Textiles					0.002*	(0.001)	0.004***	(0.001)
Machinery					-0.006***	(0.001)	-0.002	(0.001)
Marine & navigation					-0.016***	(0.002)	-0.008*	(0.003)
Construction					-0.006**	(0.002)	-0.002	(0.002)
Mining					-0.012***	(0.002)	-0.007**	(0.002)
Domestic economy					0.003**	(0.001)	0.000	(0.001)
Road & transport					-0.002	(0.001)	-0.006**	(0.002)
Weaponry					-0.021***	(0.003)	-0.008**	(0.003)
Precision instrument					-0.005***	(0.001)	0.000	(0.001)
Ceramics					-0.006**	(0.002)	-0.001	(0.002)
Lighting & heating					-0.001	(0.001)	-0.001	(0.001)
Clothing					0.024***	(0.001)	0.015***	(0.001)
Industrial arts					0.004**	(0.001)	0.005***	(0.001)
Office articles					0.009***	(0.001)	0.006***	(0.001)
Medicine & Hygiene					0.010***	(0.002)	0.006***	(0.002)
Paris articles					0.009***	(0.001)	0.007***	(0.001)
Education								
Higher education							0.005**	(0.002)
Secondary education							-0.003***	(0.001)
Schooled							0.001*	(0.001)
Lower schooled							0.007***	(0.001)
Unschooled							0.002	(0.001)
Number of observations	312,572		312,572		312,572		132,472	
Pseudo r-squared	0.0001		0.0029		0.0385		0.0815	

Note: * p<0.05, ** p<0.01, *** p<0.001. Average marginal effects. Delta-method. Standard errors in parentheses. Dependent variable: dummy variable takes value 1 if patent is female-linked, 0 otherwise. Chemistry is used as reference category for the sectors.

6. Complementary Mechanisms – The Role of Women's Marital Status

Given the importance of women's marital status in societal norms and its potential influence on women's involvement in the professional sphere, it could significantly impact patenting activities among women. We therefore choose to narrow down our focus to provide a nuanced understanding of the patenting landscape specifically for women, and how marital status might intersect with other determinants to shape their patenting behavior.

To determine the relationship between women's marital status and our set of independent variables (patent length, number of inventors, sectors, level of education), we employ a multinomial probit model. The choice of this model is driven by the categorical nature of our dependent variable. Marital status is treated as a categorical dependent variable with three categories: single, married, or widowed. Given the categorical nature of our dependent variable, we cannot directly interpret the magnitude of the coefficients. Instead, our interpretation focuses on the direction and significance of the coefficients. Specifically, coefficients will be compared against the 'married' category, which serves as our reference group. For instance, if the coefficient for the 'size of the team' is positive and significant for the 'widowed' category, it suggests that being part of a team is associated with a higher likelihood of a woman being widowed as compared to being married. The outcomes of our analysis aim to determine which factors either facilitated or hindered women's engagement in the patenting process.

The general form of our multinomial logistic model is:

$$\log\left(\frac{P(Y_i = j)}{P(Y_i = K)}\right) = \beta_{0j} + \beta_{1j} Year1844_i + \beta_{2j} PatentLength_i + \beta_{3j} TeamSize_i + \sum_{l=1}^{L} \beta_{4j}\, Sector_{li}$$

Where:

- Y is the dependent variable representing the categories of marital status.
- j is a specific category of the dependent variable, and K is the reference category (married women)
- β_0 represents the intercept term.
- β_1, β_2, β_3, and β_4 are the coefficients associated with the independent variables, namely year 1844, Patent Length, Team Size, and Sector, respectively.

The results from this analysis provide log-odds comparing the likelihood of being in one marital status category relative to another, given a one-unit change in the predictor variables, while holding all other predictors constant. The coefficients for the categories "Single" and "Widow" are relative to this reference group. We transform the coefficients into marginal effects for interpretability of the coefficients.

Table 3 presents the marginal effects obtained after transforming the coefficient of the multinomial logistic regression into interpretable coefficients.[6] The coefficients (dy/dx) represent the change in the probability of the outcome category occurring for a one-unit change in the predictor variable, holding other variables constant.[7] The number of inventors appears to be an important factor predicting the marital status of women associated with patents. Married women are 11.8 percentage point less likely to patent with another inventor, while single women and widows are more likely by 4.8 and 7 percentage point, respectively.

The sectors in which women patent are another important factors to understand differences by marital status. Married women are less likely to patent in the textile sector by 10.3 percentage point, ceramics by 17 percentage point, and industrial arts by 14%, relative to single women and widows. The only sector in which married women are more likely to be found is the construction sector, by 16.6 percentage points. Single women are more likely to be found in the clothing sector, by 9.4 percentage points, contrary to widows who are less likely to be found in this sector by 8.2%. It is in food processing and ceramics that widows have a higher probability to be found, by 13 and 13.7 percentage points, respectively.

While in proportion, married women patented to a similar extent as single women and widows (Merouani and Perrin, 2023), we find substantial differences in the type of sectors in which women patented by marital status. This finding suggests that marital statuses may have played a role in shaping the nature of women's patenting activities. Further investigation will be needed to uncover the reasons behind the differences observed.

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[6] The results of the multinomial logistic regression are available in Table C in Appendix.
[7] See Figure B in Appendix.

Table 3: Marginal Effects – Marital Status

Dependent variable	Married		Single		Widow	
	dy/dx	St.Err	dy/dx	St.Err	dy/dx	St.Err
Year 1844	-0.056	(0.050)	0.030	(0.048)	0.026	(0.045)
Patent 5-year	0.027	(0.053)	-0.038	(0.050)	0.011	(0.048)
Number of inventors	-0.118***	(0.022)	0.048**	(0.017)	0.070***	(0.017)
Sectors						
Agriculture	-0.028	(0.051)	-0.034	(0.050)	0.061	(0.044)
Food processing	-0.081	(0.057)	-0.048	(0.055)	0.130**	(0.045)
Railways	-0.064	(0.047)	0.041	(0.042)	0.023	(0.042)
Textiles	-0.103***	(0.030)	0.029	(0.028)	0.075**	(0.026)
Machinery	-0.100*	(0.042)	0.013	(0.038)	0.087*	(0.035)
Marine & navigation	0.128	(0.103)	-0.183	(0.120)	0.055	(0.088)
Construction	0.166*	(0.064)	-0.070	(0.065)	-0.096	(0.065)
Mining	-0.070	(0.072)	-0.032	(0.069)	0.103	(0.058)
Domestic economy	-0.034	(0.031)	0.021	(0.028)	0.013	(0.058)
Road & transport	0.053	(0.115)	0.004	(0.035)	-0.056	(0.036)
Weaponry	-0.153	(0.115)	0.051	(0.097)	0.102	(0.090)
Precision instrument	-0.059	(0.038)	0.054	(0.034)	0.005	(0.034)
Ceramics	-0.170**	(0.063)	0.034	(0.055)	0.137**	(0.049)
Lighting & heating	0.007	(0.034)	-0.061	(0.034)	0.054	(0.030)
Clothing	-0.013	(0.027)	0.094***	(0.024)	-0.082***	(0.025)
Industrial arts	-0.139***	(0.036)	0.065*	(0.032)	0.074*	(0.031)
Office articles	0.006	(0.039)	0.063	(0.034)	-0.069	(0.038)
Medicine & hygiene	0.033	(0.049)	0.025	(0.045)	-0.058	(0.047)
Paris articles	-0.089*	(0.037)	0.065*	(0.033)	0.023	(0.033)
Number of observations	4,847					
Pseudo r-squared	0.0183					

Note: * p<0.05, ** p<0.01, *** p<0.001. Average marginal effects. Delta-method. Dependent variable: categorical variable takes value 1, 2, or 3, if female-linked patent has been patented by a married, single, or widow women (as first depositor). Chemistry is used as reference category for the sectors.

7. Discussion

7.1. Characteristics of Patented Inventions – Gender Perspective

In this study, we examined gender dynamics in patenting activities. We tested five hypotheses to understand the factors influencing women's participation in patenting activities. Hypothesis 1 posited that married women were less likely to be involved in patenting inventions because of social norms and legal restrictions against married women in place during the nineteenth century. Contrary to this assumption, our findings reveal that marital status had no significant impact on a woman's likelihood to participate in patenting activities. Married women were just as likely to contribute to patented inventions as their unmarried counterparts. However, we find that married women were more likely to patent in teams, and in the construction than single women and widows. While single women were more likely to be found in clothing, widows had a higher probability to patent inventions related to food processing and ceramics.

Hypothesis 2 suggested that women were more inclined to apply for 5-year patents compared to men due to resource constraints. This hypothesis was confirmed by the data, indicating a distinct preference among female inventors for shorter-term patents. Hypothesis 3 proposed that female participation in patented inventions should be higher when working in collaborative teams of inventors, as shown in modern contexts. Our results support this hypothesis, showing that women were indeed more likely to be involved in patenting activities as part of a team. Collaboration could provide a supportive environment that encourages greater female involvement.

Hypothesis 4 questioned whether women were more likely to participate in patents related to female-oriented sectors. Our findings are mixed; while women had a greater tendency to be involved in these sectors, the magnitude of the effects are very small. This suggests that while there is a lean towards female-oriented sectors, women's participation in patented inventions in France during the nineteenth century was not strictly confined to these areas.[8] Finally, Hypothesis 5 explored the idea that women with higher levels of human capital (proxied by occupation titles)[9] should be more likely to participate in patenting than less educated women. Surprisingly, our findings indicate no significant difference in the patenting activities of educated versus less educated women. Both groups were engaged in

[8] See Figure C in Appendix presenting the distribution of patenting activities across sectors by gender.
[9] See Figure D in Appendix presenting the distribution of men and women by HISCO occupational groups.

patenting inventions, indicating that factors other than formal education or occupation level might play a crucial role in influencing their involvement in this domain.

7.2. Comparative Perspective

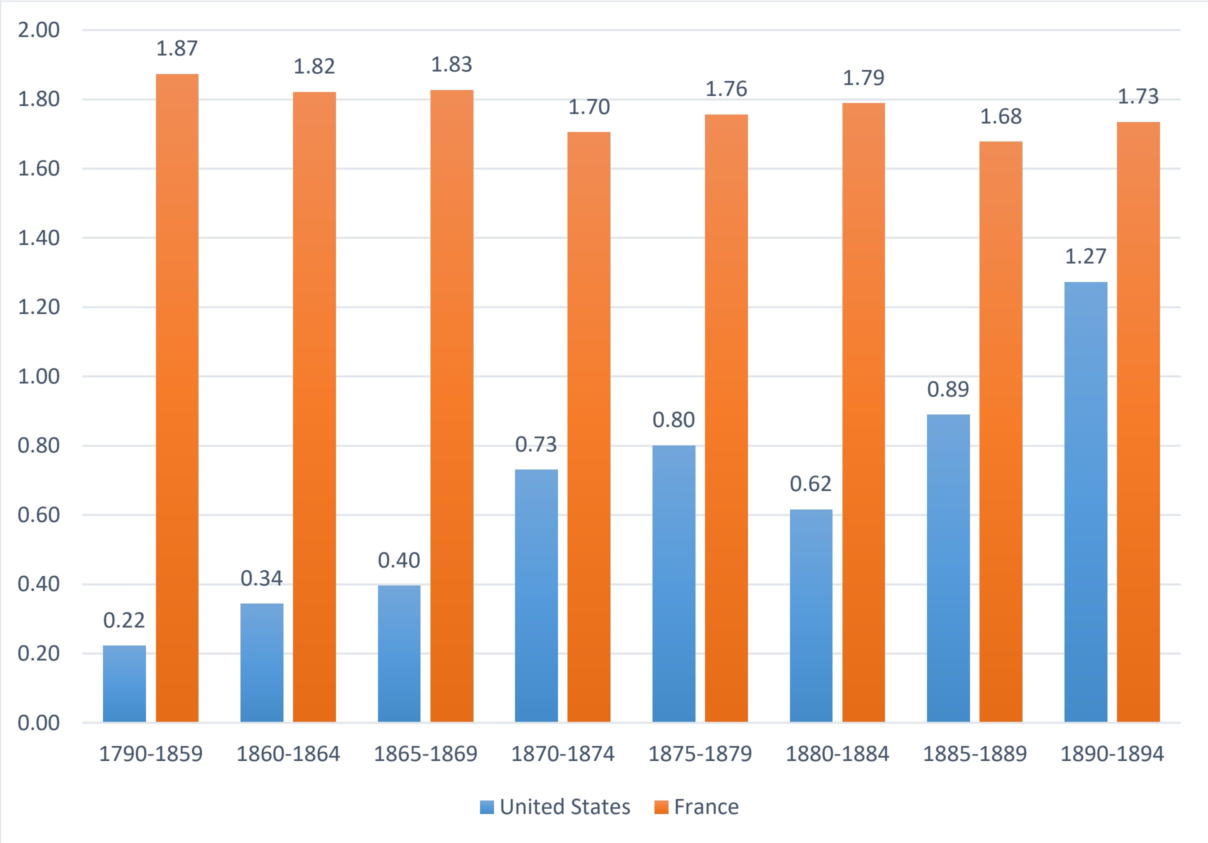
Khan (2005) compared the patent systems and concluded that the U.S. patent system was distinctively more democratized and accessible, compared to the British and French systems, allowing a broader range of people, including women, to participate. The British and French patent systems were more expensive and required more complex procedures. The stricter formalities and the higher costs associated with patenting in these countries, explain, according to Khan (2005), why women inventors were even more underrepresented in Britain and France than in the US. Women in both Britain and France faced significant societal and legal barriers.

Despite the extremely low level of US patent fees relative to France (Nuvolari et al., 2023), women patented significantly more in France than in the United States. Figure 5 illustrates the difference in the gender patenting gap in the two countries. Across all time intervals, the United States consistently exhibits a higher gender patenting gap than France. During the period from 1790-1859, the gap in the U.S. is approximately 0.2%, while France's is close to 2%. This trend continues across all periods, with the U.S. consistently registering larger gender disparities than France. As previously discussed, despite the Napoleonic Code, which limited the legal and economic independence of married women, French women did manage to secure patents in their own name and not just in areas deemed "appropriate" for women, such as textiles, clothing, and domestic appliances. French women also patented in male-dominated sectors (Merouani and Perrin, 2023).

Despite the extremely low level of US patent fees relative to France (Nuvolari et al., 2023), women patented significantly more in France than in the United States. Figure 5 illustrates the difference in the gender patenting gap in the two countries. Across all time intervals, the United States consistently exhibits a higher gender patenting gap than France. During the period from 1790-1859, the gap in the U.S. is approximately 0.2%, while France's is close to 2%. This trend continues across all periods, with the U.S. consistently registering larger gender disparities than France. As previously discussed, despite the Napoleonic Code, which limited the legal and economic independence of married women, French women did manage to secure patents in their own name and not just in areas deemed "appropriate" for

women, such as textiles, clothing, and domestic appliances. French women also patented in male-dominated sectors (Merouani and Perrin, 2023).

Figure 3: Gender Patenting Gap – United States vs France



Note: Using data from Khan (1996) for the United States and our data for France.

Although the US never catch up on France during the period analyzed, gender disparities in the US reduces over time, while the gender patenting gap in France remains extremely stable throughout the period. Changes in societal attitudes, reforms in property rights, and increased educational opportunities positively impacted women's patenting activities (Khan, 2020). French women, however, seem to face a glass ceiling. This phenomenon parallels the challenges many women face in modern times. This metaphorical barrier represents the unseen obstacles preventing women from advancing to the highest echelons of their professions, regardless of their qualifications or achievements. Just as the gender patenting gap highlights the historical constraints on women's participation to innovative activities, the glass ceiling underscores the set of hidden challenges that impeded women's advancement and achievement in innovation and patenting.

Women have traditionally been underrepresented in fields connected to science, technology, engineering, which are closely linked to innovation and patenting. The lack of female role models and the absence of visible female inventors and entrepreneurs could have discouraged women from pursuing patent-related activities. The lack of guidance and support in navigating the patenting process might have similarly hampered women's success.

Gender bias contributes to reinforce and perpetuate the glass ceiling. In the context of patenting, gender bias can manifest in the evaluation and recognition of inventions. Research has shown that inventions by women are sometimes undervalued or overlooked, leading to disparities in patent approvals and recognition for their innovative work, which could have discouraged women from actively pursuing patents. Organizational and structural barriers, combined with challenges in finding a balance between professional and familial responsibilities, could similarly contribute to explain women's limited involvement in patenting activities.

8. Conclusion

Patents, while not capturing the full breadth of innovative activity taking place on a national level, provide a consistent metric for exploring innovation across time and space. In this study, we have built an extensive database on all patents granted in France from the inception of the patenting system in 1791 to the turn of the twentieth century. Our research revealed a notable rise in the number of women patentees over time. Our findings attest the importance of women's contribution to technological advancement during the industrialization process – across all technology sectors.

We concentrated our analysis on the question, and origin, of the gender gap in patenting activities that is still observed in modern contexts. We find that before the 1840s, there were fluctuations in the gap, with a peak share of patents linked to women that is not seen until modern times. After the 1840s, the large fluctuations came to an end with a stable 1.7% share of patent being attributed to women throughout the rest of the century. Interestingly, both genders were similarly affected by external chocks.

In seeking to understand the differences between the patenting activities of both genders, we find some small, albeit statistically significant, effects. The likelihood of patents being linked to women was to a limited degree shaped by reforms, access to resources, collaborative dynamics, sectoral tendencies, and educational backgrounds. Women were slightly more likely to patent after the reform of 1844 when longer patents became cheaper, but they continued to be more likely to apply to 5-year patents, which was the cheapest alternative. Larger teams of inventors increased the likelihood of women to be involved in the patent. Additionally, we found that certain sectors, notably textiles and clothing, were more conducive to female-linked patents compared to the chemistry sector, while other sectors like agriculture and machinery were less so.

The analysis further underscores the role of educational and occupational backgrounds in influencing women's propensity to patent. Surprisingly, our results suggest a U-shaped relationship, where women with either higher education or less formal schooling but rich experiential learning were more likely to be involved in patented inventions. A closer investigation of women's probability to patent by marital status reveals that married women were less likely to collaborate with other inventors and less likely to patent in the textile, ceramics, and industrial arts relative to single women and widows, but more likely to patent in the construction sector. However, single women are more likely to be found in the clothing sector, while widows are more likely to patent in food processing and ceramics.

Our study highlights the persistent and striking gender gap in patenting, a phenomenon that has historical roots and continues into the present day. The cross-national comparison with the United States confirms the complex interplay of societal norms, legal frameworks, and economic conditions, underlying the gender patenting gap and calls for more in-depth investigations. Understanding its origins is crucial to pave the way for more gender-equal participation in innovative activities and create an environment where the inventive potential of all individuals, regardless of gender, can be fully realized.

References

Baten, J., de Pleijt, A. M. (2022). Female Autonomy Generated Successful Long-Term Human Capital Development: Evidence from 16th to 19th Century Europe, World Development, 158: 1–17.

Bell, A., Chetty, R., Jaravel, X., Petkova, N., Van Reenen, J. (2019). Who becomes an inventor in America? The importance of exposure to innovation. *The Quarterly Journal of Economics*, 134(2): 647–713.

Boserup, E. (1970). *Women's Role in Economic Development*. New York: St. Martin's Press

Bikard, M., Fernandez-Mateo, I. (2022). Standing on the Shoulders of (Male) Giants: Gender Inequality and the Technological Impact of Scientific Ideas. Available at SSRN 4059813.

Chanteux, A. (2009). Les inventives. Femmes, inventions et brevets en France à la fin du XIXe siècle, *Documents pour l'histoire des techniques*, 17(1): 90–97.

Chanteux, A. (2023). Les filles d'Athéna : Femmes et brevets au XIXe siècle en France. EHESS, Paris.

Cook, L. D., Kongcharoen, C. (2010). The idea gap in pink and black. *National Bureau of Economic Research*, No. w16331.

Diebolt, C., Perrin, F. (2013). From Stagnation to Sustained Growth: The Role of Female Empowerment. *American Economic Review* 103(3), 545–549.

Ding, W. W., Murray, F., Stuart, T. E. (2006). Gender differences in patenting in the academic life sciences. *Science*, 313(5787): 665–667.

Emptoz, G., Marchal, V. (2002). Aux Sources de la Propriété Industrielle: Guide des Archives de L'INPI. Paris: Institut National de la Propriété Industrielle, 247 pages.

Galvez-Behar, G. (2019). The Patent System during the French Industrial Revolution: Institutional Change and Economic Effects, Jahrbuch für Wirtschaftsgeschichte / Economic History Yearbook, 60(1): 31–56.

Goldin, C. (1990). *Understanding the Gender Gap: An Economic History of American Women*. New York: Oxford University Press.

Giuri, P., Grimaldi, R., Kochenkova, A., Munari, F., Toschi, L. (2020). The effects of university-level policies on women's participation in academic patenting in Italy. *The Journal of Technology Transfer*, 45: 122–150.

Hart, S. (1997). Women and Education in 19th-century France, Modern & Contemporary France, 5(1): 85–87.

Heikkilä, J. (2019). IPR gender gaps: a first look at utility model, design right and trademark filings. *Scientometrics*, 118(3): 869–883.

Hunt, J., Garant, J. P., Herman, H., Munroe, D. J. (2012). Why don't women patent?, *National Bureau of Economic Research*, No. w17888.

INPI. (2011). Les Brevets Français au 19ème Siècle. Institut National de la Propriété Industrielle.

Jensen, K., Kovács, B., Sorenson, O. (2018). Gender differences in obtaining and maintaining patent rights. *Nature biotechnology*, 36(4): 307–309.

Jung, T., Ejermo, O. (2014). Demographic patterns and trends in patenting: Gender, age, and education of inventors. *Technological Forecasting and Social Change*, 86: 110–124.

Khan, B. Z. (1996). Married women's property laws and female commercial activity: Evidence from United States patent records, 1790–1895, *Journal of Economic History*, 56(2): 356–388.

Khan, B. Z. (2000). "Not for Ornament": Patenting activity by nineteenth-century women inventors. *Journal of Interdisciplinary History*, 31(2): 159-195.

Khan, B. Z. (2005). *The Democratization of Invention: Patents and Copyrights in American Economic Development, 1790-1920*. Cambridge University Press.

Khan, B. Z. (2016). Invisible Women: Entrepreneurship, Innovation, and Family Firms in Nineteenth-Century France, *Journal of Economic History*, 76(1): 163–195.

Khan, B. Z. (2020). *Inventing Ideas: Patents, Prizes, and the Knowledge Economy*. Oxford University Press, USA.

Koning, R., Samila, S., Ferguson, J. P. (2021). Who do we invent for? Patents by women focus more on women's health, but few women get to invent. *Science*, 372(6548): 1345–1348.

Lewis, H. D. (1980). The Legal Status of Women in Nineteenth-Century France, *Journal of European Studies*, 10(39): 178–188.

Martin, L., Muller, B., Ortiz Suárez, P. J., Dupont, Y., Romary, L., de la Clergerie, É., Seddah, D., Sagot, B. (2020). CamemBERT: A Tasty French Language Model, in *Proceedings of the 58th Annual Meeting of the Association for Computational Linguistics*, (July 2020): 7203–7219.

Marovich, L. (1999). Fueling the Fires of Genius: Women's Inventive Activities in American War Eras. *The Journal of Economic History*, 59(2): 462–466.

Mauleón, E., Bordons, M. (2010). Male and female involvement in patenting activity in Spain. *Scientometrics*, 83(3): 605–621.

McMillan, G. (2009). Gender differences in patenting activity: An examination of the US biotechnology industry. *Scientometrics*, 80(3): 683–691.

Merouani, Y., Perrin, F. (2022). Gender and the long-run development process. A survey of the literature. *European Review of Economic History*, 26(4): 612–641.

Merouani, Y., Perrin, F. (2023). Myths and Biases: An Exploration of Women's Historical Patenting Activities, *AFC Working Paper Series*, No 9, 32 pages.

Meyer, P. (2022). Patent Technology Classifications for Early Aeronautics. WEHC 2022 Conference, Paris, 2022.

Mokyr J. (2010). The Enlightened Economy: An Economic History of Britain 1700–1850, New Haven, CT: Yale University Press.

Mokyr J, Sarid, A., van der Beek, K. (2019). The Wheels of Change: Human Capital, Millwrights, and Industrialization in Eighteenth-Century England, CEPR discussion paper, DP 14138.

Moser, P. (2013). Patents and innovation: evidence from economic history. Journal of economic perspectives, 27(1): 23-44.

Murray, F., Graham, L. (2007). Buying science and selling science: Gender differences in the market for commercial science. *Industrial and Corporate Change*, 16(4): 657–689.

Nuvolari, A., Tortorici, G., Vasta, M. (2023). British-French Technology Transfer from the Revolution to Louis Philippe (1791-1844): Evidence from Patent Data. *The Journal of Economic History*,83(3): 833–873.

Oldenziel, R. (1999). *Making Technology Masculine: Men, Women and Modern Machines in America, 1870-1945*, Amsterdam: Amsterdam University Press

Perrin, F. (2013). Gender Equality and Economic Growth in the Long Run: A Cliometric Analysis, Université de Strasbourg (France) and Scuola Superiore Sant'Anna di Studi Universitari e di Perfezionamento (Pisa, Italy), Ph.D. thesis.

Pilato, D. E. (2000). *The Retrieval of a Legacy: Nineteenth-Century American Women Inventors*. Westport, Conn.: Praeger.

République Française. (1793). *Bulletin des lois de la République Française*. Imprimerie Nationale des Lois.

Rosser, S. V. (2009). The gender gap in patenting: Is technology transfer a feminist issue?. *NWSA Journal*, 65–84.

Sifontes, D., Morales, R. (2020). Gender differences and patenting in Latin America: understanding female participation in commercial science. *Scientometrics*, 124(3) : 2009-2036.

Squicciarini, M. P., Voigtländer, N. (2015). Human Capital and Industrialization: Evidence from the Age of Enlightenment, *Quarterly Journal of Economics*, 130(4): 1825–1883.

Sugimoto, C. R., Ni, C., West, J. D., Larivière, V. (2015). The academic advantage: Gender disparities in patenting. *PloS one*, 10(5), e0128000.

Whittington, K. B., Smith-Doerr, L. (2008). Women inventors in context: Disparities in patenting across academia and industry. *Gender & Society*, 22(2): 194–218.

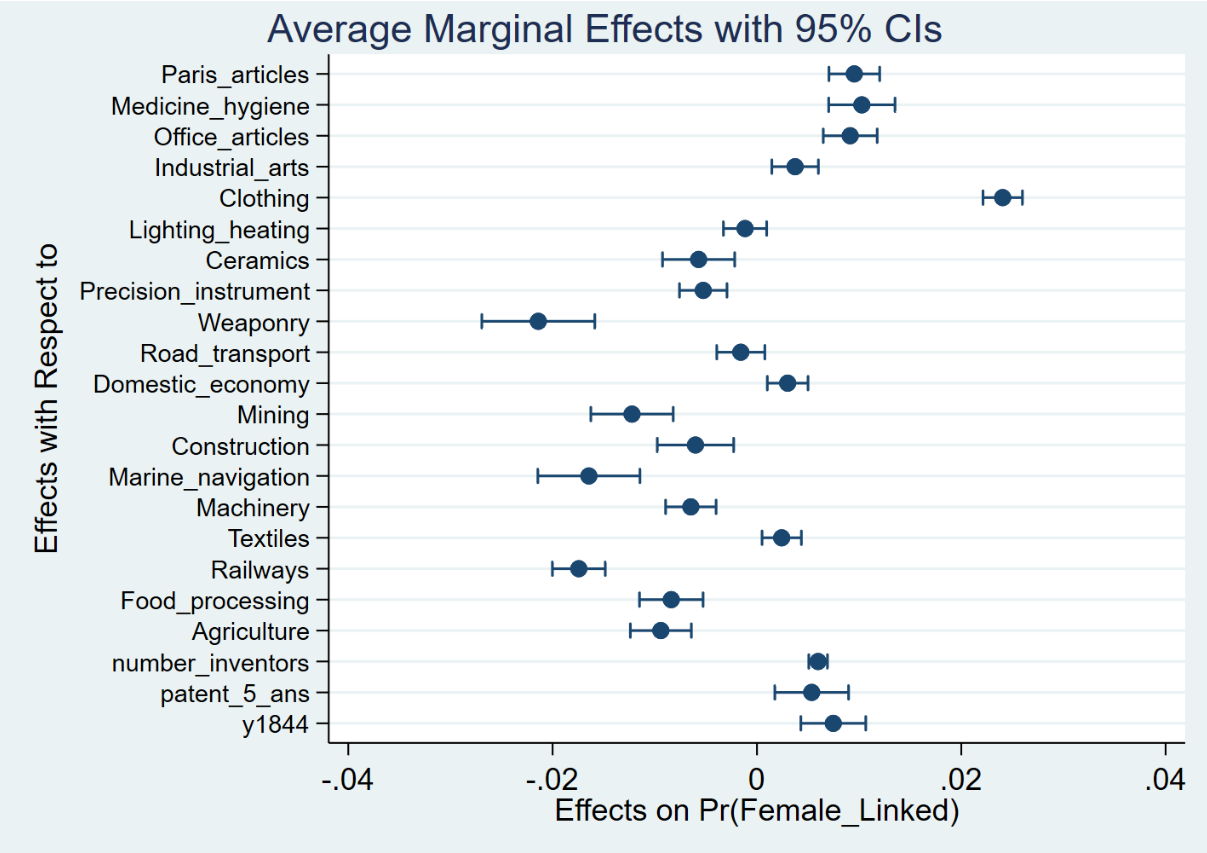
Appendix

Table A: Regression Results – Probit Model

Dependent variable	Female-linked patent							
	(1)		(2)		(3)		(4)	
	Coef.	St.Err	Coef.	St.Err	Coef.	St.Err	Coef.	St.Err
Year 1844	0.063**	(0.028)	0.170***	(0.038)	0.180***	(0.039)	0.190***	(0.061)
Patent 5-year			0.188***	(0.043)	0.129***	(0.044)	0.132	(0.069)
Number of inventors			0.131***	(0.011)	0.144***	(0.011)	0.338***	(0.020)
Sectors								
Agriculture					-0.226***	(0.036)	-0.286***	(0.080)
Food processing					-0.201***	(0.038)	-0.155	(0.082)
Railways					-0.419***	(0.031)	-0.423***	(0.080)
Textiles					0.058*	(0.024)	0.190***	(0.047)
Machinery					-0.155***	(0.030)	-0.116	(0.066)
Marine & navigation					-0.395***	(0.061)	-0.367*	(0.151)
Construction					-0.144**	(0.046)	-0.108	(0.096)
Mining					-0.294***	(0.049)	-0.317**	(0.115)
Domestic economy					0.072**	(0.024)	0.007	(0.057)
Road & transport					-0.038	(0.029)	-0.271**	(0.087)
Weaponry					-0.514***	(0.068)	-0.390**	(0.140)
Precision instrument					-0.126***	(0.028)	0.012	(0.059)
Ceramics					-0.137**	(0.043)	-0.028	(0.084)
Lighting & heating					-0.028	(0.026)	-0.029	(0.060)
Clothing					0.578***	(0.023)	0.688***	(0.047)
Industrial arts					0.090**	(0.028)	0.224***	(0.055)
Office articles					0.219***	(0.032)	0.280***	(0.067)
Medicine & Hygiene					0.247***	(0.040)	0.288***	(0.082)
Paris articles					0.229***	(0.030)	0.309***	(0.063)
Education								
Higher education							0.240**	(0.075)
Secondary education							-0.126***	(0.030)
Schooled							0.070*	(0.035)
Lower schooled							0.333***	(0.036)
Unschooled							0.091	(0.062)
Constant	-2.171***	(0.028)	-2.435***	(0.040)	-2.464***	(0.044)	-3.076***	(0.079)
Number of observations	312572		312572		312572		132472	
Pseudo r-squared	0.0001		0.0029		0.0385		0.0815	

Note: * p<0.05, ** p<0.01, *** p<0.001. Probit estimates. Standard errors in parentheses. Dependent variable: dummy variable takes value 1 if female-linked patent, 0 otherwise. Chemistry is used as reference category for the sectors.

Figure A: Marginal Effects



Note: Chemistry is used as reference category.

Table B: Logistic regression – Odds Ratio

Female-linked Patent	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Year 1844	1.597	.159	4.70	0	1.314	1.941	***
Patent 5-year	1.392	.152	3.03	.002	1.124	1.724	***
Number of inventors	1.394	.036	12.86	0	1.325	1.466	***
Sectors							
Agriculture	.556	.054	-6.04	0	.46	.673	***
Food processing	.595	.06	-5.15	0	.488	.725	***
Railways	.328	.028	-12.84	0	.277	.389	***
Textiles	1.157	.068	2.48	.013	1.031	1.298	**
Machinery	.673	.053	-5.03	0	.577	.785	***
Marine & navigation	.35	.06	-6.10	0	.25	.491	***
Construction	.69	.083	-3.08	.002	.546	.874	***
Mining	.462	.062	-5.73	0	.355	.602	***
Domestic economy	1.197	.073	2.97	.003	1.063	1.348	***
Road & transport	.911	.067	-1.28	.201	.789	1.051	
Weaponry	.248	.049	-7.08	0	.169	.365	***
Precision instrument	.724	.053	-4.38	0	.627	.837	***
Ceramics	.705	.08	-3.10	.002	.565	.879	***
Lighting & heating	.934	.061	-1.05	.295	.821	1.062	
Clothing	3.784	.201	25.09	0	3.41	4.198	***
Industrial arts	1.252	.086	3.27	.001	1.094	1.434	***
Office articles	1.705	.132	6.91	0	1.465	1.983	***
Medicine & hygiene	1.818	.171	6.37	0	1.512	2.185	***
Paris articles	1.745	.127	7.68	0	1.514	2.012	***
Constant	.007	.001	-43.94	0	.006	.009	***

Mean dependent var	0.017	SD dependent var	0.131
Pseudo r-squared	0.038	Number of obs.	312572
Chi-square	2099.853	Prob > chi2	0.000
Akaike crit. (AIC)	52790.268	Bayesian crit. (BIC)	53035.277

Note: * p<0.1, ** p<0.05, *** p<0.01. Logistic regression. Standard errors in parentheses. Dependent variable: dummy variable takes value 1 if female-linked patent, 0 otherwise. Chemistry is used as reference category for the sectors.

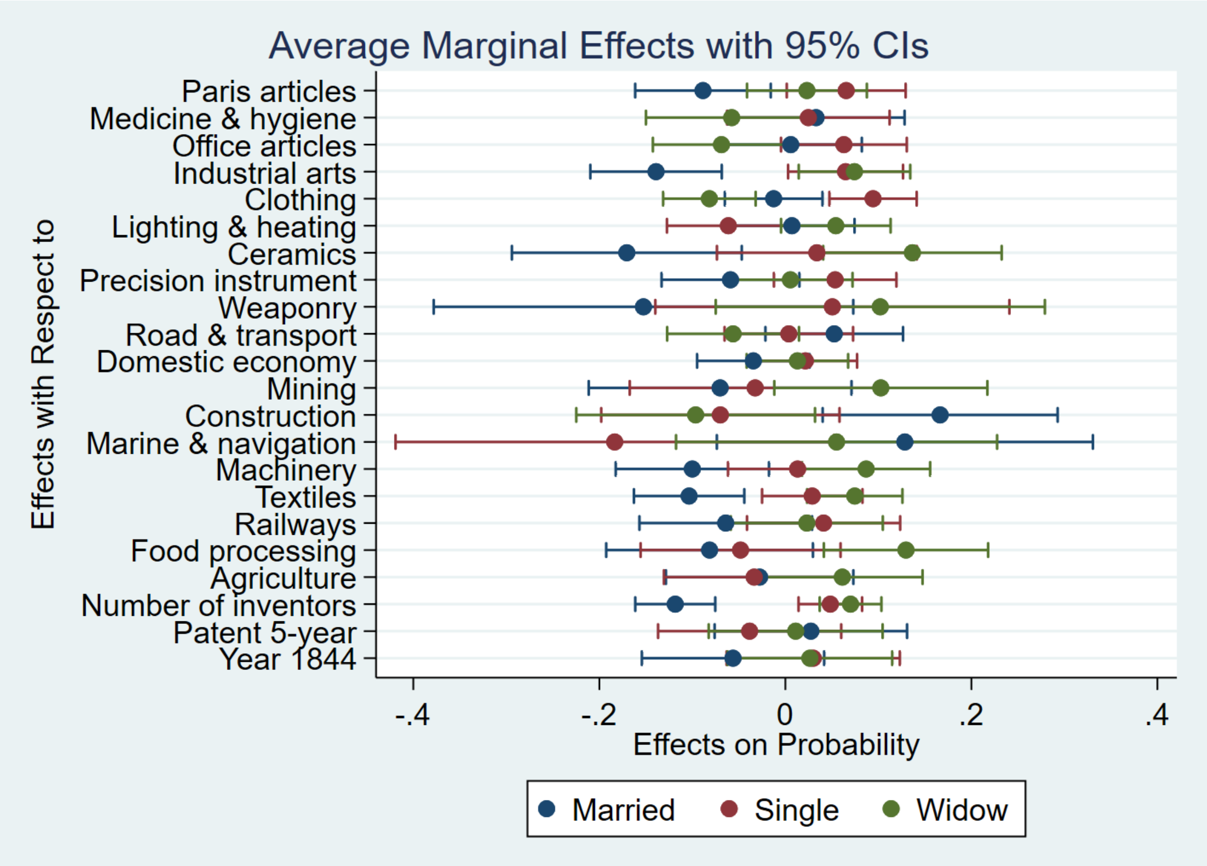
The odds ratio describes the odds of an event happening in relation to a one-unit change in a predictor variable. Example for our variables: Textiles': the odds ratio of 1.157 means that a one unit increase in the variable 'Textile' increases the probability that a patent is female linked by 1.157 times; 'Clothing': the odds ratio of 3.784 means that a one unit increase in the variable 'Clothing' increases the probability that a patent is female linked by 3.8 times; 'Mining': the odds ratio of 0.462 means that a one unit increase in 'Mining' decreases the probability that a patent is female linked decreases by 0.5 times, i.e. the event has half the odds to occur.

Table C: Multinomial Logistic Regression – Marital Status

Dependent variable	Married	Single		Widow	
	(Reference)	Coef.	St.Err	Coef.	St.Err
Year 1844		0.239	(0.260)	0.225	(0.245)
Patent 5-year		-0.206	(0.274)	-0.020	(0.259)
Number of inventors		0.448***	(0.105)	0.528***	(0.103)
Sectors					
Agriculture		-0.063	(0.273)	0.291	(0.241)
Food processing		0.003	(0.307)	0.667**	(0.252)
Railways		0.298	(0.235)	0.230	(0.233)
Textiles		0.341*	(0.154)	0.511***	(0.146)
Machinery		0.275	(0.215)	0.549**	(0.198)
Marine & navigation		-0.977	(0.636)	-0.084	(0.441)
Construction		-0.637	(0.341)	-0.734*	(0.341)
Mining		0.036	(0.385)	0.540*	(0.326)
Domestic economy		0.158	(0.156)	0.126	(0.153)
Road & transport		-0.104	(0.190)	-0.328*	(0.195)
Weaponry		0.533	(0.568)	0.724	(0.530)
Precision instrument		0.334	(0.187)	0.153	(0.189)
Ceramics		0.511	(0.319)	0.893**	(0.287)
Lighting & heating		-0.246	(0.184)	0.186	(0.163)
Clothing		0.382**	(0.132)	-0.276*	(0.139)
Industrial arts		0.556**	(0.180)	0.590***	(0.174)
Office articles		0.223	(0.188	-0.269	(0.205)
Medicine & hygiene		0.018	(0.241)	-0.289	(0.254)
Paris articles		0.445*	(0.183)	0.286	(0.184)
Constant		-1.446***	(0.299)	-1.433***	(0.284)
Number of observations	4,847				
Pseudo r-squared	0.0183				

Note: * p<0.05, ** p<0.01, *** p<0.001. Multinomial logistic. Standard errors in parentheses. Dependent variable: categorical variable takes value 1, 2, or 3, if female-linked patent has been patented by a married, single, or widow women (as first depositor). Chemistry is used as reference category for the sectors.

Figure B: Marginal Effects



Note: Chemistry is used as reference category.

Figure C: Distribution of Patenting Activities by Sector, 1791-1900

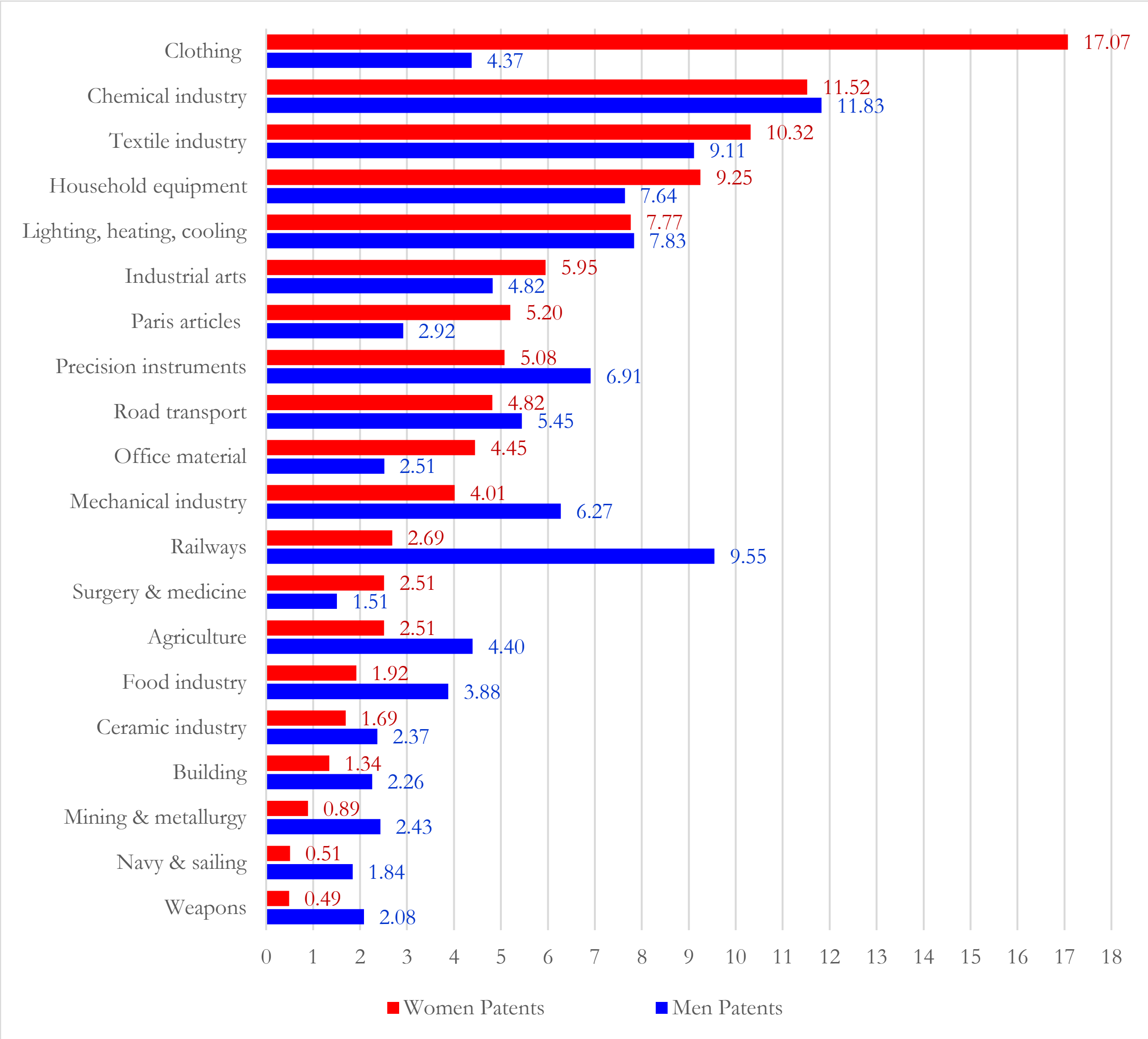
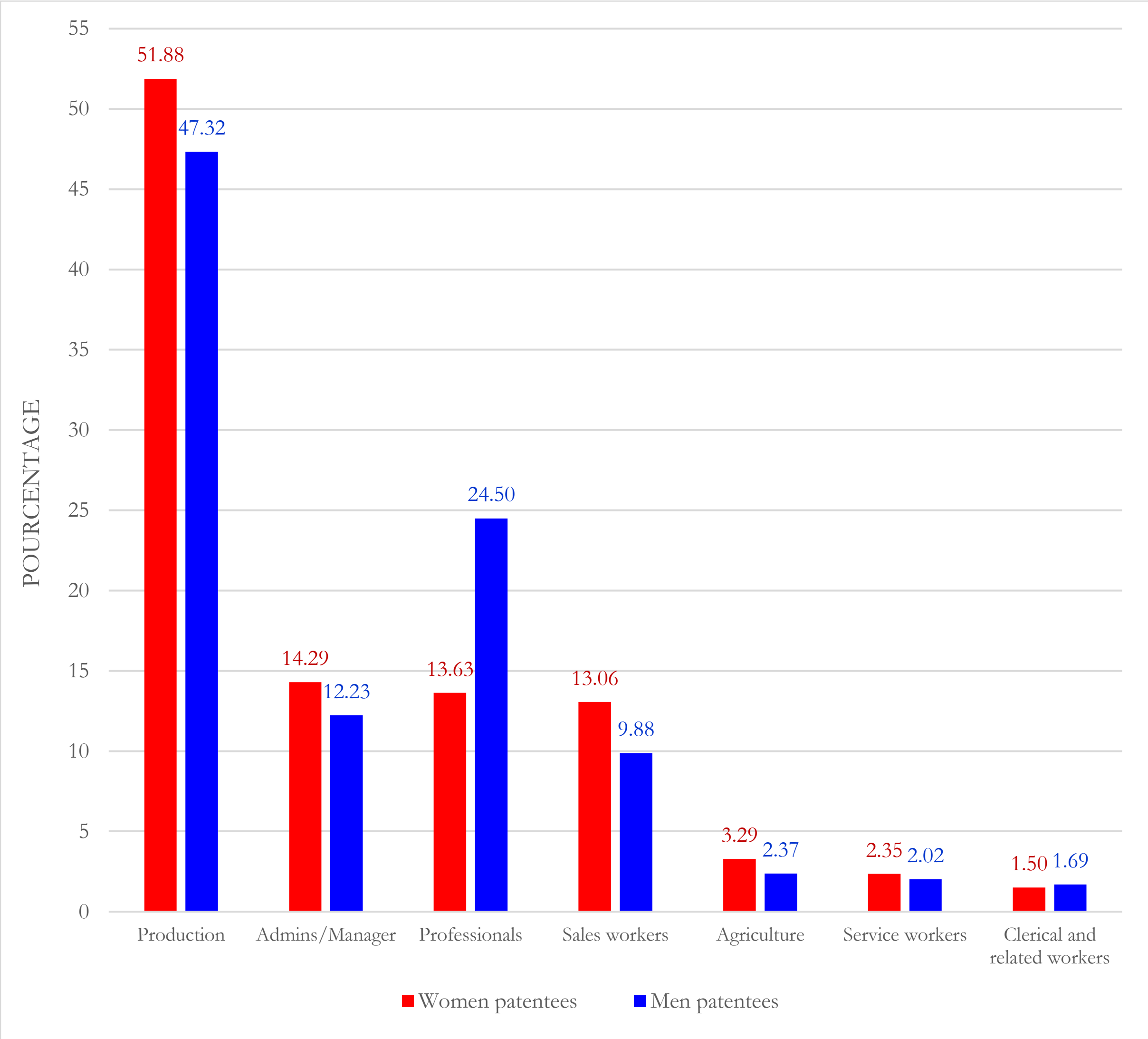


Figure D: Distribution of Patentees' Occupation (HISCO), 1791-1900



Note: Based on a sample of observations

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