The Gender-Patent Gap

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SUMMARY

The under-representation of women in science remains a persistent and widespread problem. Recent explanations for this disparity include female preferences for reading-oriented professions or social barriers in the workplace. To provide insights on female participation we investigate cross country differences in the gender-patent gap. We find that ex-Communist countries exhibit over 300% higher female participation in patenting than their NATO counterparts. Liberal countries such as the US, Great Britain, and Austria exhibit some of the lowest female participation rates in the world, with women comprising only 8% of recent patentees. By contrast, women comprise over one-third of patentees in several countries. Mechanisms that limit female-tasked home production in the middle class appear prevalent in low gender-patent gap economies. Policy prescriptions focused on anti-STEM preferences or workplace explanations, such as quotas, are arguably less relevant to the gender-patent gap than remedies aimed at mitigating the costs of home production.

1. Introduction

A prominent concern about gender inequality is the under-representation of women in innovation or science. Women comprise less than 20% of the full professors in the European Union [1]. Elsevier, using the Scopus Database on academic publications, reports that female academics comprise roughly one-third of the authors from 2011 to 2015. Women hold about 30% of science, technology, engineering and math (STEM) degrees in the US, but they are relatively unlikely to work in a STEM occupation, as they leave these fields at double the rate of men [2]. Studies on diversity in teams underscore the potential gains from eliminating the barriers to women in science, including the enlargement of the pool of qualified and capable talent and improved quality of innovative output [3].

A stream of academic research emphasizes how behavioral preferences potentially influence the educational and job-related choices of women, segregating the workforce into male and female positioned occupations [4]. Others highlight how the exchange of labor in marriage, including childcare, cooking, and household repairs, influences the workforce gender gap [5]. Cultural norms in many countries often allocate many of these home production duties to women, suggesting mechanisms that limit the time cost of home production (or homemaking) could foster greater female participation in science [6]. In contrast, [7] suggest the gender gap in science arises because women exercise their preferences for reading-oriented professions instead of seeking STEM careers.

However, little is known about the heterogeneity in the distribution of female scientists across countries or organizational structures. To identify potential factors that limit or facilitate the gender gap in science, we investigate where and when these gender imbalances arise and importantly, where they do not occur. We capture the participation of women in science using patent activity. Our results provide evidence against the anti-STEM preferences and biological explanations for the under representation of women in science. Instead, our analysis points to solutions aimed at mitigating the costs of home production.

2. Female Patenting Across Countries

We use patent data from 112 countries that span 80+ million patent applications. The sample of patents is derived from the EPO Worldwide Patent Statistical Database. Using gender-name dictionaries, we assess the relative proportion of men and women obtaining patents in the countries with at least 100 scientists [8]. Our tests rely on 22 million patentees, of which 3 million are women.[1] We find that the gender gap in patenting varies considerably over time and around the world. From the 1930s to the 1960s women comprised less than 5% of patentees, increasing to 18% of patentees by 2010.

Strikingly, western economies such as the US, Great Britain, and Austria exhibit some of the greatest gender imbalances in patenting. Female patentees account for roughly 8% of patentees in these three countries. By contrast, in numerous countries women comprise

1 Appendix I provides details on the gender assignment process, while Appendix II provides details on the sample characteristics of the data.

around 35% of patentees, with Latvia heading the list with 61% female patentees. The impediments to the participation of women clearly differ in Latvia versus Austria.

Figure 1 provides a heat map of the total participation rate of women in innovation around the world. The cross-country variation is quite prominent. The countries that we typically consider to be liberal with respect to women's rights, do poorly in female patenting. Norway, Sweden, and Germany are in the bottom 20 group of countries.[2] By contrast, Latin American countries, often characterized as highly patriarchal societies [9], exhibit substantially higher female patenting rates than found in the US, UK, Germany, or Japan. In general, developed western economies exhibit low participation rates of women in patenting activity.

Ex-Communist countries exhibit the highest levels of women in science. Among the top 20 countries in female participation in patenting, 14 of them are in the ex-Communist block.[3] By comparison, among the 20 countries with the lowest female participation rates in science, eight of them belong to NATO. A comparison of NATO with ex-Communist countries demonstrates that the ex-Communist countries exhibit 300% higher participation rate than their NATO counterparts.

Figure 2 shows that the same proportion of women in the east and the west received patents prior to the 1950s. By 1960, women in the ex-Communist countries received over 15% of the patents and over 25% by the 1980s. While communism brought numerous social changes to the countries involved, these results provide strong evidence against the biological explanation for observable gender inequality.[4] Corresponding to this rapid increase in female participation in science, the Soviet Union countries almost doubled the number of child care facilities, while simultaneously decreasing their birth rates [12]. As [13] notes, policy makers in communist countries required all eligible adults to work. They enacted numerous policies to facilitate child care, to limit meal production efforts, and to foster women's education.

[2] All these countries are in the top 15 in the World Economic Forum Global Gender Gap ranking in 2017.
[3] Table A1 in Appendix II lists countries in NATO, ex-Communist, and Warsaw pact blocks.
[4] A recent New York Times article describes the biological argument, namely that the scarcity of female scientists stems from the limited representation of women in the top and the bottom of the mathematical-intelligence distribution [11].

The fall of communism, in 1990, does not appear to change female participation in science in these countries, see Figure A1 in Appendix II. The disparities in participation between NATO and ex-Communist countries are likely the result of policies enacted by the communist governments that withstood the changes in government.[5] To assess whether these results stem from the inclusion of political appointees on patents, we exploit the role of the patent leader (first named researcher on the patent team). We find that the geographic divide between NATO and ex-Communist countries is the same for patent leaders and serial inventors (see Figure A2 in Appendix II). Rather than being coincidental or cosmetic, women participate more in innovation in the ex-Communist countries than in western democracies.

India provides an interesting example for exploring the impediments to women's participation in science. The World Economic Forum ranks India well below most Western European and North American countries on gender inequality. However, women's participation in innovation ranks much higher in India compared to the US or Germany. Middle class families in India typically hire domestic help [10]. This potentially mitigates some of the cultural-based demands for female-tasked home production. Although science output per capita is low in India, the patent evidence on female involvement in science highlights the potential importance of home care as a key impediment.

3. Female Patenting in Organizations

We also explore gender diversity in science across different organizational structures. Patents originate in both public institutions (non-profits institutions such as hospitals and academic settings) and for-profit companies (publicly listed and private corporate laboratories). Employees in nonprofits arguably enjoy greater autonomy than found in for-profit firms, allowing for greater flexibility in dealing with home production demands [15]. This home production impediment to the participation of women in science suggests that the gender gap in innovation should be smaller in public institutions compared to for-profit companies.

[5] However, more limited funding in childcare facilities could potentially undo some of these gains.

We find that the share of female patentees is markedly higher in public institutions, than in corporate settings. Figure 3 shows the female participation rate in innovation (as a proportion of the total number of patentees) by organization type from 1949 to 2013.[6] Public institutions exhibit the largest proportion of female patentees. About 10% of patentees in corporations are women, while 20% of patentees in public institutions are women.

During the 1949-1962 period, both types of institutions appear to employ comparable numbers of female innovators (2-4%). Figure 3 shows a dramatic shift in the proportion of female scientists hired in public institutions starting in 1962, which coincides with the introduction of the contraceptive pill and subsequent decreases in home production. By contrast, there is not much change in the proportion of female scientists in corporations. The gap in employing female scientists between private and public institutions has steadily increased with time, from 2% in 1949 to 14% in 2013.

4. Impact of Female Participation

We next explore the average impact or scope of women's patents. We use the number of citations per patent, to investigate the impact of women's patents, relative to their male counterparts, over time. Figure 4 shows that citations of female patents were higher than citations of male patents before the 1960s. However, their citations fell below the level of their male counterparts in the mid-1960s and have not recovered. After 1980, patents by women averaged around one less citation than their male counterparts. To limit concerns about truncation bias in citations, Figure A4 in Appendix II compares men and women in the same time-period cohorts, with quantitatively similar results. Investigating patent-based and article-based citations, we find that the lower citations for female patents are only observed in patent-based and not in article-based citations.[7]

[6] Public institutions include hospitals, universities and non-profit organizations. Companies include private companies. One conjecture is that corporations engage in different types of research and innovation compared to non-profit organizations. Further, analysis based on patent classes reveals no discernable difference in the patterns of patenting between public and private institutions.

[7] Additional analysis reveals that this occurs across a wide variety of patent classes and patent types.

Patent citations are not symmetrically distributed. Specifically, citations are skewed to the left with numerous patents receiving zero citations. Of particular interest are highly-cited patents and the identity of patentees who produce numerous patents. We, therefore, explore the proportion of women among high achiever patentees (top 1% in number of patents received) and research superstars based on citations (top 1% of citations).

Figure 5 provides data on the proportion of women research superstars, based on both the number of patents and the number of citations. During the 1950s and early 1960s, women accounted for approximately 3% of top patentees and 2% of highly-cited superstar patents. These figures began rising in the 1970s, with women now accounting for over 16% of superstar patents. Women also account for over 20% of the top number of people getting patents each year. Therefore, the rise in participation by women has led to a dramatic increase in the number of superstar patents.

Evidence in Figure A5 in Appendix II indicates that the proportion of scientists generating patents without any citations has dramatically increased. In the 1950s, a quarter of patents received zero citations, where less than 20% of female and over 40% of male patentees had zero citations. Approximately 40% of all patentees have zero citations today. The zero-citation rate among male patentees has not changed over time. However, female patentees have experienced a substantially higher rate of non-citation, with roughly 50% of them not receiving citations. These differences could potentially be due to cultural influences on citation patterns or differences in patents [16].

5. Home Production

We explore the role of home production in the observed decline in women's patents over the past several decades. This involves investigating issues related to child-care and taste issues in the patenting of women. Preliminary analysis indicates that women, who leave the workforce due to child commitments, have lower citations than men with child commitments.

In addition, women in countries that have substantial childcare infrastructure, exhibit similar citation patterns as the men in that country (see Figure A6 in Appendix II).

Figure 6 provides evidence on home production and patenting by women. We show the difference in citations per patent between female and male patents (female minus male citations). We find no evidence of a citation gap between male and female patentees in the 1950s and 1960s. However, they begin to diverge in the 1970s. NATO countries exhibit a marked decrease in citations of female patentees after 1970, as documented in Figure 5 for the whole sample. By contrast, the ex-Communist countries continue to exhibit no difference in citations. Ex-communist countries substantially increased their child care infrastructure in the 1960s and 1970s, relative to western democracies. During the 1960s, the Soviet Union built four times as many new child care facilities than existed in the entire US [12].

It could be argued that there are substantial cultural differences between NATO and the ex-Communist countries, which explains these disparities in female participation in science. To address this issue, we investigated patenting patterns in East and West Germany. East Germany provided women one paid day a month for housework, developed crèches or nurseries for small children, and funded after-school care facilities [17]. The differences between East and West Germany were dramatic. A total of 80% of toddlers attended full-time crèches, and 81% of 6-10-year-old children received after-school care in East Germany. By contrast, the totals in West Germany were only 4% and 3.6%, respectively [18]. Figure 7 shows the percentage of female patents and the difference in citations between female and male patents in East and West Germany. Panel A shows that female participation in patenting was higher in East Germany from the start of the data reporting in 1965, and by the end of communism in 1990, it was double the percentage in West Germany. Citations by female patents in West Germany exhibited the same decline around 1970 as the world and NATO counterparts in Figures 5 and 6. However, there is no such decrease in East Germany.

6. Conclusion

The limited participation by women in the workforce, especially science, represents a common and persistent thread in policy discussions about economic growth and social justice [19, 20]. One policy prescription focuses on imposing gender quotas, without understanding the underlying rationale [21]. There are several different arguments or explanations for these observable differences, including discrimination and cultural attitudes related to home production [22, 23].

Our results indicate that women's participation in innovation varies considerably over time and around the world. Prior to the 1950s, women appear infrequently in innovation. However, by 2010 they account for 18% of all innovation. Countries such as the U.S., Great Britain, and Austria exhibit some of the highest gender gaps in innovation in the world, while developing countries routinely exhibit higher female participation rates.

A comparison reveals that the ex-Communist countries demonstrate substantially greater participation by women than their NATO counterparts. Our results also show that the participation of women in science increased across different institutions over the past 60+ years. The proportion of women scientists grew much faster in public institutions than in corporate research laboratories. The proportion of superstar women inventors has tripled during the same time-period.

The under-representation of women scientists is a complex problem that will likely require a variety of solutions. Our results show that the gender participation gap in science cannot be explained by preferences or biological differences (unless one is willing to believe that women, who happen to be allocated in East Germany, are different from women in West Germany). Cultural norms together with home production requirements appear to be at the root of the gender gap. Combining our results with the evidence that career interruptions and working hours influence the gender gap [24], our analysis suggests that limiting the cost of home production represents a key factor in increasing female participation in science. Gender quotas, without the provision of home production support, are unlikely to address the persistent underrepresentation of women in innovation and science.

Data availability

The data that support the findings of this study are available from the corresponding author on reasonable request.

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Supplementary information is provided in the online appendix.

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Contributions
E.C. conducted the disambiguation and gender matching. E.S., W.T. and D.R. initiated the project. E.S. and D.R. mapped out the analysis and W.T designed the study. W.T. cleaned the patent data and E.S. performed the empirical analysis. E.S. and D.R. wrote the manuscript with contributions from W.T.

Competing interests
The authors declare no competing financial interests.

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Figure 1: Average Percentage of Female Patentees

The figure shows the percentage of all females filing for patents, for all countries in the sample. We include the number of female and male patentees in each country for the sample period 1870-2013.

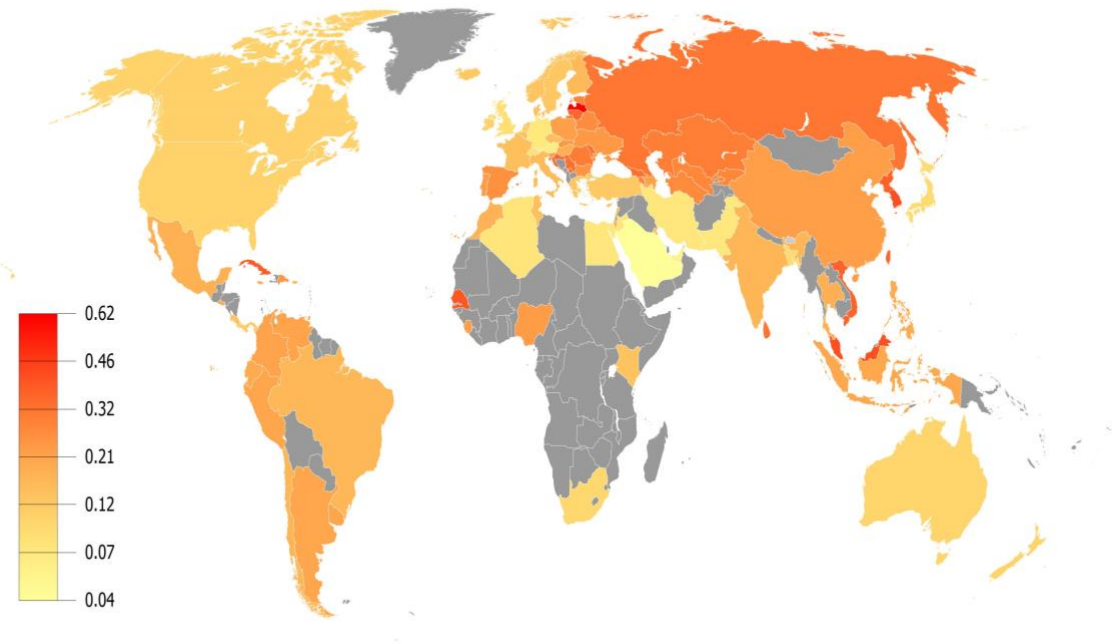


Figure 2: Women Participation in Innovation

The figure shows the average percentage of female patentees (by decade), in Ex-Communist countries and in NATO countries.

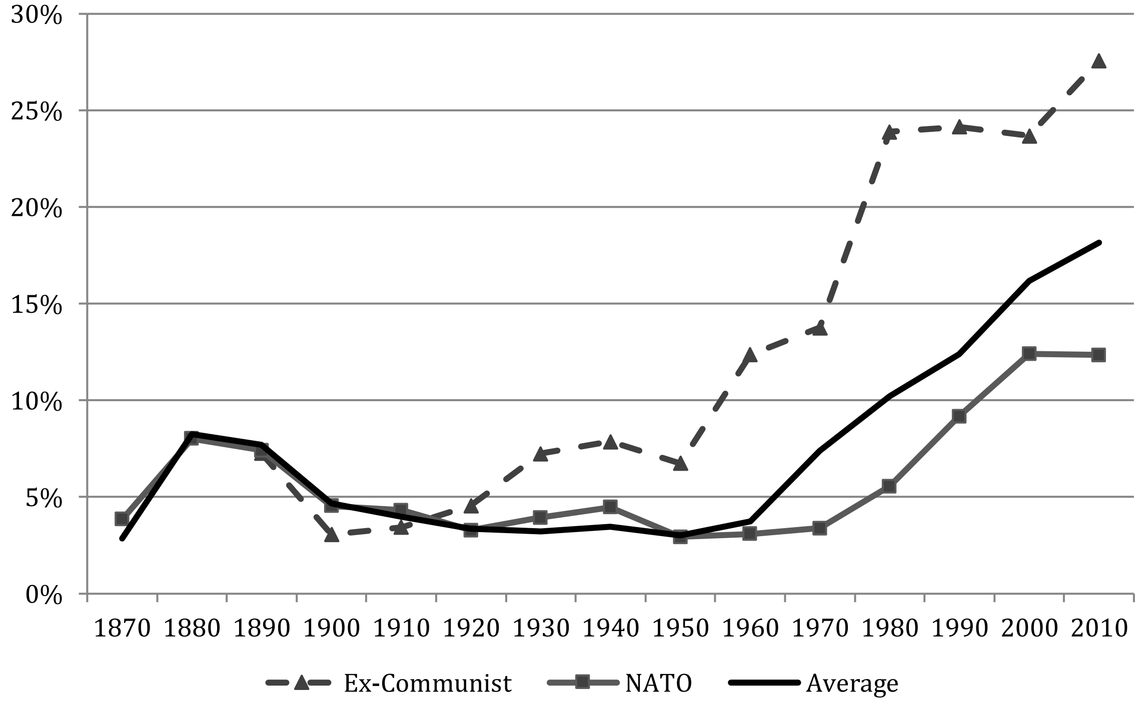


Figure 3: Women Participation in Innovation in Different Organizations

The figure shows the percentage of female patentees (5-year moving average) in private companies (*Company*) and public institutions (*Public*). *Company* represents private companies, *Public* represents all public institutions including universities, hospitals and non-profit organizations. The shaded areas represent the years in which the contraceptive pill was introduced in different countries. Slope represents the rate of change in the percentage of women in innovation for three periods, pre-pill 1949-1960, during pill introduction 1960-1970, and post-pill 1971-2013.

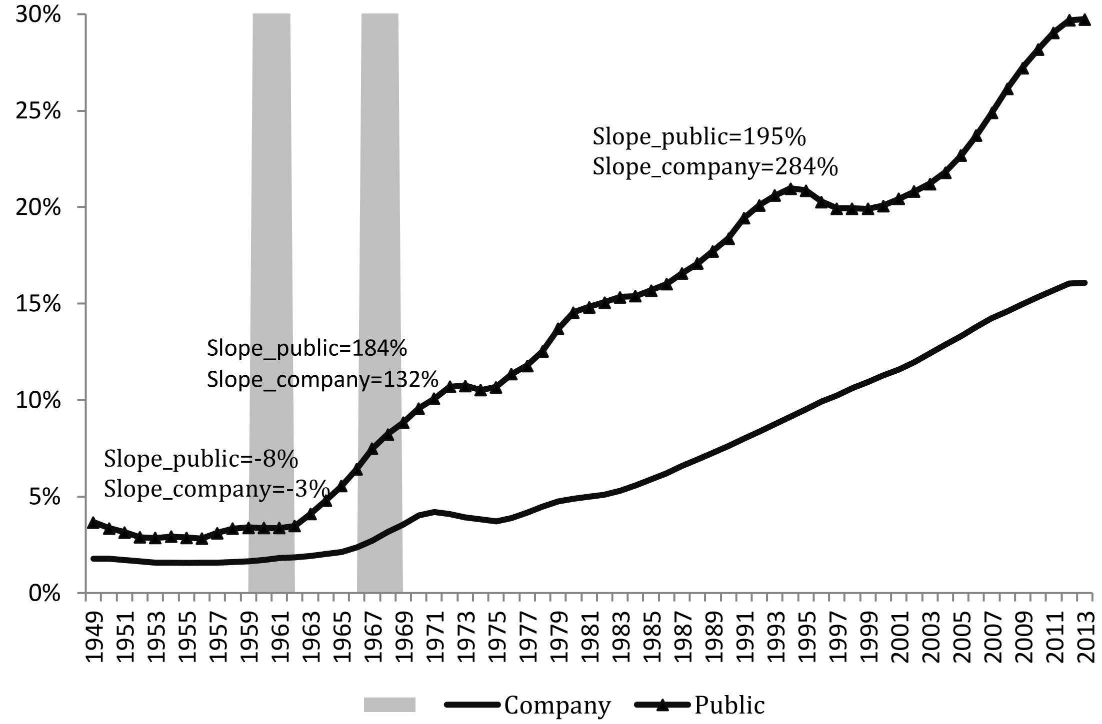


Figure 4: Difference in Citations

The figure shows the difference in patent citations (5-year moving average) between female and male patents (citations of patents by women –citations of patents by men) from 1949-2013.

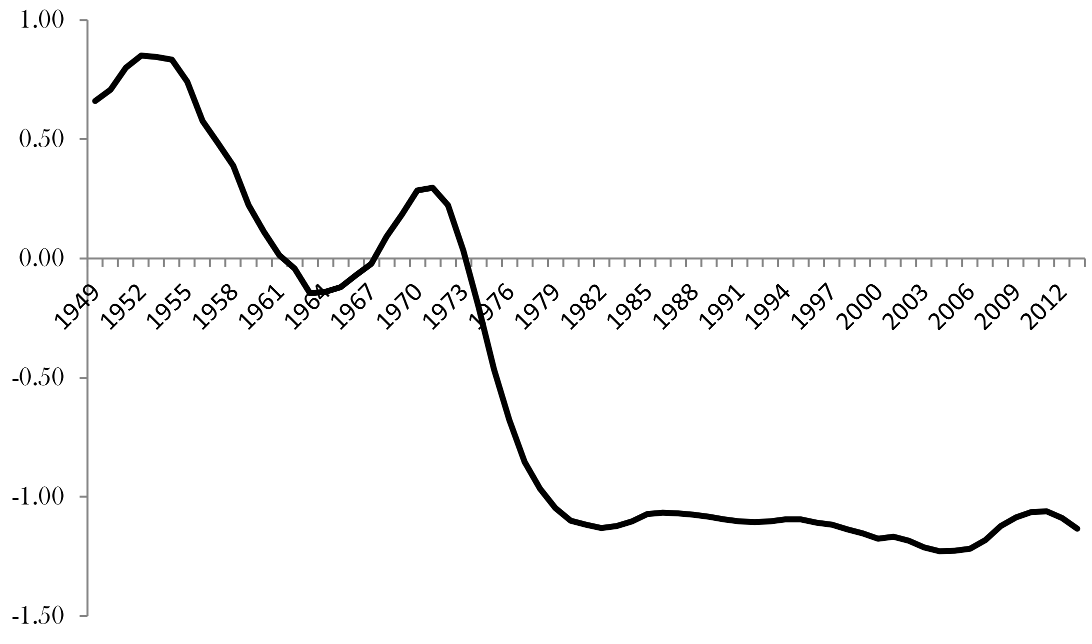


Figure 5: Percentage of Women Superstars

The figure presents the percentage of women who were superstars, according to the year of their first patent. Superstar *Patentees* are identified as the individuals with the top 1% of number of patents granted during the sample period between 1880 to 2013. *Leader* represents the percentage of women that are superstar leaders, listed according to the year of their first patent. A superstar leader is identified as the top 1% of number of patent leaderships in the period between 1880 to 2013. *Citation* presents the percentage of women that are superstars in citations, listed according to the year of their first patent. A citation superstar is identified as the top 1% of total number of citations during the period between 1880 to 2013. The figure shows the three-year moving average.

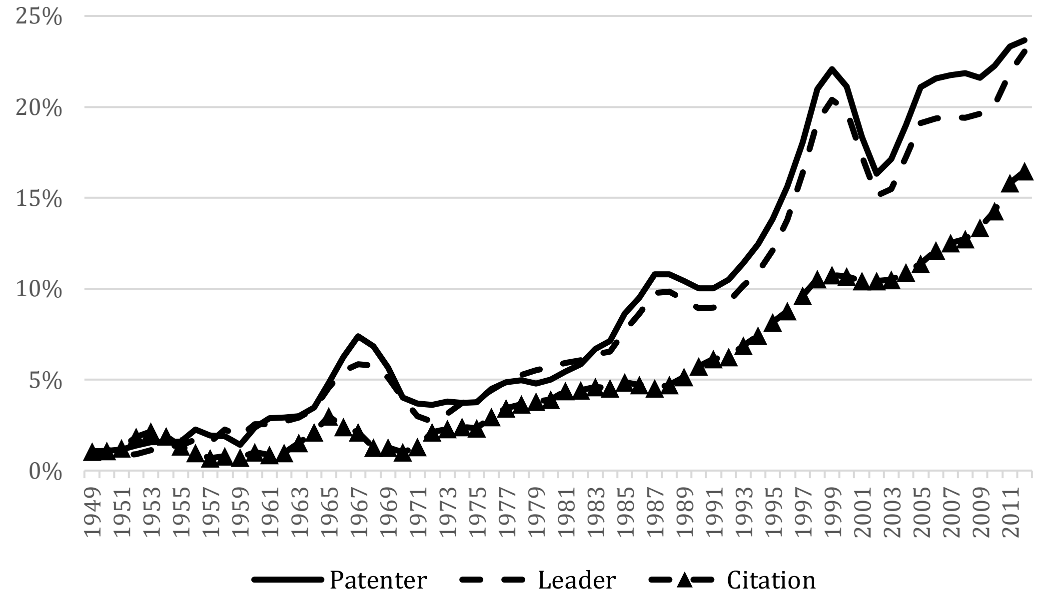


Figure 6: Home Production and Women's Patents

The figure presents the difference in patent citations per patent (5-year moving average) between women and men (citations of patents by women –citations of patents by men) from 1949-1995, in NATO and ex-Communist countries.

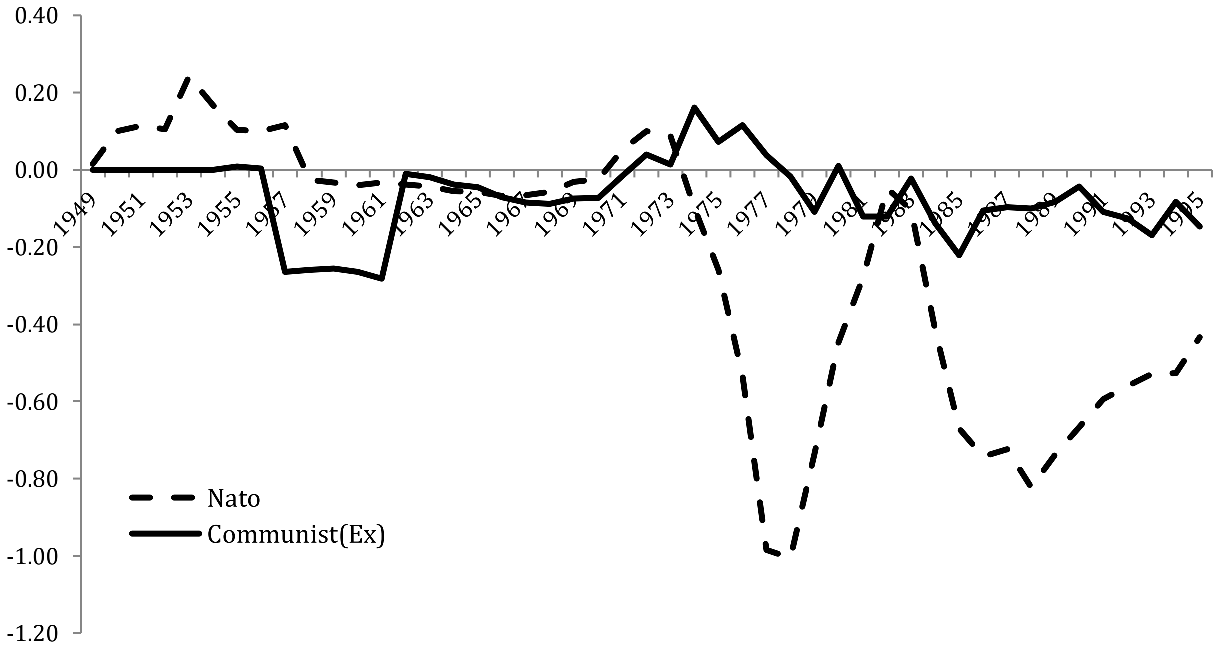
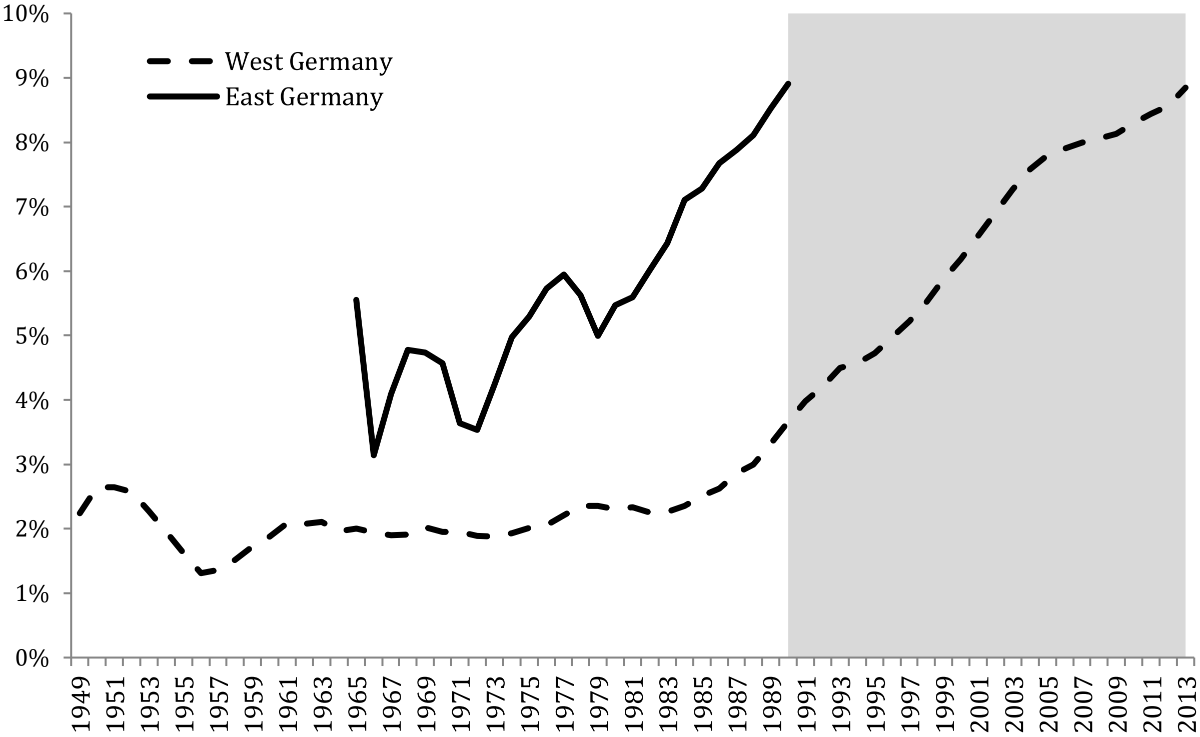


Figure 7: Home Production and Women's Patents in Germany

The figure presents patents in East and West Germany for the period between 1949 and 2013. The data for East Germany starts in 1960 and ends in 1990. Panel A presents the percentage female participation (5-year moving average) in East and West Germany. Panel B shows the difference in patent citations per patent (5-year moving average) between women and men (citations of patents by women –citations of patents by men). The shaded area covers the post-Berlin wall fall period.

Panel A. Participation



Panel B. Citation Difference