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Property rights and innovation dynamism: The role of women inventors

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Abstract
How do stronger property rights for disadvantaged groups affect innovation? I investigate the impact of strengthened property rights for women on U.S. innovation by analyzing the Married Women's Property Acts, which granted equal property rights to women starting in 1845 in New York State. I examine the universe of granted patents from 1790 until 1901, exploiting the staggered adoption of the laws over time across states. The strengthening of women's property rights led to a 40% increase in patenting activity among women in the long run, with effects peaking about a decade after the laws were introduced. Importantly, women's innovations were not of lower quality (as measured by a novelty index based on patent text analysis) and did not generate negative effects on male innovation. Finally, I show that the main mechanism was through higher human capital accumulation among women inventors and innovation incentives, rather than an increase in participation in STEM fields, labor force participation, or relieving financial frictions.

Keywords: innovations, gender, property rights, economic development
JEL codes: J16; N00; O12; O34; P14

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1. Introduction

Disadvantaged groups are underrepresented in innovations and the innovation process. In many societies, women have no independent rights to run a business, own property, or even travel without their husband's consent. Hence, they lack sufficient means to access innovations or engage in entrepreneurial activities. A growing body of literature on institutions suggests that strong economic rights promote economic development (Acemoglu, Johnson, and Robinson (2002), Field (2007), Hornbeck (2010), North (1990), and more). Studies also find that equal legal rights can improve economic outcomes for women (World Bank (2012), Geddes et al. (2009, 2012), Duflo (2012)). Moreover, creating an even playing field for individuals can pave the way for societies to employ talents more efficiently and increase the chances of uncovering the "lost or hidden Marie Curies or Einsteins" (Bell et al., 2019). Yet, there remains limited evidence regarding the effects of the inclusion of disadvantaged groups on aggregate innovations and the direction of technology in an economy.

In this paper, I study the effects of higher economic incentives through women's enhanced property rights on aggregate innovations in the 19th century in the United States. In particular, I exploit the plausibly exogenous variation in the timing of enacting the Married Women's Property Acts, which relaxed restrictions on women's property rights and provided significant economic and financial incentives to women. This legislation allowed them to own and control property, write contracts, engage in business, and keep their labor and capital earnings independently without any consent from their husbands or other close male kin.

To identify the effects of these enhanced property rights on innovations, I use the Comprehensive Universe of U.S. Patents (CUSP), which provides the universe of granted patent starting from 1836 onward (Berkes (2018))[1]. However, patent data do not contain information on a patentee's gender. Hence, I identify gender using popular female and male names in the 19th century. In case of uncertainty, I search the origin of the name,

[1]Patent applications were not recorded and therefore not available for this time period.

including its biblical origins, to determine its femininity. Additionally, I use the female share of names with Census data in 1900 and provide lower and upper bound estimates of women inventors in this period.

Moreover, I combine the patent data with an importance or novelty index, measuring whether a patent was a groundbreaking innovation that relied less on prior art and influenced the next 10 years of innovations. Since the citations of a patent were not required before 1947 in the United States, I use the data and methodology from Kelly et al. (2021) for breakthrough innovations by comparing the change in the similarity of an innovation to its predecessors and successors. The more a patent resembles the subsequent patents, the more likely it is a breakthrough innovation, representing a departure from established norms or practices. Hence, the novelty data by Kelly et al. (2021) allow for a quality test on patents by gender in addition to the quantity effect.

To analyze the effects of these rights on innovations, I employ a Poisson regression analysis to accommodate the count data structure of patents as the outcome variable. Moreover, due to the staggered timing of policy adoption across states, I also use the staggered adoption design analysis developed by Callaway and Sant'Anna (2021). I show that these property rights gave rise to more innovations among women by 40% on average without replacing men. This finding suggests that the provision of equal opportunities to women contributed to aggregate innovations without displacing innovations by men. Hence, there does not appear to be a trade-off between equity and efficiency.

In addition to the quantity effect, I also show that these rights led to more high-quality innovations patented among women. In other words, women in states that adopted enhanced property rights patented more novel or groundbreaking innovations that resemble less to prior art, and influenced more subsequent innovations in the next 10 years.

Moreover, based on the staggered adoption design event study, I observe that the positive impact on innovations materialized in the long run, approximately ten years on average after policy adoption. Given that innovations are not an overnight activity but require time and effort, the long-run effect is not only statistically significant but also

economically meaningful.

Innovations within disadvantaged groups may exhibit a certain direction, implying that an innovator's background can exert a social push effect on the type or direction of innovation (Einio, Fen, and Jaravel (2022)). In the 19th century, women possessed a notable comparative advantage in household appliances, clothing, and food production. In line with their background, I show that women's innovations were predominantly concentrated in human necessities, transportation, mechanical engineering, and textiles technology categories. However, I show that strong property rights did not lead to a significant rise in all these technology classes. Specifically, the rights led to a significant rise in mechanical engineering and performing operations, suggesting that women patented practical and innovative apparatus and articles that facilitated better production means and provided an advantage in the production process, such as tools for sewing, dishwasher machines, refrigerators, cutting tools, measurements, and more.

Furthermore, I provide additional analysis on regional trends, the effects of the Civil War, availability of financial institutions, participation in STEM fields, labor force participation rate, literacy rate, and other policies such as compulsory schooling laws. Firstly, due to the existing economic and social regional differences and trends that could be correlated with innovations and policy adoption, I include regional trends and show that the rise in women's innovations as a result of property rights are robust to the inclusion of heterogeneous regional trends. I also show that the exclusion of Civil War years, the availability of a national or state bank in a state, participation in STEM fields, and labor force participation do not explain the rise in innovations among women. Moreover, I control for other policy changes during the 19th century, i.e., compulsory schooling laws, and I find that schooling laws only amplify the effect of property rights on innovations, suggesting that the effect of property rights could be underestimated rather than overestimated.

On the other hand, human capital accumulation could be important explanatory factors for the rise of innovations among women. I find that literacy rate had a significant effect on

the number of innovations by women. These findings are also supported by the individual level descriptive analysis from Census records from 1850 to 1900, that women inventors had notably higher levels of human capital accumulation compared to their non-inventor counterparts, suggesting that a greater accumulation of knowledge played a significant role in their engagement in innovations. Moreover, the analysis reveals that inventors, both male and female, tended to be slightly older than the average age of the general women population. This finding is consistent with prior research, including the study conducted by Andrews, Sarada, and Ziebarth (2019), suggesting that experience and the accumulation of knowledge are significant factors influencing involvement in innovative endeavors.

Additionally, it is noteworthy that approximately 60% of women inventors were married, with at least 55% of all women inventors also being mothers. Similar trends, albeit slightly higher, were observed among male inventors. These characteristics underscore the significance of independent property rights and the potential impact of compulsory education policies for children, as supported by the empirical evidence presented in this study.

My research builds on several strands of the literature: innovations, gender, and economic history. There is a growing body of research studying inventors by using recent and historical data on patents (e.g., Andrews and Rothwell (2023), Bell et al. (2019), Khan and Sokoloff (1993), Akcigit, Grigsby, and Nicholas (2017), Aghion et al. (2017), Moser et al. (2014), and more). However, there is little research studying the gender component in patenting mainly because patent data do not provide demographic information such as age or gender. Bell et al. (2019) use administrative tax records to identify women inventors and analyze who becomes an inventor. They find that girls are more likely to invent, especially when interacting with women inventors rather than men. Akcigit, Grigsby, and Nicholas (2017) also use historical patent data and show that the probability of an individual becoming an inventor increases if one of their parents is also an inventor.

Previous work on women's property rights suggests some evidence on education, financial

intermediation, labor force participation, marriage, and commercial activities (Geddes et al. (2012), Khan (1996), Hazan et al. (2019), Evans (2006)). For instance, Geddes et al. (2012) and Koudijs and Salisbury (2016) study how women's property rights created a great incentive for women to invest in their education to use their rights optimally and climb the socioeconomic ladder. Khan (1996) examines the relationship between women's property rights and commercial activities in the United States using a sample dataset on patents from the 19th century. However, the econometric analysis in Khan (1996) does not account for heterogeneity and unobservables within states over time, potentially contaminating the estimates and raising concerns about causality. Hazan et al. (2018) demonstrate that adopting women's rights created a more relaxed financial environment, leading to decreased interest rates and increased cash deposits and loan supply. Evans (2006) analyzes whether independent property rights led to higher labor force participation among women and finds mixed results on labor force participation.

Due to data limitations and endogeneity concerns, conducting a study on economic incentives, patenting, and gender is challenging. One of the main contributions of this paper is that I use the universe of granted patents with gender identification and a novelty index for each patent. Second, I use several name identification methodologies to provide a comprehensive and coherent set of inventors by gender for lower and upper bound estimates in the 19th century in the United States. Third, I provide a multidimensional analysis of the role of other economic and policy indicators with seven different datasets to examine the change in innovation dynamics in the 19th century in the United States. I demonstrate that strong property rights enhanced security over the returns on innovation, thereby incentivizing more women to produce novel innovations without displacing men, and contributing to the overall aggregate number of innovations.

2. Institutional Background

2.1. Property Right Laws and the Rights of Women

Before the Married Women Acts in New York in the late 19th century, laws in the United States did not allow women to possess property or engage in business independently. Yet, property rights played an essential role in the economy, and individual family heads had almost a monopoly over both the ownership and the management of capital. As family heads had complete control over the property, the eldest son inherited the most significant part of the property. Women in the family could receive dowers or gifts — as long as they remained 'chaste'; however, they had no ownership rights over an asset (Shammas, Salmon, and Dahlin, 1987).

Moreover, even in the case of no sons, brothers, or husbands, the closest male kin had the ownership right to the property. Distributing property among family members was perceived as a threat to the accumulation of wealth; hence, women were not allowed to own and have the ultimate control over property.

Toward the 18th century, the most significant change was the abolition of the primogeniture rule, meaning that the division of properties among children should be equal. However, even though primogeniture ended, women still did not have an independent stance regarding owning property. It is certain that it was a significant change for women; nevertheless, few of them gained any advantage from this legal change (Shammas, Salmon, and Dahlin, 1987). Ownership would easily pass on to husbands or male siblings. If a woman got married, the husband could claim ownership of what she brought to the marriage. In the case of no children, a non-family male member could be in charge; therefore, widows did not have complete control over the property. So women were not only dependent on their husbands and children but also dependent on their closest male kin. Overall, while some single women may have had relative independence compared to married women, women were not recognized as independent economic actors in the 18th century.

In the 19th century, women's relative economic position improved significantly. They became significant economic actors with new legal rights. New York initiated the Mar-

ried Women's Property Acts, which granted full rights to women for the ownership of any property in 1845, and other states passed the law consecutively. But what precisely did the Married Women's Property Acts change? Women obtained the following complementary rights with these laws:

1. Inherit, own, and control a property independently (property rights),
2. Keep the earnings from their labor and capital (earnings rights),
3. Write contracts and engage in business on their account (sole trader's rights) without the husband's consent.

They could also give bequests to whomever they chose; daughters and sons could inherit as equals. More importantly, women could use any assets in any way they prefer regardless of their marital status.

An important question is whether women obtained the right to patent under these laws. Before property rights reforms in the 19th century, women were allowed to apply for and hold patents for their inventions. The Federal Patent Laws of 1790 and 1793 allowed everyone to apply for a patent, as inventing is a unique intellectual outcome of an individual. No one other than the inventor herself was allowed to apply for a patent. Hence, the rise in innovations was not a mechanical outcome but rather a response to economic incentives through independent property, earnings, and business ownership rights. The asymmetric distribution between men and women—being able to patent but not run a business, sue in case of infringement on their innovation, or monetize a patent—decreased the economic incentives and returns on engaging in entrepreneurial or innovative activities. Therefore, well-defined property rights that secured the right to keep the monopoly rents from inventions were a strong incentive to patent an innovation. Moreover, I show that the number of patents owned by women was positive but very rare before these rights, and the rise in innovations was achieved after the establishment of independent property rights.

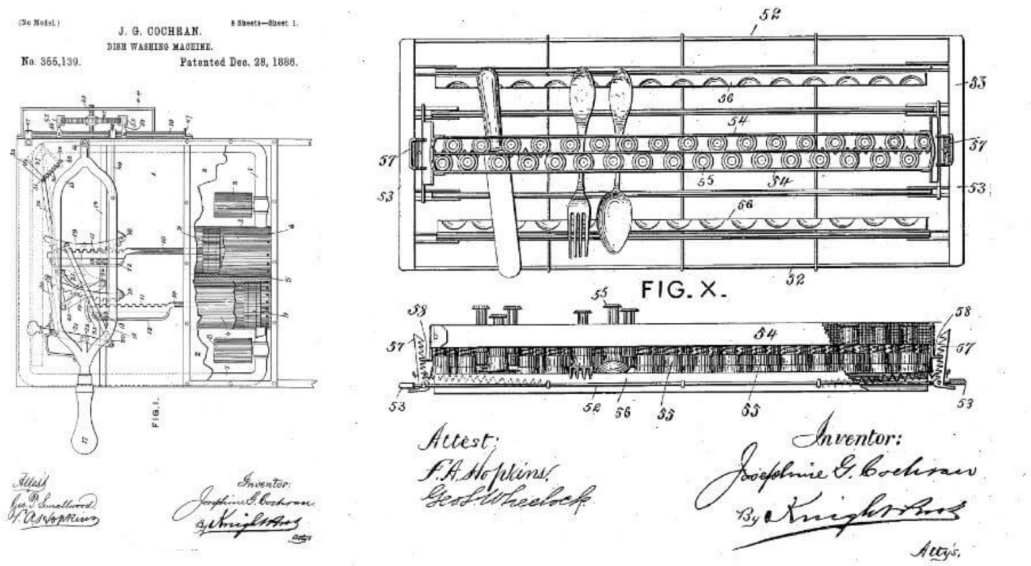
Lastly, the cost of a patent application was important for who could apply for a patent in the 19th century. If the process is unaffordable on average, individuals or women who

lack sufficient resources may not afford the cost of applying for a patent. The application cost in the United States was regarded as relatively cheaper. For instance, Moser (2013) and Lerner (2000) find that British inventors faced a costly process due to high legal fees, which were around $37,000 (in 2000 US dollars). In contrast, Americans could mail their applications and pay only $618 in 2000 dollars (translating to $30 in 1890). The annual average wage for a worker was around $300 in 1890.

2.2. Anecdotal Evidence

The following patent represents a significant example of why independent property rights matter and why independent rights to utilize patents for an income stream are crucial.

Figure 1: Dishwasher Patent by Josephine Cochran



Josephine Cochran is the inventor of the first successful dishwasher, patented in 1886. She was born in Ohio to an inventor and engineer father and the granddaughter of an inventor of the first steamboat (USPTO Office, 2021). However, she could not pursue higher education[2] and got married when she was 19 and eventually had children. After her husband passed away in 1883, she inherited a huge debt and had no income.

[2]Her example also shows the importance of parental education and exposure to scientific knowledge. "Dinner table capital" may have played a role although she did not have a formal higher education.

When she invented the dishwasher, she was 45. She also presented her work and won an award at the World's Columbian Exposition in Chicago in 1893. After her successful invention, she established Cochran's Crescent Washing Machine Company to produce this machine. She became very successful as there was a growing demand for her invention. Her company later became KitchenAid, part of the Whirlpool Corporation."[3]

As demonstrated in this example, one cannot emphasize enough the importance of revealing hidden talents in an economy by providing economic incentives. An idea transformed into an invention, a patent, and a corporation that not only generated employment and an income stream but also influenced future inventors at large.

3. Data

3.1. Data Sources

This section describes seven sources of data on patentees, along with each state's Married Women's Property Acts policy enactment years. In particular, I use the most comprehensive patent data on granted patents including names, surnames, states, patent numbers, technology classes, novelty, historical state-level observables, and policy enactment years.

Married Women's Property Acts Policy Data. Each state passed Married Women's Property Rights in different years. There are minor differences in the economic history literature regarding the policy adoption date. Geddes et al. (2012) obtained the relevant state legislative session laws for every state by consulting legal treatises in the related area. Therefore, I use Geddes et al. (2012)'s policy dates, which focus on women's ownership and control rights per se.

The policy adoption was also gradual for some of the states. For instance, several states passed the right to own and control property and adopted the earnings rights a few years later. Therefore, I take the earliest adoption of these rights for these states as the initial treatment year. In addition, two states passed specific patenting laws before these

[3]https://www.uspto.gov/learning-and-resources/journeys-innovation/historical-stories/ill-do-it-myself

economic rights, according to Khan (1996). Therefore, I use the patenting law years for these two states as the beginning of the treatment. Table A1 in the Appendix shows the policy adoption years by state.

Comprehensive Universe of U.S. Patents (CUSP)[4]. CUSP data, collected by Enriko Berkes, provide the universe of granted patents starting from 1836 to the 2000s. In this dataset, I observe patentee's name, surname, location information, and technology classes of their patents. However, since there is no demographic information on patents, I identify the gender based on the names of the inventors. First, I use the popular female names in the 19th century by focusing on the origins and strength of the femininity of the name. For instance, names such as Mary, Annie, Sarah, Anna, Elizabeth, Martha, Margaret, Minnie, Ida, Alice, Clara, Maggie, and Ella are amongst the most popular female names in the 19th century. In addition to popular female names, the structure of names signal its femininity through the addition of suffixes like "a" or "ica" at the end of the name such as Frederic versus Frederica. I also identify gender of names based on the origins of a name. For example, most of the names have biblical origins, hence, in cases of uncertainty, I search the origins of a name and assign gender based on that information.

In case of initials only, I refer to the original patent data. If no information is found, it is recorded as a male inventor. Moreover, in case of typos such as 'Claeissa", which is supposed to be "Clarissa", I correct them manually. As the CUSP data start from 1836 due to a fire damaging the patent files in the Patent Office, I include women's patents reported by Google Patents between 1790 and 1836, providing a handful of women inventors before 1836. Overall, I use the strongly female-sounding names to identify the women inventors.

Additionally, for potentially false positives or false negatives, I provide lower and upper bound estimates with the female share of names from the 1900 Census data. Each name has a female share based on the number of women and men using that name in 1900. For

[4]To gain access, email to berkes.8@osu.edu.

the lower bound, I re-assign gender for female-identified potential male inventors when the female share of the names is less than 50%. For the upper bound, I re-assign gender for male-identified highly-likely female inventors if the female share of the names is more than 75% which allows for a more conservative estimate by making sure the names are strongly feminine[5].

In addition to the level of patents, it is important to analyze the quality or novelty of innovations. One of the most common methods is to use citations for the quality of a patent. However, citations were not mandatory before 1947 in the United States. Therefore, I use the data created by Kelly et al. (2021) on the novelty of a patent by measuring its similarity to future patents and earlier patents. In more detail, a patent is considered to be novel if it is more similar to innovations in the future but distinct from any earlier patents. They provide the novelty data for every granted patent starting from 1840 with a 10-year window of prior and prospective innovations in terms of resemblance.

Integrated Public Use Microdata Series (IPUMS). In my analyses, I use historical decennial Census Data at the state level, which is available for 1850, 1860, 1870, 1880, and 1900. The historical decennial census data include population, literacy, and labor force participation rates. Population measures are decennial and available starting from 1790 until 1900 depending on the state. I interpolate the values of population, literacy rate, and labor force participation rate for the interim years in the decennial data.

In addition to the decennial Census data, I also analyze the demographic information of patentees with a match with the individual historical Census data (IPUMS). The matching process between patentees and individuals in the Census data primarily relies on assigned historical IDs. A historical ID is a unique number designated for each person in the Census data. A patentee may have multiple potential historical IDs in cases of name and location similarities. In the analysis, I focus on the unique historical ID matches and restrict the age group to [16, 64].

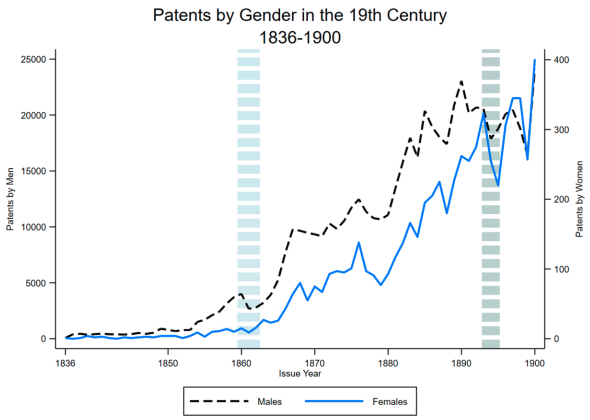
[5]Names may be misspelled or uncommon both in the patent data and Census. Therefore, I restrict the re-assignment of gender to names that occurred at least 100 times.

STEM Field Occupation Data and Bank Data. I use the STEM job or occupations for the 19th century based on the categorization provided by Berkes et al. (2023). Based on the occupations provided in the IPUMS data, I identified the total number of women participated in a STEM occupation. For the bank data, I use whether a national or state bank was available in that state from 1860 to 1880 provided in the public datasets by Sergio Correia.

3.2. Descriptive Statistics

To assess how the number of patents assigned to women changed over time, I first present Figure 2, which plots the time series of the total number of patents by gender from 1836 to 1901. The total number of distinct patents with women inventors is 6,618[6], as shown in Figure 3. The average annual number of patents women is 1% of total patents for the time period of interest[7].

Figure 2: Long-Run Trends in Patents by Gender

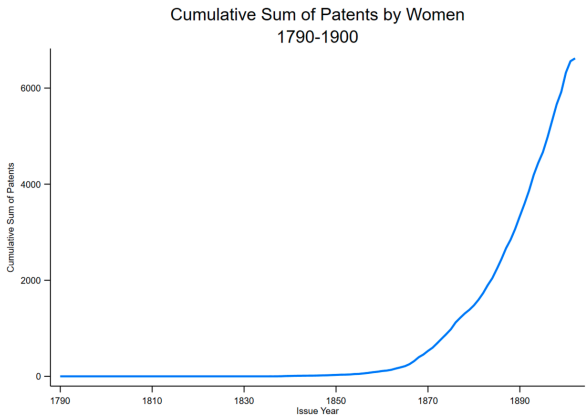


Notes: This panel shows the trend in the annual total number of patents owned by men and women from 1836 until 1901. The black dashed line represents patents by male inventors, and the blue line represents patents by women inventors. The first dashed reference area represents the Civil War years, and the second reference area represents the Panic of 1893.

[6]The lower bound estimate where the femininity of names are restricted to at least 50% female share suggests 5389 unique patents with women inventors. The upper bound estimate correcting for potentially false negatives with at least 75% probability suggests 7491 unique patents with women inventors.

[7]The increasing pattern also exists for collaborated patents, yet they are only 1% of all women's innovations on average. The rise in the number of collaborated patents with other men and women indicates women's increased participation in entrepreneurial and innovative activities. It could also suggest a gradual change from garage inventors to research teams being more dominant in innovation process.

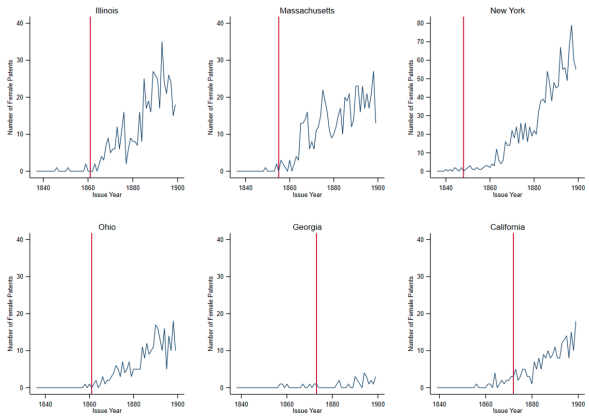
Figure 3: Cumulative Long-Run Trends in Patents of Women



Notes: This panel shows the trend in the annual total number of unique patents from 1790 until 1901.

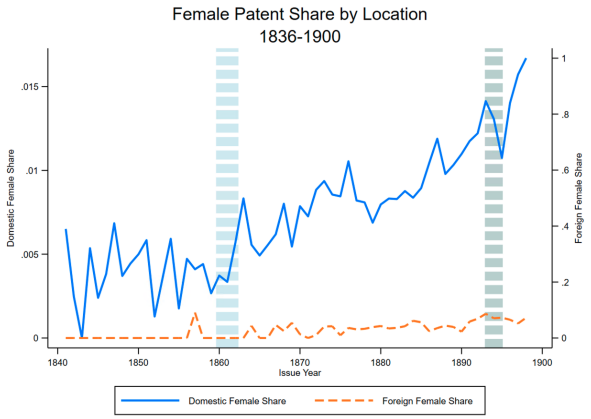
In addition to the aggregate time-series plot of the total number of patents, Figure 4 provides a disaggregated state-specific picture of how patenting among women changed before and after the policy adoption. I provide examples of several states with strong economies from four regions to demonstrate the change in the number of patents granted to women from 1836 to 1900. Figure 4 shows that the patenting activity among women increased considerably in Illinois, Massachusetts, New York, Ohio, and California, especially after adopting property rights, which is indicated with the red line for each state. The rate of increase is higher in the post-treatment period, providing suggestive evidence on effective incentives with better property rights. Moreover, Figure 5 shows that most of the patent rise comes from domestic women rather than foreign women patentees in the 19th century. Overall, these examples provide suggestive evidence of the remarkable growth in patents of women as a result of the attempt to correct the asymmetric distribution of rights.

Figure 4: Annual Total Number of Patents Held by Women Across States



Notes: This panel shows the total number of unique patents of women in Illinois, Massachusetts, New York, Ohio, Georgia, and California. The vertical reference lines represent the Married Women's Property Acts adoption years in each state.

Figure 5: Domestic vs Foreign Women Patent Shares



Notes: This panel shows the trend in the annual total share of female patentees and foreign female patentees between 1836 and 1901. The red line represents the annual total share of innovations patented by domestic females whereas the dotted red line represents the annual total share of innovations patented in the United States by foreign females. The first dashed reference area represents the Civil War years, and the second reference area represents the Panic of 1893.

4. Empirical Strategy

I employ the differences-in-differences methodology using the variation in policy adoption by state and time to identify the effect of women's property rights on patents. The ideal causal identification experiment would be to randomly assign property rights to women and observe subsequent effects on patenting. Since this is not achievable, I use a quasi-experimental approach to identify the effect of property rights on the innovative activities of women. I exploit the variation in different timing of policy adoption across states and run analyses at the state level to first achieve aggregated state-level evidence. Moreover, I also incorporate a very recent development in the literature for time-varying treatment heterogeneity, i.e., Staggered Adoption Design (SAD) by Callaway and Sant'Anna (2021), as a robustness check.

4.1. Differences-in-Differences Methodology

The state and time variation in property rights adoption allows for a DID, i.e., quasi-experimental identification methodology. Since the policy variation is at the state-by-year level, I estimate evidence at the state level. Given the assumption that the adoption of women's property rights is uncorrelated with previous patenting behavior of women conditional on observables, I estimate models of the following form:

$$patents_{st} = \alpha + \beta_1 Rights_{st} + \lambda_s + \gamma_t + \Pi X_{st} + \epsilon_{st}$$

$$Rights_{st} = \begin{cases} 1, \text{if the law is adopted} \\ 0, \text{otherwise} \end{cases}$$

where $patents_{st}$ represents the total number of patents by women in state s year t, $Rights_{st}$ is equal to one after a state is treated in year t, λ_s is state fixed effects, γ_t is year fixed effects, and X_{st} represents population estimates, and a specific patent trend for the New York State to control for its outlier effect. I use *Poisson Estimation with High-Dimensional Fixed Effects* (PPML) methodology given that the dependent variable is a count variable. The coefficient of interest, $\hat{\beta}$, shows the coefficient on the effect of the

property rights. The gap between the states with and without the property rights is calculated through $(e^{\beta} - 1)$.

Moreover, I use the states that existed in the 1840s to have a balanced panel with pre-trends for all the states as the first treatment year is 1845. Therefore, the total number of states included in the balanced panel is thirty-one. I also restrict the time period to 1840 to 1901 to ensure a comparable analysis with the quality index, as it is only available since 1840. Due to zero values and differences between male and female inventors across states in the early 19th century, I limit the analysis to post-1840 to maintain a comparable sample, the same number of degrees of freedom and observations, and to avoid inflating the results with zero values from the early 19th century.

The identifying variation is at the state-by-year level. The identifying assumption of the main estimating equation is that absent the change in property rights policies, patenting by women would have evolved in a parallel fashion as in the states that did not change their laws. More formally, the key identifying assumption is $E(Rights_{st}\epsilon_{st}|\lambda_t, \lambda_s, X_{st}) = 0$: conditional on state and year fixed effects and observables, policy adoption are uncorrelated with the error term. In addition to the main identification assumption, a differences-in-differences model assumes away general equilibrium effects (SUTVA), interference, and spatial correlation in errors.

To test the exogeneity of policy adoption, I illustrate several robustness checks related to the historical context and incorporate a staggered differences-in-differences design to check the pre-trends. Based on these findings, I first show that both the historical context and the number of patents being nearly zero before the adoption of these rights suggest that the previous patenting behavior of women does not predict policy adoption. Then, I use a dynamic staggered DID event study technique to show that the pre-trends are indistinguishable from zero, suggesting that there is no evidence of a systematic trend in the outcome variable before the policy adoption, supporting the assumption that any observed changes in innovations among women can be attributed to the property rights rather than pre-existing trends or differences between the treated and control groups.

4.2. Staggered Adoption Design

A classical two-state/two-period DID analysis calculates the effect of a policy by taking the changes in outcomes into account before and after the policy adoption for both the treated and control state. The difference in these changes represents the effect of the policy on the treated state, i.e., the naive DID estimate. Given that the treatment is as good as random, the DID estimate is then simply unbiased. However, in a more complex policy adoption process where many states pass a policy at different times, treatment and control groups are not as straightforward as in a two-state/two-period DID case, as pointed out by Borusyak and Jaravel (2017), De Chaisemartin and D'Haultfœuille (2020), Goodman-Bacon (2019, 2020), Sun and Abraham (2020), and Athey and Imbens (2022). Recent research suggests that staggered policy adoption designs represent a weighted average of all possible two-state/two-period DID estimates, i.e., all possible ATTs. And the weights depend on the sizes of treated and control groups, the size of early-treated and late-treated states, frequency of policy adoption, and variance in treatment in each of the two-state/two-period DID pairs ((Barrios (2022), Athey and Imbens (2022)). That is, the TWFE method puts more weight on states that adopted the policy at the same time (Barrios (2022)).

Moreover, early-treated state groups can dominate the estimates as they are treated for a more extended period, and as the sample panel length changes, the two-way fixed effect estimates can also change. In addition to the weight problems, treated groups implicitly act as control groups even though they are treated. As a result, the coefficient of interest becomes biased when the treatment effect varies over time within a treated state group, i.e., when some treated states that passed the policy earlier act as a control group to later treated states and vice versa.

To alleviate concerns regarding the classical DID methodology with staggered policy adoption nature, I provide a robustness check with Staggered Adoption Design using Callaway and Sant'Anna's suggested methodology (2021). One of the main advantages of *csdid* methodology is that it allows for causal inference, dynamic effects, and addresses

treatment heterogeneity. Moreover, this methodology is suitable when the policy adoption setup includes early-treated, not-yet-treated, and never-treated states or in the presence of ex-ante behavioral changes due to anticipation. I first provide the Poisson methodology results with 2WFE and then present the suggested staggered adoption design by Callaway and Sant'Anna (2021). More specifically, I use the *csdid* package to recover the group-time average treatment effect where the group is defined by the time period when states are first treated. The comparison is between the groups of treated states and states which are never treated.[8]

Lastly, the event studies with a varying base and universal base might be crucial for the pre-treatment period. Roth (2024) states that the varying base constructs the pre-treatment period differently or asymmetrically than post-treatment coefficients. In the case of the varying base, the comparison of the treatment is made with the one year before the treatment. Moreover, if anticipation is expected to be an issue, then the varying base could provide a clearer picture. In the case of the universal base, all states are compared to the one year before the initial treatment. This methodology is also more similar to a typical dynamic DID event study. Discussions by Roth (2024), Callaway and Sant'anna (2021) suggest that the universal-base option can provide a better visualization in the case of long-run violations of parallel trends. In this paper, since there are long-term differences in trend across states, and the number of pre-treatment periods is large, I first show the event study with the universal base. The results are very similar to the varying base event study provided in the Appendix. In either way, no violation of parallel trends is detected.

4.3. Exogeneity of Policy Adoption

In a DID framework, the identifying assumption is that the outcome of interest would have evolved in a parallel fashion absent the change in property rights policies. In other words, there should be no pre-trends before the policy implementation of interest. If the

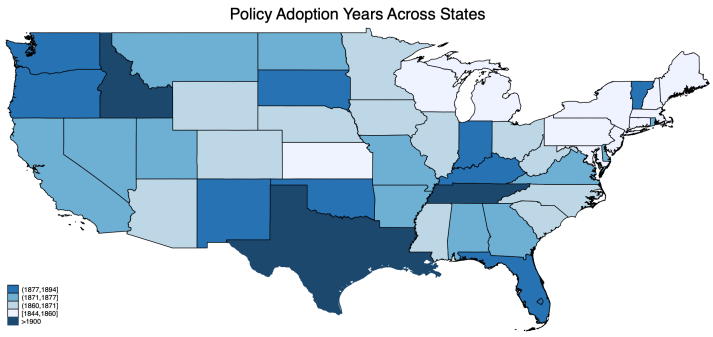
[8]The results are also robust when not-yet-treated states are included in addition to the never-treated states.

identifying variation, i.e., within-state and within-time changes in property rights policy adoption, is correlated with previous innovative activities of women or other unobservables that might affect both patenting and policy adoption, then the coefficients would reflect a correlation rather than causality.

Various hypotheses exist in the economic history literature regarding the adoption of these rights and the variations in adoption timing among states. First, historians argue that the economic crises in 1835 and 1837 might have led to equal property rights for women rather than a social and cultural change. In the 19th century, financial crises were happening often compared to today due to speculations as the financial and monetary systems were immature.

Moreover, the absence of a central bank contributed to a disorganized and unchecked monetary system. As a result, frequent economic crises significantly impacted households, often leading to the loss of family assets. For instance, during an economic downturn, the exclusive control and use of property by husbands often resulted in the confiscation of all assets due to debt. In times of crisis, women, under equal property rights, could retain some assets that were protected from confiscation owing to their husband's debt. Therefore, equal property rights served as a safeguard, protecting the welfare of families.

Figure 6: Policy Dates Heat Map



Notes: Darker color represents later adoption of the rights.

Another hypothesis suggests that the variation in the timing of adopting these laws could be attributed to differences in judicial or legal systems. For instance, according to Geddes et al. (2012), reforms were comparatively slower in the South due to disparities

in the judicial systems. During the 19th century, states operated under different legal systems, including community property law, common law, and equity courts. One of the hypotheses is that states with equity courts could enforce marriage agreements or contracts that allowed women to own property, thus adopting property rights earlier. Conversely, the states with a community property system where household assets were held in common but husbands still had exclusive rights to control the joint property and wealth passed these laws later due to costs of coverture. Geddes et al. (2012) find that states with equity courts passed these property rights earlier and community property states enacted them later than other states.

In addition to judicial differences, another argument for relatively early adoption is the active involvement of women in political activism, advocating for equal rights. Globally, feminist movements were gaining momentum, pressing for equality with men. The heightened demand for equal rights likely facilitated the earlier adoption of these laws. States experiencing a surge in demand for improved property rights may have witnessed a corresponding increase in innovative activities. Activist women were not only focused on property rights but also expressed interest in political rights, advocating for children's welfare reforms and compulsory schooling, as highlighted by Geddes et al. (2012).

Among these hypotheses, the differences in judicial or legal systems are particularly emphasized in the literature. However, recognizing that the nature of policy adoption may be correlated with state-specific or region-specific unobservables, I employ econometric methods to address these concerns. First, I incorporate state fixed effects to mitigate potential issues related to time-invariant observables, unobservable factors, and state heterogeneity. The inclusion of year-fixed effects further eliminates any year-specific factors that might introduce bias to the results. Additionally, alongside the fixed effects, I introduce additional controls for heterogeneity across states in terms of industrialization, urbanization, or other unobserved state-specific characteristics with proxies such as literacy rate, labor force participation rate, financial institutions, and participation in the STEM occupations. Moreover, I provide additional analysis with regional trends

by decade, revealing that the shift in women's involvement in innovation cannot be attributed to regional disparities, but rather to the strengthening of property rights.

Finally, persistent gender inequality, norms, and racism during this period might affect the decomposition of inventors. For example, a recent study by Andrews and Rothwell (2023) reveals disproportionate patenting rates among Black Americans in the South compared to those in the North. Consequently, the impact of property rights may differ for black women due to racial discrimination, marginalization, and hence lack of institutional trust. Based on the individual level analysis, I find that almost 99% of women inventors was white in the 19th century, suggesting that these property rights did not have the same effect for colored women in the 19th century.

5. Results

Quantity Analysis. In this section, I first present quantity effect of property rights on innovations based on the Poisson analysis. The results from estimating equation (1) are presented in Table 1. In column (1), I first estimate the model with the PPML method for women's innovations by including state fixed effects, year fixed effects, population controls, and a specific trend for the State of New York. In column (2), I show the effects by also including the regional trends by decade. The results suggest that providing equal economic rights significantly increases the number of patents of women by 40% on average. In other words, women showed higher patenting activity in states that passed these laws than women in states that have not passed these laws yet. In the pre-treatment period, patenting was extremely rare and around 0.3 on average. After the states started adopting the laws, the number of patents increased to around 90 patents on average per year between 1845 and 1900. Although women's share represents 1% of patents, the property rights caused a significant rise from around zero patents to two or three digit numbers per year, suggesting that lifting the legal and institutional barriers translated into high participation in innovative activities.

The overall average effect presents a compelling narrative of the substantial impact of

Table 1: Long-Run Effects of Women's Property Rights on Innovations

Dep. Var. *Women's Innovations*	(1)	(2)
Property Rights	0.355	0.219
	(0.147)	(0.131)
State FE	Yes	Yes
Year FE	Yes	Yes
Controls	Yes	Yes
Regional Trends	-	Yes
N	1770	1770

Notes: This table shows the results of the first estimating equation with the Poisson likelihood method with and without regional trends. All columns include a specific trend for the New York state, state fixed effects, year fixed effects, and log(population). Regional trends are the trends specific to each region by decade. Standard errors in parentheses and clustered at the state level.

economic incentives and well-defined property rights on innovations or patenting. However, the effects of property rights may vary across regions. Additionally, the economic activities existing in each region that could influence participation in innovations might differ. For example, in the 19th century, the Midwest and the Northeast had more capital-intensive industries and were more industrialized, while the South was characterized by labor-intensive and agrarian activities. It is also possible that differences in terms of transportation, communication, urbanization across regions could contaminate the estimates, i.e., the margin of women's contributions to innovations.

Moreover, persistent gender roles may have impeded the effects of property rights. Inequality was evident not only in terms of gender but also in terms of race, stemming from slavery and racism. For instance, Dray et al. (2023) examine spatial wealth accumulation in the 19th century United States, revealing that Southern states were major contributors to spatial inequality. They demonstrate that lower subsequent growth occurred in property, particularly in counties with a higher percentage of enslaved population. Hornbeck and Logan (2023) also show that emancipation generated aggregate productivity gains.

Hence, considering different potential trends across regions, I conduct an analysis by incorporating an interaction term for region-by-decade trends. This interaction term allows for the effect of the region to vary over time. In Column (2), I find that the results

are still positive and significant even after controlling for regional trends by decade. Given that the coefficient for property rights remains positive and statistically significant after including these interaction terms, it suggests that property rights consistently and positively affected innovations by accounting for regional differences. Moreover, these trends alleviate concerns about unobservables due to regional differences or heterogeneity that could potentially affect the policy adoption timing and innovative activities among women. In terms of the magnitude change, I also find that these two coefficients on women's innovations are not significantly different from each other, with a back-of-the-envelope calculation of t-value 0.731.

Novelty Analysis. The increase in patents may not necessarily imply a corresponding improvement in the novelty of innovations. Therefore, to answer whether women only contributed to the rising pile of patents or they introduced important or novel innovations that could influence the prospective innovators, I use Kelly et al. (2021) novelty index and perform the same test as in the main estimating equation. In Table 2, I show the average difference in novelty of innovations in states with independent property rights compared to states without these rights for women. The dependent variable is the total number of breakthrough innovations for 10-year window in the top 10 percentile within a year in a state. Novel innovations are defined as being different from their predecessors, and resembles to prospective subsequent innovations. Therefore, these innovations rely less on prior art but influences subsequent innovations more.

In Table 2, I find that women in states with independent property rights patented significantly more novel innovations in the top 10th percentile. In other words, women's innovations had a significant influence on innovations in the next 10 years as a result of better property rights. In Column (3) and (4), I control for regional trends by decade and I find that the rise in novel innovations is still strongly explained by the property rights rather than differential region-specific trends.

Based on the findings in Table 1 and 2, the magnitudes suggest that one out of five patents induced by these property rights was novel, which is both a statistically and economically

significant change. Considering the total number of patents to be around 90 on average per year, at least 20% of the patents by women were deemed important and novel. Hence, enhanced property rights decreased such a significant barrier for women that they patented more novel innovations, creating a positive spillover effect on subsequent innovations and innovators.

Table 2: Breakthrough Innovations and Property Rights

Dep. Var. *Women's Breakthrough Innovations*	(1) p90sim10	(2) p80sim10	(3) p90sim10	(4) p80sim10
Rights	0.757	0.839	0.569	0.531
	(0.356)	(0.203)	(0.329)	(0.214)
State FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Regional Trends	-	-	Yes	Yes
N	1196	1540	1196	1540

Notes: This table shows the effects of property rights on the novelty of innovations for top 20 percentile with 10 year windows for women, men, and in total. All columns include a specific trend for the New York state, state fixed effects, year fixed effects, and log(population). Column (3) and (4) include regional trends by decade. Standard errors in parentheses and clustered at the state level.

Direction of Technology. Due to strong property rights, women engaged in more innovative activities and produced novel innovations. However, in which technology categories were women more dominant? Was there a specific field that they patented in? I provide both a descriptive and an econometric analysis of the technology classes of women's innovations in the 19th century by using Cooperative Patent Classification (CPC) in the CUSP data[9]. I provide a comparison between male and female inventors to analyze the similarities and differences in innovation technologies by gender.

In Table 3, I first show the share of the general classification of patents held by men and women. Almost half of the innovations of women were in Class A, i.e., human necessities which represents the patents in agriculture, foodstuffs, tobacco, personal or domestic articles, health, and amusement[10]. On the other hand, men's innovations were mostly

[9]I also use IPC categories in case the CPC category is not informative about the exact type of technology. For instance, Y category in the CPC classification is not very informative in terms of the content of the patent. Hence, if a patent is classified under the category Y, I refer to the IPC classification to retrieve more detailed information.

[10]https://www.uspto.gov/patents/search/classification-standards-and-development

concentrated on performing operations or transporting such as shaping, printing, transporting tools, and machinery. Although the rankings are different, top three categories include the same technology classes for both men and women.

Table 3: Technology Class Comparison between Men and Women Inventors

Men		Women	
Rank	%	Rank	%
#1 Transporting	31%	#1 Human Necessities	44%
#2 Human Necessities	19%	#2 Transporting	20%
#3 Mechanical Engineering	15.5%	#3 Mechanical Engineering	8%
#4 General	9.2%	#4 Textiles	7%
#5 Fixed Constructions	8.3%	#5 General	5.9%
#6 Physics	4.8%	#6 Fixed Constructions	5.2%
#7 Textiles	4.1%	#7 Physics	4%
#8 Chemistry	3.5%	#8 Chemistry	2.1%
#9 Electricity	2.7%	#9 Electricity	1.2%

Notes: This table shows the CPC technology class comparison percentages between men's and women's innovations from 1790 to 1901. Class Y is further specified with the IPC class when available.

The patents starting with classifications of A47 (furniture), Y10 (appliances), and A41 (hardware, wearing apparels) are amongst women's top technology subcategories of innovations. These findings may indicate the "social push" phenomena among women inventors. The comparative advantage gained through household production or participation in the labor market -especially the textile industry or manufacturing- may have significantly contributed to the technology class of women's inventions. The gendered division of labor due to the patriarchal structure of society pushed many women to be responsible for household production or work in jobs that were compatible with household work. Many women in the 19^{th} century mostly participated in the economy as cooks, homemakers, workers in the textile industry, and various unreported jobs. Moreover, most women and daughters produced clothing for the household (Gordon (2016)). Hence, the increase in clothing demand in urban areas and rising GDP per capita during the late 19th century complemented women's sewing skills, potentially enhancing their comparative advantage in apparel and machinery, which in turn could lead to more innovations and patents in this area as shown in Table 3.

While the classification of technology classes or the gender-specific division of labor may suggest a certain concentration in particular technology categories, the crucial factor lies

in the proportion of *novel* innovations, which can vary across different categories. In Table 4, I show the shares of novel innovations within each category by gender. As opposed to Table 3, higher quality of patents among men were dominantly in electricity, physics, and chemistry areas which is also correlated with a higher level of education. Moreover, although the top category has not changed for women, patents in physics had a higher share of novel innovations although the relative numbers are small compared to men. For example, Josephine D. Viney patented an innovation related to gas-meter bellows within the subcategory of "measuring volume, volume flow, mass flow of liquid level" under the physics category in 1895. Surprisingly, although women had a high ranking and engagement in textiles in the economy, it had the lowest share of novel innovations.

Table 4: Technology Quality Comparison between Men and Women Inventors

Men		Women	
Rank	%	Rank	%
#1 Electricity	35%	#1 Human Necessities	18%
#2 Physics	21%	#2 Fixed Constructions	17%
#3 Chemistry	18%	#3 Physics	17%
#4 Fixed Constructions	16%	#4 Mechanical Engineering	14%
#5 Transporting	16%	#5 General	14%
#6 General	15%	#6 Transporting	13%
#7 Mechanical Engineering	14%	#7 Chemistry	13%
#8 Human Necessities	14%	#8 Electricity	13%
#9 Textiles	11%	#9 Textiles	8.7%

Notes: This table shows the CPC technology class comparison percentages between men's and women's innovations from 1790 to 1901. Class Y is further specified with the IPC class when available.

In that regard, women's property rights may have affected the *direction* of technology among women. That is, secure property rights may have amplified the volume of innovations in specific categories deemed to be more valuable to patent due to its contribution to a field. Alternatively, it could also be the case that better property rights gave rise to more innovations with a higher commercial value.

As shown in Table 5, property rights gave rise to specific technology classes: Class B and Class F, referring to mechanical engineering, performing operations, and transporting. In more detail, these categories refer to tools, machines, and apparatus related boiling, cutting, or in general mechanical processes. Such machinery would result from experience and expertise that have a commercial value. For instance, Josephine Cochran's

dishwasher invention was also a commercial success that created a lucrative business. Hence, the fact that women patented even more in mechanical or practical areas shows that they converted their comparative advantage and experience into monetary value in the economy by protecting their ideas with a patent.

Table 5: The Effects of Property Rights on the Direction of Technology

Dep. Var.: *Women's Innovations by Technology Class*	A	B	C	D	E	F	G	H	Y
Rights	0.235	0.678	0.360	0.0202	0.530	0.998	-0.864	-0.885	0.334
	(0.195)	(0.274)	(0.454)	(0.286)	(0.648)	(0.378)	(0.398)	(0.729)	(0.393)
State FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1430	1430	703	1035	936	1104	966	351	920

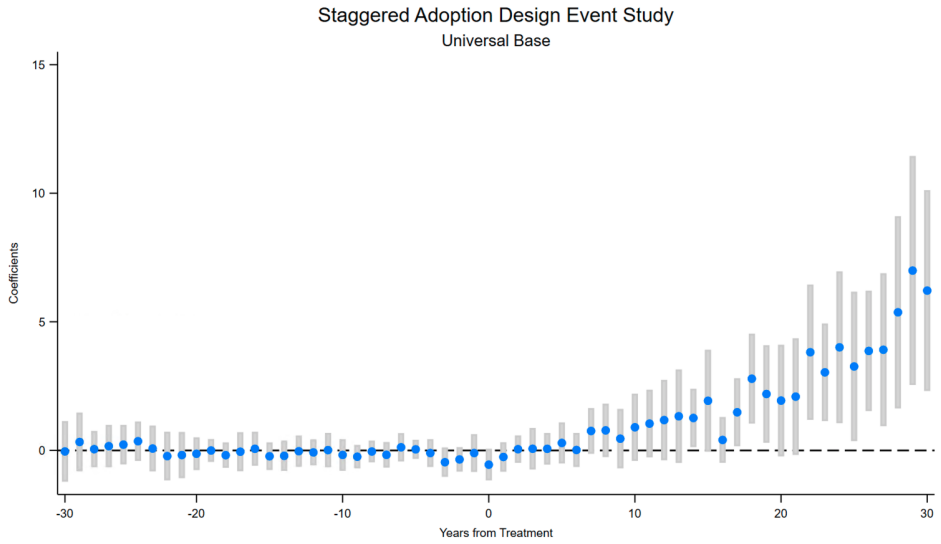
Notes: This table shows the effects of property rights on the direction of technology for women. The analysis is performed for each technology class which in the alphabetical order refers to human necessities (A), performing operations/transporting (B), chemistry (C), textiles/paper (D), fixed constructions (E), mechanical engineering (F), physics (G), electricity (H), and general category (Y). All regressions include states fixed effects, year fixed effects, and population controls. The results are robust with standard errors clustered at the state-by-technology class level. Standard errors in parantheses and clustered at the state level.

Event Study. Property rights and economic incentives are important components of innovations, but did the positive change happen immediately after the laws or did it happen in the long run? Were there any pre-trends prior to policy adoption? To answer these questions, I use *csdid* method suggested by Callaway and Sant'Anna (2021). The two-way fixed effects (TWFE) method for multiple states with time-varying policy adoption years weight all possible ATTs. The estimate heavily depends on the group size, i.e., how many states adopted the rights simultaneously, and the variance in the treatment, i.e., how long they were treated. Furthermore, due to the time-varying nature of policy adoption across states, states that adopted the rights earlier may act as a control group for states that adopted them later. As the naive purpose of quasi-experimental methods is to compare clean treated and control groups, the fact that early treated states can be a control group to the later treated states may threaten the causal inference. Therefore, studies suggest new methodologies that can incorporate treatment heterogeneity and varying treatment timing across states. For instance, Callaway and Sant'Anna (2021) suggest a staggered adoption design where good variation is used to calculate the average treatment effects

by arranging the weights.

Figure 7 illustrates the event study using the csdid methodology, offering compelling evidence of absence of differential pre-trends and how women's patenting evolved over time in response to changes in property rights. The pre-trends are indistinguishable from zero and the corresponding average value for the pre-treatment years is -0.020 with (s.e. 0.066). The average post-treatment effect is 2.56 with (s.e. 0.752)[11] positive and significant effects become more pronounced after a decade of policy adoption, suggesting that the rise of women inventors was realized in the long-run.

Figure 7: Staggered Adoption Design (Callaway and Sant'Anna (2021))



Notes: This graph shows the staggered adoption design aggregated event study based on Callaway and Sant'Anna (2021) (*csdid*) methodology. Dependent variable is the level of patents. Confidence bands are at the 95% level. Universal base is used to use the long-differences. All inference procedures use clustered standard errors at the state level.

The event study also addresses concerns about changes in expectations and behaviors before policy adoption. For instance, if individuals anticipated their state adopting women's property rights soon, they could change their behaviors and invest in their innovation process more. Empirically, such a behavioral response would be observed with a shift right

[11]Including the *notyet* option using not-yet-treated states as a control in addition to never-treated states, the post-treatment coefficient for t +/− 30 becomes 2.44 with (s.e. 0.730). The results are robust to the natural logarithm of women's patents as the dependent variable. The pre-trends are indistinguishable from zero and post-treatment average is 0.638 (s.e. 0.176).

before the policy adoption or after. However, the event study shows that pre-trends and short-run response in the post-treatment period are indistinguishable from zero.

Similarly, one could argue that households could pool resources and women could share their patentable ideas with their husbands so that men could obtain the patent, and the whole household benefits. Neither the event study nor anecdotal evidence or the effects on men identifies such a manipulation in patenting as there could be a patent shift from men to women after the policy, i.e., a decline in men's patents.

Moreover, a similar argument could be made for voting rights: granting one pooled vote per household is equivalent to providing every single member of a family or society the right to vote. Aside from the equality perspective, non-unitary household models both theoretically and empirically suggest that both women and children experience positive effects in terms of education, health, and financial gains compared to the outcome of pooling votes (Duflo (2003); Qian (2008); Luke and Munshi (2011); Harari (2019)).

Based on the findings of this paper, the increase in the number of patents obtained by women is attributable to higher private incentives and returns through independent property rights. Moreover, working on an innovative idea to retain the monopoly rents through patents is not a short-term process. It requires time and effort. Given the traditional gender roles and the segregation of gender roles in domestic and public spheres, it was not an easy task either. Therefore, the evidence of the long-run effect is not only statistically significant but also economically meaningful.

Equity versus Efficiency Trade-Off. Inclusion of a disadvantaged group in the innovation process raises questions regarding equity versus efficiency. If the new group replaces the already-existing group, then there could be a trade-off between equity and efficiency. However, if the new group contributes to the overall pool of innovations rather than displacing another group, it could stimulate economic growth by increasing the aggregate number of innovations. For instance, Moser, Voena, and Waldinger (2014) show that Jewish emigres to the US contributed significantly to innovations by attracting new researchers to their fields, suggesting that a new group of innovators did not lead

to a displacement but rather to a growth of new technologies in that field. Similarly, I perform an analysis to study the effect of women's rights on innovations by men as they were the most dominant group with a share of 99% of patenting activity in Table 6.

Column (1) presents a test on the number of innovations among men to examine whether they were affected by women's property rights. I find that men were not negatively affected by the adoption of women's property rights, indicating that these rights spurred innovative activities among women, the target group, without negatively impacting men. Hence, it suggests that the inclusion of disadvantaged groups in innovations did not create a replacement effect but instead led to new innovations, contributing to the overall number of innovations within an economy. Moreover, it further alleviates concerns about men patenting women's ideas due to the absence of strong property rights. In other words, a negative impact on men could imply that they were also depending on women's ideas to patent under their own names. However, the findings indicate that this is not a concern or a pattern on average.

Table 6: Long-Run Effects of Women's Property Rights on Innovations by Men

	(1) *Innovations*	(2) p90sim10	(3) p80sim10
Property Rights	0.115	0.059	0.089
	(0.072)	(0.088)	(0.069)
State FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Controls	Yes	Yes	Yes
Regional Trends	Yes	Yes	Yes
N	1770	1770	1770

Notes: This table shows the analysis for men with the same regression model. All columns include a specific trend for the New York state, state fixed effects, year fixed effects, and log(population). Regional trends are the trends specific to each region by decade. Standard errors in parentheses and clustered at the state level.

6. Robustness Checks

In this section, I provide contextual robustness checks for the estimates. I examine the effects for Civil War, other laws that existed at the time, i.e., the compulsory schooling laws, and lower and upper bounds of names with the 1900 Census data.

Civil War. One of the most pivotal events in United States history is the Civil War. The social and political upheaval that fueled the war may have also influenced women's choices in employment. For instance, with many men fighting in the war, women might have been compelled to enter the workforce. If states that were most negatively affected by the war enacted women's rights earlier, it could have led to more women participating in the labor market and potentially having higher patenting rates. In that case, the Civil War could be the main driver of the timing of the policy and patenting rates. Another potential mechanism could be that patenting rates may have declined during the war period naturally and risen after the end of the war. The rise could either be a natural mean reversion or due to gained technical knowledge, or a decline in competition as a result of military duties of men. Hence, to address concerns arising from the potential influence of the Civil War, I follow two methodologies: (i) exclude the war years (1861-1865), and (ii) exclude the post-war years (1865-1869). The first method is to exclude the effect of the mechanically declining patenting rate during the war period so as not to inflate the effects of the post-war period. After the war ended, economic and innovative activities might have disproportionately increased. Hence, the second method aims to exclude the initial changes in the economy in the immediate post-war period. As shown in Table 7, the results remain positive and significant for women both when the war and post-war years are excluded.

Table 7: Long-Run Effects of Property Rights and the Civil War

	War Years Excluded	Post-War Years Excluded
	Women's Innovations	Women's Innovations
Rights	0.315	0.319
	(0.147)	(0.149)
State FE	Yes	Yes
Year FE	Yes	Yes
Controls	Yes	Yes
N of Obs	1680	1680

Notes: This table shows the results for estimates with Civil War years excluded (1861, 1865) and post-war years excluded (1865-1869). All regressions include state fixed effects, year fixed effects, a trend for the State of New York, and log(population). Standard errors in parentheses and clustered at the state level.

Compulsory Schooling. In addition to property rights, states may have enacted various policies during a similar time period. One of the most significant changes was the

implementation of compulsory schooling laws for children. While these laws targeted specific age groups in childhood, women could still be positively affected by the free time created when their children were at school. Alternatively, the increasing importance of education could influence women's decisions to invest in their human capital. Moreover, if states that adopted more egalitarian education policies were also more likely to adopt women's property rights earlier, the omitted policy could be positively correlated with the adoption year of other policies and women's participation in innovations. Hence, I also control for compulsory schooling along with women's property rights to assess if compulsory schooling laws played a crucial role in the increase of women's innovations.

In Table 8, I include compulsory schooling laws in the main estimating equation in Column (2). The results show that women's property rights had a consistent and even larger effect conditional on compulsory schooling. Hence the effect is bigger in the states with Married Women's Property Rights conditional on having a compulsory schooling law for children. The fact that the coefficient rises conditional on compulsory schooling shows that the effects of property rights on innovations could be underestimated.

Table 8: Property Rights, and Education Policies

Dep. Var. *Women's Innovations*	(1)	(2)
Property Rights	0.358	0.402
	(0.147)	(0.157)
Compulsory Schooling Laws	-	0.259
		(0.098)
State FE	Yes	Yes
Year FE	Yes	Yes
Controls	Yes	Yes
Observations	1770	1770

Notes: This table shows the robustness check with the compulsory schooling laws. Column (1) uses property rights only. Column (2) includes the compulsory schooling laws in addition to the property rights. Control variables include a trend for the State of New York, and log(population). Standard errors are clustered at the state level.

One hypothesis for such a change in the coefficient could be that women are better educated, contributing to long-term innovations. Tennyson, Geddes, and Lueck (2012) use women's property rights and compulsory schooling laws to investigate whether property rights increased the education level of women not affected by mandatory schooling laws.

They find that women beyond the compulsory schooling age were affected only through the introduction of women's property rights in terms of education. The authors state that families recognized the importance of human capital as it complements these economic rights, allowing daughters or women to exercise their rights better when they are more educated.

However, without secure property rights, the incentives for more educated women to innovate could be still suboptimal given an environment with high marriage rates resulting losing control over property, not being able to sue in case of infringement, or run a business. Hence, Married Women's Property Rights redefined women's status from being dependent on their marital prospects to being independent of their marital status. Considering that women themselves were once perceived as *property* prior to these rights, education alone would be insufficient to explain the rise of women's presence in innovations without these property rights. Instead, with the establishment of equal rights, education played a complementary or facilitator role as further discussed in the following section.

Moreover, the role of compulsory schooling could be that children spending time at school rather than at home may have increased women's time available to invest in themselves and their interests. The innovation process takes time and effort; therefore, as women's household workload is alleviated through schooling, they could be more active in innovations. Overall, finding a consistent and substantial effect of property rights in the presence of the schooling law shows that well-defined property rights created a robust innovation dynamic among women.

Estimates with Lower and Upper Bounds Census Names. As name identification may vary depending on the femininity of a name, I provide sensitivity analysis with the female and male share of a name by using the 1900 Census. I provide (i) a lower bound estimate, and (ii) an upper bound estimate of names. The lower bound uses the original data but re-assigns gender as men if the popularity of a given name is less than 50% among women in 1900. Therefore, it restricts the potentially false positives in the data

and keep the femininity of names between 51% and 100% for women. The upper bound detects false negatives and re-assigns gender as female if the name was initially identified as a male and the share of females is higher than 75% for the given name[12]. This cut-off provides a more conservative and accurate name identification by keeping probability of including false positives low, hence, the number of patents by women goes up with a conservative measure. Given these methodologies, the number of distinct patents by women inventors varies between 5,389 to 7,419[13].

Table 9: Estimates with Lower and Upper Bound Census Names

	Lower Bound Names	Upper Bound Names
Rights	0.358	0.389
	(0.124)	(0.141)
State FE	Yes	Yes
Year FE	Yes	Yes
N	1680	1770

Notes: This table shows the results of the first estimating equation by using the number of patents based on Census names. All columns include a specific trend for the New York state and log(population). Standard errors in parentheses and clustered at the state level.

Table 9 shows the results for the main estimating equation by using the lower bound and upper bound name identification methodologies. I find that the results are robust and statistically indistinguishable from the main estimates in Table 1. These findings suggest that although the number of patents by women may vary depending on the name identification strategy, the effect of property rights remains robust.

7. Mechanisms

In this section, I discuss the potential mechanisms of the effects of equal property rights on innovations. Firstly, as shown in the analysis so far, innovation incentives with high returns and gaining a market advantage is a crucial channel. Eliminating institutional barriers for disadvantaged groups and incentivizing them through strong property rights

[12]A name may occur only a couple of times due to misspelling in the patent data or Census data. Hence, I use 100 as a cut-off for the names that appear more than 100 times.

[13]The name identification described in the Data section finds 6,618 distinct patents by women inventors.

can further promote innovative activity. The increase in the aggregate number of innovations due to these rights suggests that institutional structures can uncover lost or hidden Josephine Cochrans or Marie Curies in an economy.

There might be other channels that could explain the distinctive patenting trend among women. The first additional channel could be human capital accumulation. The development of skills requires a significant investment of time and effort. Investing in education serves as a crucial channel for innovations, provided that the returns on education exceed the costs (Becker (1962)). Direct expenditures or investments in education pay off through higher earnings or improved prospects in the labor market. While economic analyses often emphasize the direct effects of education on earnings, it is important to recognize the positive externalities of education, such as its impact on innovations. The increase in inventions or innovations stimulates economic growth and development (Romer (1990); Aghion and Howitt (1992)), with human capital accumulation serving as a key driver of innovations (Akcigit (2017)). Moreover, human capital accumulation not only has a direct effect on educated individuals but also positively influences others with lower education levels. Studies by Lucas and Moll (2014) and Perla and Tonetti (2014) demonstrate that less knowledgeable economic actors become more productive when interacting with more knowledgeable economic actors, as they imitate them to enhance their productivity.

The literature also discusses human capital accumulation as a crucial step to answer who becomes an inventor. Bell et al. (2019) show that both parental socioeconomic background and environment matter to become an inventor. They show that the probability of being an inventor increases as exposure to innovations during childhood increases. Moreover, women are shown to more likely invent in an area where there is a woman role model. Akcigit, Grigsby, and Nicholas (2017) study inventors in the 19th and 20th centuries, revealing that inventors are highly educated. Furthermore, they show that parental income and parental education are significant indicators for prospective inventors.

To test whether education could be one of the explanatory channels, I provide discussions

based on three analyses: (i) effects of property rights on literacy rate at the state level, (ii) effects of literacy rate on innovations at the state level, and (iii) individual level comparison between inventor and non-inventor women demographic characteristics.

First, I show the effects of property right adoption on literacy rate among women as women could invest in their education to benefit better from the growing economic opportunities as a result of better property rights. Table 10 reveals a positive yet statistically insignificant association between literacy rates and women's property rights. Also, considering the high levels of literacy rate in the United States in the 19th century, only a slight change may have been induced through these rights rather than a significant jump.

Table 10: Property Rights, Literacy Rate and the Labor Force Participation Rate

	(1) Literacy Rate	(2) LFPR	(3) Literacy Rate	(4) LFPR
Rights	0.679	1.620	1.008	1.265
	(2.303)	(1.380)	(1.962)	(1.282)
State FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Observations	1076	986	1076	986
Adjusted R^2	0.91	0.98	0.92	0.98

Notes: This table shows the effects of property rights on the literacy rate and the labor force participation rate of women. Labor force participation was not collected for women in 1850. Hence, the analysis for LFPR are available from 1860, 1870, 1880, to 1900 and interpolated in between. Literacy rate is available for 1850, 1860, 1870, 1880, and 1900, and interpolated in between. Standard errors are clustered at the state level.

Second, I use literacy rate as a control variable to analyze its effects on innovations among women. Although controlling for literacy may be endogenous and create dirty variation, I find that the literacy rate is strongly correlated with the number of innovations in Table 11. Moreover, the effect of property rights remains significant even with these additional controls. Finding a positive association suggests that higher human capital accumulation may have played an important role in facilitating the effects of these rights on innovations among women.

In addition to performing a test at the aggregate level, I further analyze the demographic characteristics between inventor and non-inventors women from 1850 to 1900 at the individual level in Table 12. Matching women based on name and surname is more difficult as their surnames change upon marriage. In addition, some names and surnames might be

Table 11: The Effects of Literacy Rate and LFPR of Women on Innovations

Dep. Var. *Women's Innovations*	(1)	(2)	(3)	(4)
Rights	0.374	0.394	0.288	0.281
	(0.153)	(0.143)	(0.151)	(0.145)
LFPR	-	-0.015	-	-0.015
		(0.026)		(0.022)
Literacy Rate	-	-	0.033	0.032
			(0.011)	(0.011)
State FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes
Observations	1230	1107	1107	1107

Notes: This table shows the effects of property rights on patents with the literacy rate and LFPR of women and men as controls. All columns include a specific trend for the New York state and log(population). All columns use post-1860 due to LFPR availability and comparability. Standard errors are clustered at the state level.

very common, such as Mary Smith, that may lead to several potential matches. Therefore, in my analysis, I exclusively consider individuals with a unique exact historical ID match with the Census data.

Based on the results in Table 12, I find that women inventors were significantly older, and more likely to be literate compared to non-inventor women. They were predominantly in urban areas, with over half of them residing in cities or metropolitan areas. Additionally, the majority of these inventors were married[14], had children, and were predominantly white. The fact that married women inventors were a significant portion of the innovations in the 19th century shows that securing property rights through Married Women's Property Rights was a crucial policy change for innovation dynamism.

Labor force participation rate between inventor and non-inventor women is not significantly different from each other, except in 1870. Since these rights provide legal security to retain earnings from labor, write contracts, and own businesses, participating in the labor force could enhance the potential to utilize patents. Moreover, participating in the labor market could increase exposure to technical knowledge, potentially leading to the creation of more efficient products. On the other hand, working could also lead to

[14]The marital status information is available in 1880 and 1900 in the individual level IPUMS data.

a decline in time allocated to innovative activities due to long hours of work. However, the fact that labor force participation rate is not strongly correlated with property rights as shown in Table 10, 11 and the individual level analysis in Table 12 show that labor supply is likely to be a weaker channel.

However, working in an occupation or industry that could provide a higher exposure to technological knowledge and spillovers might suggest a different picture than the correlation between innovations and labor force participation rate. For instance, working in a STEM occupation may indicate a higher education level or exposure to frontier technological progress, new techniques, and developments in an area that could further be correlated with the propensity to innovate. To analyze whether working in a STEM field I use Berkes et al. (2023) classification of occupations that require science-based education[15]. As shown in Table 13, the number of women in STEM occupations is indistinguishable from zero.

Finally, another crucial channel could be access to financial resources and wealth accumulation. Financial assets s can act like a collateral to produce an innovation and use a patent. Moreover, relaxed financial constraints can encourage an individual to take risks as engaging in an innovative or entrepreneurial activity is inherently risky.

For instance, Cagetti and De Nardi (2006) study the role of borrowing constraints on entrepreneurial decisions, finding that financial constraints reduce the fraction of people engaged in entrepreneurial activities. They also study that entrepreneurs tend to have a higher saving rate, and bequests play a crucial role in motivating high-ability workers to participate more in entrepreneurial activities. Similarly, Quadrini (1999) and Gentry and Hubbard (2004) observe that entrepreneurs have higher saving rates before initiating entrepreneurial activities compared to non-entrepreneurs.

In a historical context, Baskerville (2008) argue that women historically lacked the motive to invest in intangible or tangible assets as they would belong to their husbands. How-

[15]The STEM classification includes engineering, medicine, basic science, technician, and more. For further information, refer to Berkes et al. (2023).

Table 12: Demographic Characteristics of Inventors

	Women			Men		
	Non-inventor (1)	Inventor (2)	Difference (3)	Non-inventor (4)	Inventor (5)	Difference (6)
Panel A: Census 1850						
Age	31.772	30.358	1.281	32.204	36.458	4.254
			(1.106)			(1.218)
Farmer	0.488	0.154	-0.200	0.506	0.189	-0.318
			(0.049)			(0.008)
In Labor Force	-	-	-	0.897	0.944	0.047
						(0.005)
Literate	0.864	1.000	0.091	0.918	0.987	0.069
			(0.037)			(0.004)
Child	0.578	0.692	0.008	0.468	0.645	0.177
			(0.0.048)			(0.009)
White	0.976	1.000	0.024	0.98	0.99	-0.011
			(0.015)			(0.002)
Panel B: Census 1860						
Age	32.098	33.843	1.350	32.734	37.371	4.637
			(0.547)			(0.096)
Farmer	0.407	0.157	-0.176	0.428	0.178	-0.251
			(0.162)			(0.004)
In Labor Force	0.147	0.176	0.005	0.753	0.817	0.064
			(0.016)			(0.003)
Literate	0.893	0.979	0.069	0.930	0.990	0.060
			(0.065)			(0.002)
Child	0.588	0.588	0.013	0.477	0.643	0.166
			(0.006)			(0.005)
White	0.979	1.000	0.008	0.97	0.99	-0.016
			(0.006)			(0.001)
Panel C: Census 1870						
Age	32.599	37.233	2.152	33.420	38.429	5.008
			(0.330)			(0.057)
Farmer	0.374	0.178	-0.128	0.401	0.175	-0.226
			(0.013)			(0.002)
In Labor Force	0.154	0.163	0.023	0.869	0.842	-0.027
			(0.009)			(0.002)
Literate	0.803	0.959	0.121	0.833	0.964	0.131
			(0.006)			(0.002)
Child	0.585	0.624	0.013	0.480	0.624	0.144
			(0.013)			(0.003)
White	0.876	0.977	0.084	0.883	0.986	0.103
			(0.009)			(0.002)
Panel D: Census 1880						
Age	33.039	34.255	1.216	33.499	36.167	2.668
			(0.316)			(0.033)
Farmer	0.391	0.244	-0.147	0.423	0.174	-0.249
			(0.012)			(0.001)
In Labor Force	0.189	0.198	0.019	0.920	0.936	0.016
			(0.009)			(0.001)
Literate	0.852	0.962	0.111	0.873	0.983	0.109
			(0.009)			(0.001)
Married	0.611	0.623	0.013	0.568	0.695	0.128
			(0.012)			(0.001)
Child	0.580	0.576	0.004	0.476	0.558	0.082
			(0.012)			(0.002)
White	0.877	0.968	0.090	0.881	0.982	0.101
			(0.008)			(0.001)
Panel E: Census 1900						
Age	33.679	37.673	3.995	34.232	38.867	4.635
			(0.217)			(0.034)
Farmer	0.319	0.181	-0.138	0.338	0.125	-0.214
			(0.008)			(0.001)
Literate	0.915	0.974	0.059	0.922	0.990	0.068
			(0.005)			(0.001)
Married	0.605	0.595	-0.010	0.555	0.737	0.181
			(0.008)			(0.001)
Child	0.540	0.535	0.005	0.441	0.558	0.117
			(0.010)			(0.002)
White	0.887	0.970	0.083	0.891	0.982	0.091
			(0.007)			(0.001)

Notes: This table shows the demographic characteristics of female and male inventors in the 19th century. This table uses the exact and unique matches of the historical ID. Although the results are similar, any inventor with multiple potential matches in the Census are excluded for a precise comparison. The number of matched women inventors is 14, 51, 263, 1638, and 2279 for 1850, 1860, 1870, 1880, and 1900 respectively. Women inventor group is restricted to feminine names to compare with the general population. Labor force participation is not available for women in 1850.

ever, Baskerville (2008) also shows that women in late 19th-century Canada became very active in increasing their wealth and business activity after being granted property rights. Shammas, Salmon, and Dahlin (1987) provide a similar pattern in women's wealth accu-

Table 13: The Effects of Property Rights and Women in STEM on Innovations

	(1) Fem. Pat.	(2) Fem. Pat.
Rights	0.358	0.367
	(0.147)	(0.177)
log(# Women in STEM)	-	-0.033
		(0.246)
State FE	Yes	Yes
Year FE	Yes	Yes
Controls	Yes	Yes
Observations	1770	1230

Notes: This table shows the results of the effects of property rights on women's presence in the STEM field. All columns include state fixed effects, year fixed effects, a specific trend for the State of New York, and log(population). Standard errors in parentheses and clustered at the state level.

mulation, providing numerical examples from wills. Therefore, women's property rights created dynamism in wealth accumulation through bequests, inheritance, and financial intermediation. For instance, Holtz-Eakin, Joulfaian, and Rosen (1994) demonstrate that receiving a bequest or an increase in wealth stimulates entrepreneurial activity. Similarly, studies for other countries show that women's wealth accumulation in terms of tangible assets has greatly increased as a result of the Married Women's Property Rights in Canada and in the UK respectively (Inwood and Sligtenhorst (2004), Combs (2005)). Inwood and Sligtenhorst (2004) specifically shows that both single and married women benefited from the law. They show that inherited property by women increased considerably after the law knowing the risk of expropriation by the husband is lowered.

Based on the evidence provided in the literature, stronger property rights may have affected families' behaviors towards daughters with a more positive attitude in terms of allocating a larger share of inheritance. Such a change could create a new dynamic for property accumulation among women, which could also act like a collateral. Such financial backup could allow for greater flexibility to engage in commercial or innovative activities with risky and uncertain returns. Hence, wealth accumulation among women or a higher possibility to create an income stream, and have property independently may have further encouraged economic activities that resulted in patents.

To assess whether financial opportunities motivated women's involvement in entrepreneurial

activities, one can examine the effects of the presence of a state or national bank in a state. Due to data availability, a useful proxy is to consider the accessibility of a bank that facilitates easy access to credit. As demonstrated in Table 14, controlling for the presence of a state or national bank does not account for the increase in women's patents. The coefficient on property rights remains robust, and notably, it becomes larger conditional on the availability of a state or national bank in a state. Hence, it may not be an external financial institution that allowed more economic freedom for women inventors, but rather a more favorable wealth accumulation through inheritance. Inherited property could act as collateral for risky investments, such as innovation, and that may explain the rise of innovations among women.

Table 14: Long-run Analysis of Women's Property Rights and Banks

	(1) Fem. Pat.	(2) Fem. Pat.
Property Rights	0.358	0.416
	(0.147)	(0.144)
State or National Bank (=1)	-	-0.240
		(0.905)
State FE	Yes	Yes
Year FE	Yes	Yes
Controls	Yes	Yes
Observations	1770	1534

Notes: This table shows the effect of property rights conditional on the presence of a national or state bank. All columns state fixed effects, year fixed effects, a trend for the State of New York, and log(population). Standard errors are clustered at the state level.

Finally, an alternative perspective on the rise of women inventors could suggest that the increase in the number of patents was due to the ease of finding a patentable idea with little competition. However, the 19th century marked a crucial era of industrial and technological inventions, witnessing a significant increase in the number of patents. This surge indicates intense competition in gaining advantages through innovations in the market. Therefore, the "low-hanging fruit" phenomenon resulting from low competition was likely not the case. Furthermore, empirical evidence does not support characterizing the process of inventing or innovating for women as "low-hanging fruit", as women patented important and novel innovations.

In light of these findings, the establishment of property rights emerges as a fundamental catalyst for innovations. Hence, with the Married Women's Property Acts, women obtained this first step that resulted in more novel and aggregate innovations.

8. Theoretical Model

The absence of human capital or initial wealth can pose barriers to entrepreneurial activities. The model explained below outlines three key propositions based on the findings.

Proposition 1. *Strong property rights enhance economic incentives and anticipated returns for entrepreneurial activities, significantly reducing entry barriers to the market.*

Proposition 2. *Having secure property rights can incentivize increased investments in education and wealth accumulation.*

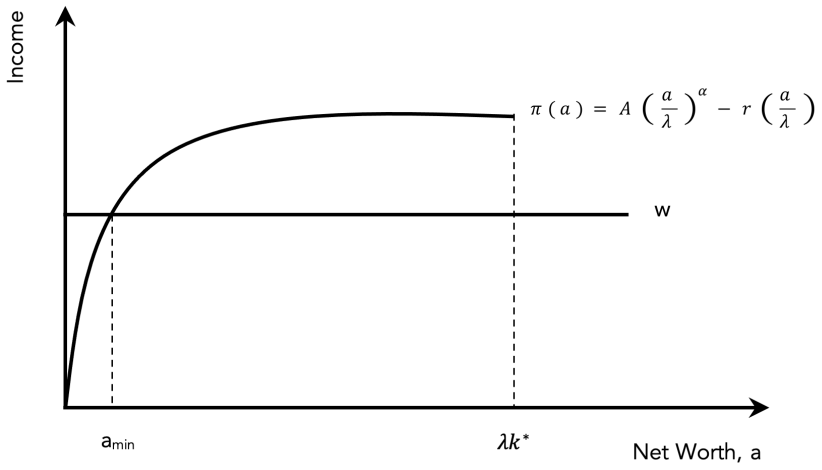
Proposition 3. *The presence of strong property rights, coupled with complementarities such as human capital and wealth accumulation, can further enhance the likelihood of patenting an innovation.*

To illustrate how human capital accumulation and wealth accumulation affect the choice of being an entrepreneur, the main theoretical approach is as follows[16]. Consider an environment where an agent has an initial wealth, a. She uses a fraction of her wealth, $\frac{1}{\lambda}$, in order to invest in capital to start her entrepreneurship. She can work at a wage rate w. The output derived from capital investment can be written as: $\pi(a) = Ak^{\alpha}$ where "A" represents her entrepreneurial ability and "k" represents capital. Based on her wage, initial wealth, and ability, she chooses how much to invest in capital to initiate her entrepreneurship. Also, suppose that she can only borrow up to a fraction of her wealth, $\frac{1}{\lambda}$. The optimal input of capital is derived by the first-order condition of the following equation: $\pi(a) = A(\frac{a}{\lambda})^{\alpha} - r(\frac{a}{\lambda})$ where r represents gross interest rate. Maximizing income by taking the first-order condition generates the optimal yields: $A\alpha k^{\alpha-1} = r$. By plugging this equation back into the profit function, the optimality is achieved: $\pi^* = k^{\alpha}A(1 -$

[16] I theoretically follow and build upon Quadrini (1999).

α). As shown in Figure 11, women who have sufficient ability would choose to be an entrepreneur as long as $\pi^* > w$.

Figure 8: Occupational Choice on Entrepreneurship and Labor



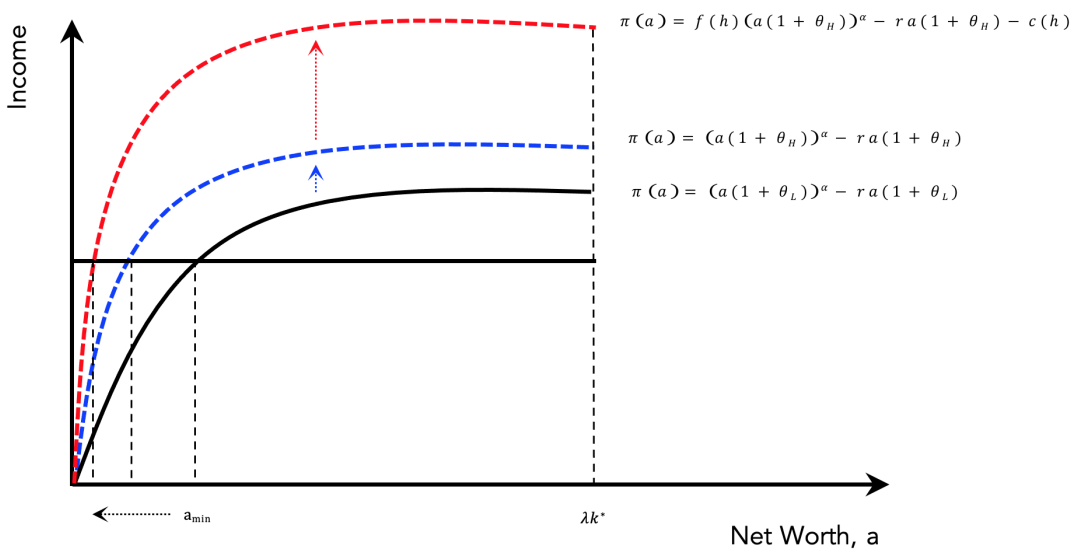
This model so far suggests that as long as the expected return on investment in entrepreneurship exceeds wage, she chooses to be an entrepreneur. However, the threshold of switching to entrepreneurship became lower when women's property rights were granted. For instance, as the rights regulated the property rights on inheritances, the initial wealth is expected to rise. The literature shows that the wealth accumulation of women increased after these rights. Hence, as the initial wealth increases, the likelihood of engaging in entrepreneurial activity increases.

Moreover, women may choose to invest in education to use their rights at best and promote social mobility. Hence, these rights impacted not only wealth accumulation but also human capital accumulation. Therefore, it is essential to incorporate the human capital accumulation aspect of women's property rights in the model.

Now consider that entrepreneurial ability, A, is a function of human capital or education $f(h)$. As investment in human capital accumulation increases, the entrepreneurial or innovative ability also increases; hence f is increasing in h. However, the decision to invest in education depends on its returns and costs: women choose to invest in education

if its expected returns are higher than its costs. Therefore, costs are incorporated in the decision-making process and represented in the model with $c(h)$. In order to represent the well-defined or ill-defined property rights, I include a scale parameter, $\theta \in [0, 1]$. When states adopt women's property rights, θ increases greatly, promoting women's higher human capital and wealth accumulation. In that sense, θ_L represents low or almost no property rights, and θ_H represents strong property rights. Hence, the wealth parameter is multiplied with $[1 + \theta]$. Ability is also a function of human capital, which is also affected by the adopted rights. After re-arranging the terms, the maximization outcome becomes: $\pi^* = f(h)[a(1 + \theta)]^{\alpha}[1 + \alpha] - c(h)$.

Figure 9: Occupational Choice on Entrepreneurship and Labor



Visually, Figure 9 shows the shifts when (i) wealth accumulation (blue) (ii) human capital accumulation (red) exogenously increases. When there is a shift in wealth, as realized with women's property rights, the curve **(black line)** shifts to left **(blue line)** which means that the minimum required initial wealth threshold to start entrepreneurship decreases. Hence, the likelihood of engaging in entrepreneurial activities increases compared to participating in the labor market. Moreover, as women's property rights stimulate human capital accumulation, as shown in the data, expected returns on entrepreneurship increase even more **(red line)**. As a result, the threshold of choosing entrepreneurship

is smaller and easier.

As shown in this static model[17], the choice of entrepreneurship becomes more likely as property rights are stronger. If policymakers provide an environment where step zero, i.e., property rights are well-defined and strong, is established, then the number of innovations and economic actors participating in entrepreneurial or innovative activities increases.

9. Conclusion

Innovations are one of the main engines for economic growth and micro-foundations play a key role in terms of technological progress. Yet, innovations are often under-supplied and disadvantaged groups are underrepresented in innovations, suggesting that there are many lost or hidden talents to uncover. Therefore, this paper employs a quasi-experimental approach to investigate the impact of economic incentives on innovations through a shift in the legal and institutional framework concerning women's property rights in the 19th century United States.

The key finding of this paper shows that strengthened property rights increase women's innovative activities by 40% on average, without decreasing innovations by men. This would suggest that providing equal opportunities to individuals contributed to aggregate innovations by uncovering the lost or hidden talents in an economy. Furthermore, novel innovations among women, that influenced subsequent inventors and innovations, increased significantly due to enhanced property rights.

Additionally, the study demonstrates that this effect is prevalent in the long run, approximately 10 to 15 years on average in the post-treatment period. Innovations require time, intellectual investment, complementary skills, and motivations. Hence, the long-run effect is not only statistically significant but also economically meaningful.

This study also shows that women specifically patented in certain technology classes that

[17]In this static toy model, there are important assumptions such as no uncertainty or no risk associated with income or choice of entrepreneurship. Nevertheless, this toy model illustrates the basic intuition behind such an unprecedented change in women's behavior clearly and straightforwardly.

are correlated with their socioeconomic background and gender roles in the 19th century in the United States. I show that women's innovations in mechanical engineering and transforming areas that are related to household appliances, machinery, and apparels, rose significantly due to the property rights.

A thorough exploration of the empirical channels reveals that the rise in innovations is not driven by factors such as labor force participation, engagement in STEM occupations, or other policies like compulsory schooling. On the contrary, the findings suggest that human capital accumulation, and increasing the private returns over their investments led to more innovations.

In conclusion, the empirical results underscore the primary importance of establishing incentives through institutions. Providing an equal playing field for disadvantaged individuals significantly enhances the likelihood of unveiling latent talent in an economy, akin to discovering the hidden or lost Josephine Cochrans or Marie Curies.

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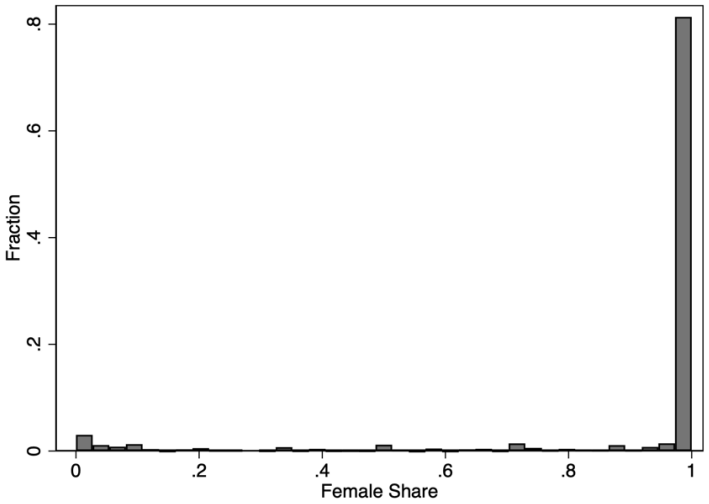
11. Appendix

Figure 10: Likelihood of Femininity of Names based Census Data



Notes: This histogram shows the probability of being a woman based on name identification in the patent data by Census-matched names. Gender identification based on names in the patent data are on average 86% likely to refer to a woman inventor.

Policy Years. In Table A1, I use policy years provided by Geddes et al. (2012). There are three main rights granted in these laws: property, earnings, and sole trader rights. Some states pass these rights in a few years apart. Therefore, I use the earliest adoption year to specify the earliest treatment period. Bold letters represent the places that existed in the 1840s and included in the analysis.

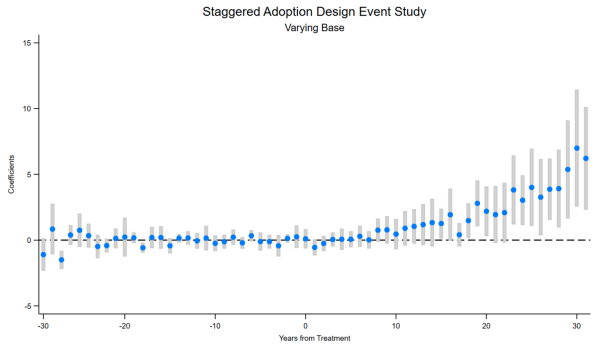
Table A1: *Earliest Policy Adoption Years by State*

State	Date	State	Date
Alabama	1887	Nebraska	1871
Arizona	1871	Nevada	1873
Arkansas	1878	**New Hampshire**	1860
California	1872	**New Jersey**	1852
Colorado	1861	New Mexico	1884
Connecticut	1856	**New York**	1845
Delaware	1873	**North Carolina**	1868
Florida	1892	North Dakota	1877
Georgia	1873	**Ohio**	1861
Idaho	1903	Oklahoma	1883
Illinois	1861	Oregon	1878
Indiana	1879	**Pennsylvania**	1848
Iowa	1873	**Rhode Island**	1872
Kansas	1858	**South Carolina**	1868
Kentucky	1873	South Dakota	1877
Louisiana	1916	**Tennessee**	1919
Maine	1844	Texas	1913
Maryland	1860	Utah	1872
Massachusetts	1855	**Vermont**	1881
Michigan	1855	**Virginia**	1877
Minnesota	1869	Washington	1881
Mississippi	1871	**West Virginia**	1868
Missouri	1874	**Wisconsin**	1850
Montana	1874	Wyoming	1869

Notes: This table shows the earliest policy adoption year for each state. I use the data from Geddes et al. (2012). Bold letters represent the places included in the analysis. Connecticut and New York pass a law specific to patenting prior to property rights acts so those years are used as the initial treatment year (Khan, 1996).

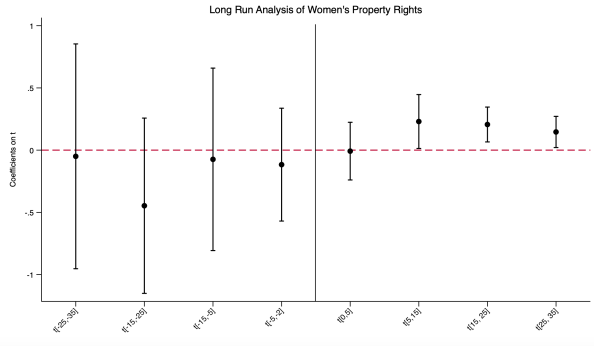
11.1. Additional Analyses

Figure 11: Staggered Adoption Design (Callaway and Sant'Anna (2021)



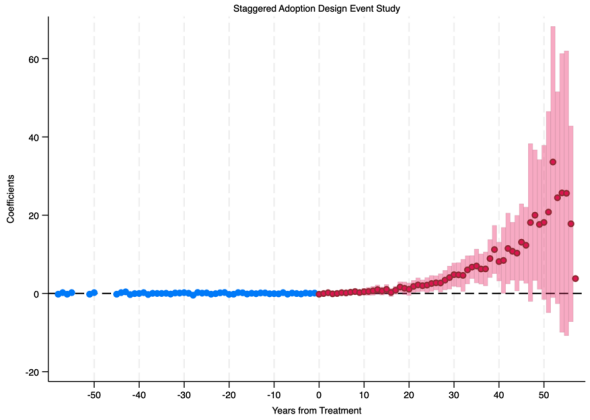
Notes: This graph shows the staggered adoption design aggregated event study based on Callaway and Sant'Anna (2021) (*csdid*) methodology. Varying base is used to compare with the universal base event study.

Figure 12: Event Study for Pre-Treatment and Post-Treatment Period



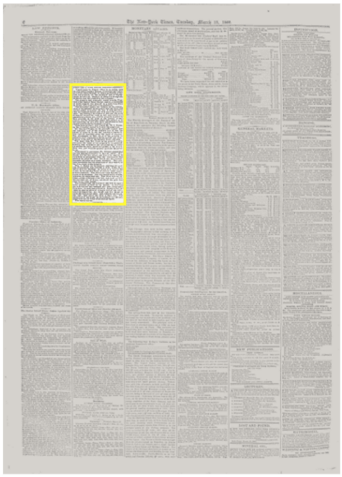
Notes: This graph shows the long-run analysis of women's property rights with a dynamic DID event study. PPML methodology is used and the dependent variable is the level of innovations patented by women. This graph includes state fixed effects, year fixed effects, a trend for the State of New York, and log(population). Standard errors are clustered at the state level and intervals are at the 95 percent confidence level.

Figure 13: Staggered Adoption Design (Callaway and Sant'Anna (2021) with All States Included



Notes: This graph shows the staggered adoption design aggregated event study based on Callaway and Sant'Anna (2021) (*csdid*) methodology. Dependent variable is the level of patents as in the main estimating equation. Confidence bands are at the 95% level. Varying base is used. All inference procedures use clustered bootstrapped standard errors at the state level.

Figure 14: The New York Times Archives: News on Women's Property Rights, 21 March 1860



The New York Times Archives

Rights of Married Women.

AN ACT CONCERNING THE RIGHTS AND LIABILITIES OF HUSBAND AND WIFE.

SECTION 1. The property, both real and personal, which any married woman now owns, as her sole and separate property ; that which comes to her by descent, devise, bequest, gift or grant ; that which she acquires by her trade, business, labor or services, carried on or performed on her sole or separate account ; that which a woman married in this State owns at the time of her marriage, and the rents, issues and proceeds of all such property, shall, notwithstanding her marriage, be and remain her sole and separate property, and may be used, collected and invested by her in her own name, and shall not be subject to the interference or control of her husband, or liable for his debts, except such debts as may have been contracted for the support of herself or her children, by her as his agent.

SEC. 2. A married woman may bargain, sell, assign and transfer her separate personal property, and carry on any trade or business, and perform any labor or services on her sole and separate account, and the earnings of any married woman, from her trade, business, labor or services, shall be her sole and separate property, and may be used or invested by her in her own name.

SEC. 3. Any married woman possessed of real estate as her separate property may bargain, sell and convey such property, and enter into any contract in reference to the same, but no such conveyance or contract shall be valid without the assent in writing of her husband, except as hereinafter provided.

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