THE UNIVERSITY OF CHICAGO

U.S. Section H Patents:
From Women to Human

By

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Abstract

This project identifies the gender gap exist in Section H – Electricity patents under the Cooperative Patent Classification. Using meta data analysis and text analysis with all the section H patents from 1976 to 2021, I found that the gender gap within Section H patents is still large and is closing up slowly. Few women get to invent, few women majority teams exist, and few patents are female-focused. On average women have higher productivity than men within section H patents creation. I also found that, during economic recessions, female job switchers are the most productive while non-top assignees' female inventors suffer the most; during normal times, non-top female inventors have the best performance while top assignees' female inventors ranks the lowest.

Keywords: Diversity, Gender, Patent system, Inventors, Productivity

Part I: INTRODUCTION

The inventor gender gap is well established. According to USPTO's 2020 update on U.S. women inventor-patentees, patents with at least one female inventor accounted for 21.9% in 2019, compared with 20.7% in 2016 (USPTO 2020). Although this report highlights a series of improvements in the share of new women inventor-patentees and the degree to which those women remain active in patenting again, it still shows that we still have a long way to go in terms of gender equity. Currently, the USPTO adopts three types of metrics that measure women's participation in patenting and invention: 1) the women inventor rate, namely the percentage of unique women inventors across all patents granted in a given year; 2) the percentage of patents granted in a given year that have at least one women inventor; 3) women's share of total patenting, whereby an equal share is attributed to each inventor if this patent has multiple inventors, and the resulting "fractions" of patents are summed across men and women to provide total patent output by gender for each year. The first two often occur in official reports like the one I have shown above, which are "prettier" since they grow much faster than the third one. Meanwhile, this biased evaluation output has two drawbacks: 1) it fails to pay attention to women's impact during the invention process; 2) it fails to track the deeper reasons why women drop out of the inventor workforce, such as resources provided by the inventor's organization.

Even though visible progress has been made to lessen the gender gap, the problem still exists in multiple stages, from patent application to patent licensing. Compared to male counterparts, women from the beginning tend to have a lower chance of entering STEM occupations, are less likely to continue in scientific careers, and are less likely to become inventors ((Ding, Murray, Stuart 2006), (Long and Fox 1995)). These effects are already problematic, but as the cycle loops on, fewer female inventors might stay in this environment, and it further discourages women from entering.

According to a World Intellectual Property Organization report, women inventors file patents in all technology areas, but they are mostly concentrated in life sciences (Lefeuvre, et al., 2018). I am interested in the H section - Electricity under the Cooperative Patent Classification (CPC), which makes up most of the patents used in the CS industry but has never been investigated by researchers. My question will be **how has the impact of female inventors in H section patents changed through time, and how does labor transfer affect this impact?** This project should interest the public administration, such as the USPTO, all sizes of Section H relevant companies and institutions, their management, research, hiring divisions, and female inventors in the patent industry. This project aims to display the role women inventors play in 46 years of electricity patents history and how their work is important to both women and innovation.

The Research Excellence Framework defined impact as 'an effect on, change or benefit to the economy, society, culture, public policy or services, health, the environment or quality of life, beyond academia' (Smith, Ward, and House 2011). Under our context, I will answer the above question based on quantifying the impact into three dimensions: 1) the overall gender gap represented by the trend of patents with a majority of female (≧50% women) inventor teams; 2) the pattern of female inventors' labor transfer; 3) the extent of majority-female teams yielding female-oriented patents.

The novelty of this project lies in two aspects: 1) Even though there is ample literature studying how race and other determinant factors affect the gender gap in STEM education and careers, today, the body of patent gender gap literature is small, and there is even scarcer literature paying attention to the specific industry patents and the female inventors behind them. 2) This project will not only be the first to trace the labor transfer within the H section innovation industry, but also be the first to look into labor transfer study in the intellectual property industry. Researching the labor force composition will allow us to indicate better the labor-market bias spilling over into product-market bias.

PART II: LITERATURE REVIEW

Among all kinds of literature, many authors focused on the system input process, showing that inequality already exists before and during the patent application process since female-led teams received a lower level of grants (Hunt, et al. 2013). This can only be partial help since it is still the granted patents that ultimately influences the product and brings value to it. Hence, relevant literature can be broken into two parts for easier comprehension in this section: 1) the overall gender gap exists in the patenting system – its causes, effects, and the patent system's output in specific industries' patents. For example, indicating that women have fewer opportunities to enter the inventing process affects the invention outcome; 2) the relationship between Labor transfer and gender; 3) Gender-related text mining methods that serve for our abstract analysis. This theoretical background is unique because it bridges two different and rather disconnected fields of study.

II.i. Gender gap in patenting – causes and outcomes

Many reasons contribute to the gender disparity within patenting; it could be because of a lack of IP expertise, the gender filters and leaky pipelines in STEM, negative bias during patenting, lack of access to networks and resources, and under-representation within the USPTO. A leaky pipeline is a system that loses some quantity of what it carries before it reaches the destination. The STEM leaky pipeline describes women gradually “leaked out” during education; that is, fewer and fewer women are channeled into higher education in STEM hence making women underrepresented minorities in STEM fields. For example, fewer women chose to major in mathematics and engineering before undergrad (Sheltzer and Smith 2014). The gender filter is a sum of those leaky pipelines happening during different education periods. Negative bias in terms of gender is a stereotype that believes women are less able in their work compared to men, less talented, and less suitable for challenging assignments. In our scenario of inventing, even if a woman successfully passed the filters and landed a research job in STEM industries, negative bias will make people question their expertise, play a less dominant role in inventing process, having fewer opportunities for self-development lessened because of having children, etc. (Williams et al., 2005).

There is no dispute that women are underrepresented in STEM majors and careers (National Center for Education Statistics 2011). A handful of literature describes such a problem well. The absence of women in STEM can be both progressive and persistent; that is, the farther along the pipeline, the fewer women you find. Furthermore, despite treatments, the problem did not vanish (Cronin and Roger 1999). Such findings can also be applied to patenting – as women advance further in their work, we found fewer women inventors stay in inventing and maybe produce lesser inventions. Numerically, in the US during 2011, half of all MD degrees and 52% of PhDs in life sciences were awarded to women, as were 57% of PhDs in social sciences (Ceci, et al. 2014). However, in 2018, the share of women in CS Ph.D. receivers only consisted of 21.58%; for engineering, it was 24.53%, and 27.97% for mathematics and statistics (National Science Foundation 2018). Moreover, women’s share of full-time tenured or tenure-track faculty positions in science and technology was 28% in 2006 (Burrelli 2008).

Per under-representation within USPTO, in USPTO's patent examining corps, 27% are women (Hosler 2018). In the general workforce, 50% of women who originally worked in STEM leave after 12 years, while women in other professions have a rate of 20% (Glass, et al 2013). At the USPTO, there is less than 5% attrition for both men and women patent examiners (Hosler 2018). This result shows that overall, in STEM fields careers, fewer women persist, and this pattern still holds in USPTO with the paucity of female examiners.

The lack of expertise and access to networks and resources can be observed both in my past work experience and have been an issue in many countries. Research has found that women life scientists have smaller and lower-level professional networks than men. Sugimoto et al. have argued that one reason that female patenting is more prevalent in academia is due to the less hierarchical organization of academic institutions, which is useful for helping to build social networks (Sugimoto, et al. 2015). Lack of collaboration with industry also explains the considerable difference in patenting between male and female academics (Meng 2016). Sri Lanka female scientists' potential and career prospects were adversely impacted by social barriers (Kariyawasam 2013).

The scarcity of resources for patenting has two aspects – monetary and knowledge. Monetary resources come from research funding and the cost of the patenting process. The development of patents tends to require significant financial commitments. Further, patenting as a part of the product development process will also require knowledge about registration money for hiring a patent attorney and preparing for potential lawsuits. Research has shown that women are under-resourced in Sri Lanka and Tanzania in terms of registration facilities (Kariyawasam 2013). It is still unclear how the situation of women is in developed countries. To support inventors with the assistance of patenting costs (application, maintenance, etc.), the USPTO launched the Patent Pro Bono program to match under-resourced independent inventors and small businesses with free or reduced legal assistance costs in preparing and filing patent applications. Nevertheless, this applies to all inventors regardless of their gender.

Till this point, I would like to raise the difference between women in life sciences and CS and engineering again. Early in 2011, life sciences successfully reduced the effects of leaky pipelines to ensure that enough amount of females continued in their careers. This also makes it a better sample while discussing patenting: life sciences patents are more likely to be invented by women and benefit women. Koning et al. have found that biomedical patents from 1976 to 2010 show that all-female inventor teams are 35% more likely than all-male teams to focus on women's health and the effect is prevalent no matter the research area (Ferguson, Samila and Koning 2021). Explanations were given that women are more knowledgeable about female-based topics and are more willing to respond to the gender-based deficiencies of products.

We have three conclusions from the above literature: 1) Due to reasons such as pipelines and unbalanced granting results, female inventors suffer from the gender gap within the patenting process. 2) most of the gender gap research laid its attention on life sciences rather than the rest (life sciences patents are mainly seen in section C – Chemistry and Metallurgy, a few in section G – Physics). 3) Few pieces of literature trace the composition of the female inventor within a team – mainly, it is teams that contain one or more women, which aligns with the USPTO system and overlooks whether women play a major role in the inventing process.

II.ii. Gender-based labor patterns

One frequently used conceptualization to explain the underrepresentation of women in the STEM labor force is gender differences in abilities. According to this line of research, biological factors such as exposure to prenatal and postnatal testosterone and brain lateralization patterns enable men to outperform women in mathematics and visuospatial tasks (Baron-Cohen 2005). This weakened ability led to lower productivity.

Currently, there is no literature to be found that connects patent and gender-differentiated productivity, so I look into STEM research and publication for reference. One of the main claims is that women are less productive than men (for example, there is a gender productivity gap), and therefore, they write fewer scientific papers, receive fewer grants, and are hired less frequently than men. Some also suggest that women in STEM fields are, on average, significantly less productive than men at the assistant professor rank (Ceci, et al. 2014).

On the contrary, recent research shows that it is not the case in CS publications. A hand-curated list of education and academic appointment histories of tenure-track or tenured CS faculty dataset shows that productivity scores do not differ between men and women by taking a weighted z-score for overall subfields distribution (Way, Larremore and Clauset 2016). This result holds true even for men and women who moves down the rank. A Croatian research on the University of Zagreb STEM faculties found that STEM full professors are significantly more cited than their male colleagues (Wild, Jurcic and Podobnik 2020). Scientific productivity in western European economics and psychology also indicates that in younger generations, performance differences disappeared, and young women outperformed young men (Astegiano, Sebastián-González and Castanho 2022).

Moss-Racusin et al. found through an experimental approach that scientists rated a female candidate for a technician position to be less competent than a male candidate with an identical academic background (A., et al. 2012). Such gender bias against women contributed to the productivity gap because it implies that a woman scientist needs to outperform a man to be perceived and evaluated as similar.

PART III: DATA AND METHODOLOGY

This project uses USPTO's patentviews database and download five files: the "patents" dataset, which contains the patent number, the abstract, date of grant, etc.; the "cpc_section" dataset that contains NBER patent classification such as the unique id, the patent number, the category id, and the subcategory id; the "rawgender" dataset, that contains the inventor id and binary gender info (The current patent system does not allow registering for genders outside the binary gender so our calculations are all based on women by birth).; the "patent_inventor" dataset, which match the patent number to inventors; the "patent_assignee" dataset, which match patent ids to assignees. All data are public. Even though the patent inventor dataset carries names and one can indeed trace down the person's organization using existing info, this project does not utilize any private information, only ids rather than names were used in the analysis.

Our assumptions are as follows:

1) Due to a lack of resources, female inventors who moved from top companies to companies in the back of

the industry will invent less, female inventors who moved from the bottom will invent more, and female inventors who moved within bottom companies will continue to invent at a low amount.

2) Assume each inventor has an equal share of contribution within the patent.

3) Assume that in top-tier companies/institutions, opportunities and resources are fairly similar and available to workers of both genders.

The first and second section in Part IV points to the overall gender gap represented by the trend of patents with a majority of female (≧50% women) inventor teams and the pattern of female inventors' labor transfer. For the first section, I investigate the composition of female-majority teams and their outputs; for the second section, I look further into the individuals and their corresponding assignees.

Discrete steps for section two are as follow: A list containing the top 30 assignees in each year was formed and then matched with individual inventors to see whether they belong to the "top" assignees. For patents with multiple assignees, we extract the first rank assignee, which is the major assignee. This top-30 list contains 6901 assignees (duplicates included); after removing duplicates, 983 unique assignees are left. For each inventor, we check if his/her corresponding assignee is in that year's top 30; if yes, we assign them a "Top" tag. We then trace the change in their tag status: if one's tag changed from 0 to 1, this means the inventor moved upwards; if one's tag changed from 1 to 0, this means the inventor moved downwards; if one's tag stays the same, he or she could switch places within the lower or higher assignees.

The third section in Part IV measures the extent of majority-female teams yielding female-oriented patents. This section uses a series of topic modeling techniques and utilizes patent abstract and NLP models to determine if a similar pattern exists in section H; that is, patents made by women are more likely to benefit women. I again performed several large data mappings, merging, and transforming. I also created a library set based on several linguistics texts referenced above.

This set was based on aspects including pronouns, gendered nouns, proper nouns, gender revisions, gendered adjectives. This set eventually contains direct and indirect words that indicate grammatical gender, which is used to identify if the abstract contains words that indicate gender. For example, direct words include "women, woman, female, girl," etc. Indirect words include " actress, waitress," etc. One has to be very careful since in electricity, a female gendered word does not necessarily mean it is connected with women. One special case would be the word “female”, for example “The connector plug may be employed both with female outlets that are fitted with two and with three prong receptacles.” Another special case would be the words “mother” and “daughter” – sometimes they represent the relationship between different devices rather than “father” and “son”. See part of the abstract of id 3941442 for a better understanding: “An electrical connection between spaced and parallel mother and daughter boards including terminals secured to the mother board and projecting toward the daughter board having a pivot link arm with a daughter board-engaging member at the free end of the link arm and a daughter board spring contact.”

Based on the cleaned dataset, an abstract gets a "Female" tag if it hits one of the words in this library. The justification is that those tags capture meaningful differences in whether a patent is specifically used to benefit women.

Before heading on to the next section, I need to mention that it is not useful to identify only the "gender" of the text; in other words, we do not care if the writer of this abstract is male or female. A common situation is that even if a female majority team creates the patent, it could go through the hands of a male patent attorney and be written in a manly fashion. Moreover, gender-neutral words such as ‘people’ and ‘person’ are perceived as male for a lot of times (Cimpian and Williams 2022), chances are that if we make a male tag and create a library, the library may fail to catch those words. Based on such theory, Koning et al.’s gender gap calculated by male-tags minus female tags may not be accurate.

PART IV: STUDY RESULTS

IV.i. the overall gender gap represented by the trend of patents with female majority teams

Section H contains over 11 million patent records (however, this number contains multiple counts of different inventors on the same team, and some inventors’ records of gender are N/A). Our result shows that in 1976, among 10183 teams and individuals who received licenses, only 515 were female majority teams or single women, which reflects in a 5.06% of female-majority teams rate. In 2020 this percentage grew to 25.58%, increasing five times in the span during our sample span of 46 years. Figure 1 shows the general trend in the percentage of the female majority; the overall trend is increasing smoothly while a spike happened during 2021. The reason for such a phenomenon is unclear since the dates in our dataset are the date patents are being granted – not the date it was applied. It could be that during 2019 and 2020 significant number of women inventors submitted applications, or it could be that due to USPTO’s internal policy changes, female-majority teams’ applications are more likely to be granted. No matter how it is, we should acknowledge that there is still a long way to go to gender parity. It took 21 years for this percentage to double from 5.06% to 10.95%, and another 20 years to double from 12.72% to 25.58%, and it would be reasonable to believe that if nothing was changed, we could only reach gender parity in 2041.

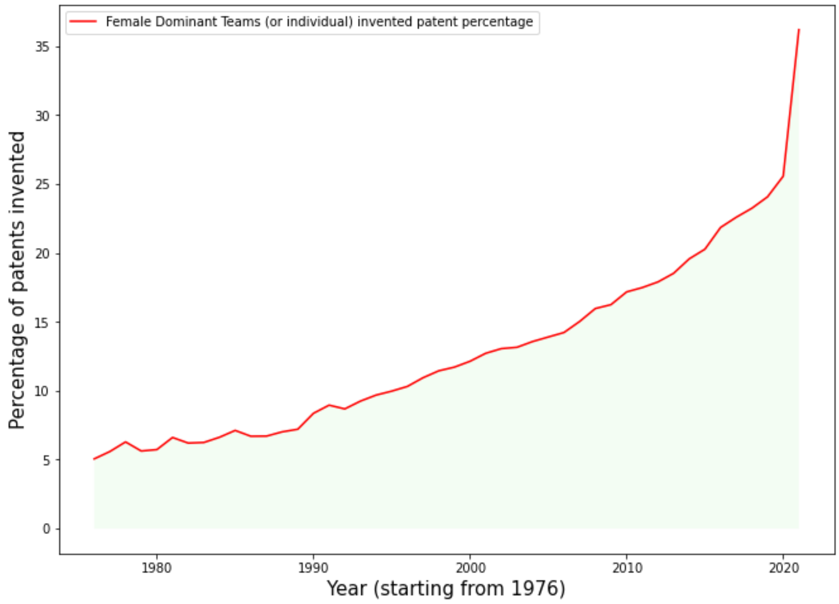

Figure 1: Percentage of Female Dominant Team invented patents to overall patents. (1976 – 2021)

Before being very optimistic about the future, Figure 2 shows a more concerning situation. Both the overall number of patents granted and the number of patents granted to male majority teams grew much faster than patents granted to female majority teams. The overall sum of patents also shares a similar pattern with male-dominated patents' growth. The overall sum of patents has a mean of 47049.9 and an STD of 40262.3; the male-dominated teams' patents have a mean of 44088.9 and an STD of 37005. However, the female trend has a mean of 3006 and an STD of 3359.9. This is our other evidence that the gender gap is not reducing as great.

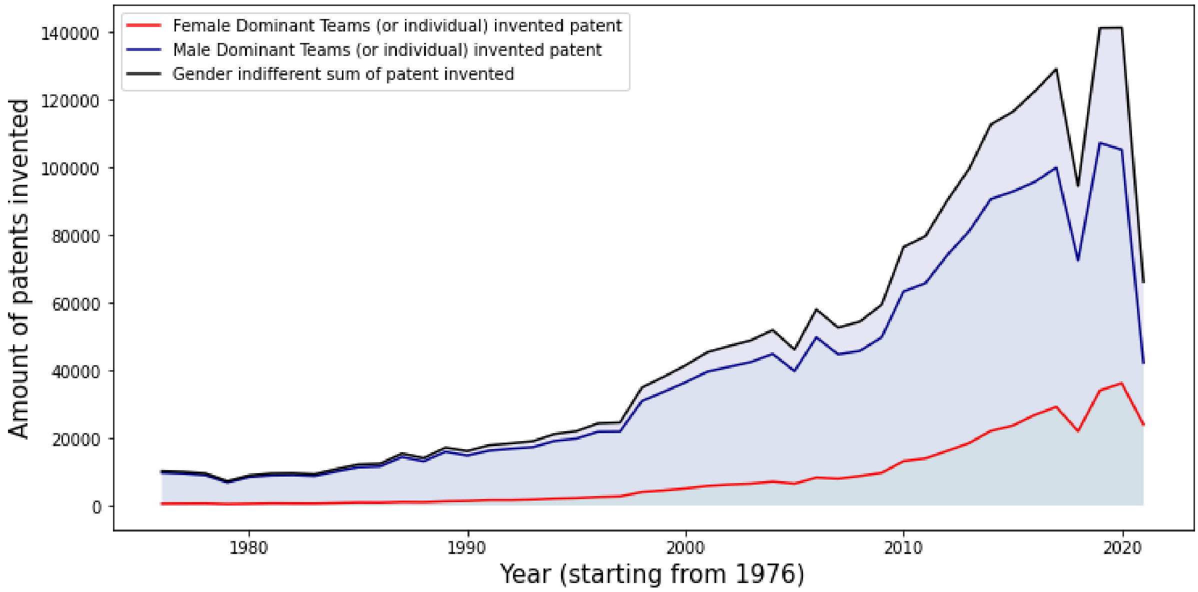

Figure 2: Trends of Patent volumes with respect to gender-based domination (1976 – 2021)

IV.ii. Individual labor transfers

In this section, I examine the change in the organization of individual female inventors and their corresponding productivity. It is common sense that granted patents are higher in quality and more advanced, representing a higher level of the patent assignee's (or the organization/institution) ability to invent and offer relevant resources for patenting.

We first discuss the trends happening in the top 30 assignees' male and female inventors. The detailed tagging process is already shown in the data and methodology part. We incorporate the same process on male inventors and compare them with our female numbers. Figure 3 & 4 displays an interesting phenomenon – the percentage of patents invented by the Top 30 assignees over the total invention pool has an overall decreasing trend through the years with small fluctuations. Figure 4's Top 30 Male inventor percentage in overall male inventors starts with 69.78% in 1976, peaked at 71.92% in 1981, and then falls from then on to around 53% in 2020. For women, it starts with 69.68% in 1976, peaks at 76.32% in 1981, and then falls to around 60% in 2020.

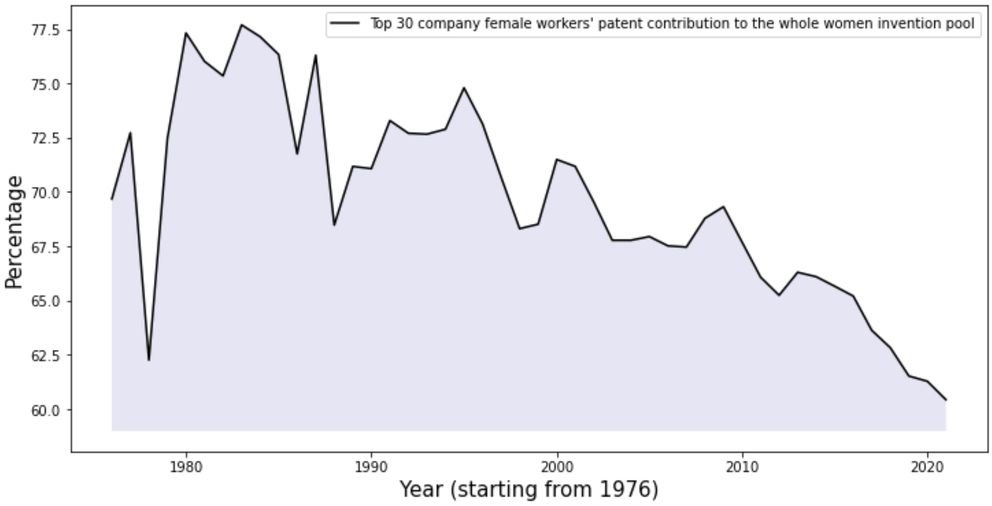

Figure 3: Percentage of patents created by Top 30 assignees' female inventors over the sum of the whole women inventors work force (1976 – 2021)

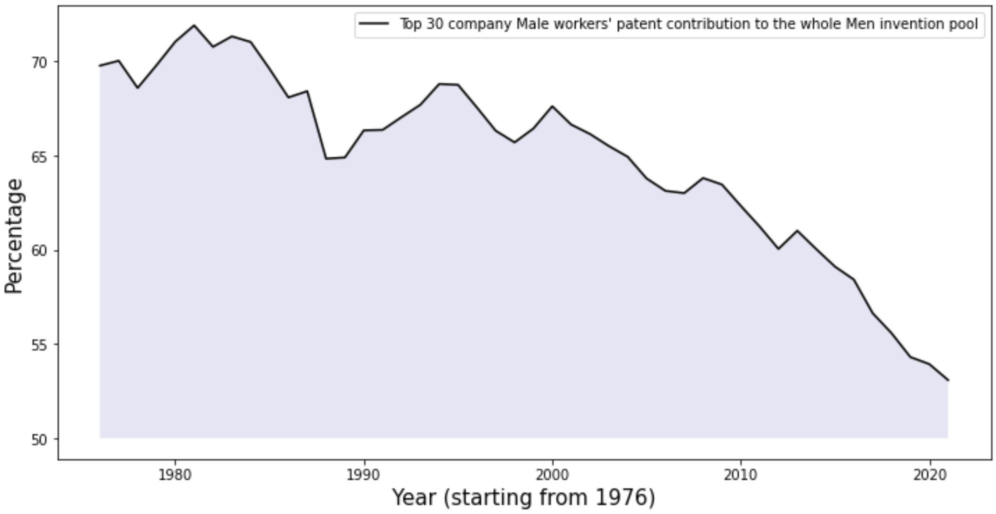

Figure 4: Percentage of patents created by Top 30 assignees' male inventors over the sum of the whole men inventors work force (1976 – 2021)

Looking closer to the timeline, those fluctuations of upward trend occurred during the 1980s Latin American debt crisis, the 1989-1991 United States Savings & Loan Crisis, the 1997 Asian Financial crisis, and the

2008 Global Financial crisis and recession. This makes complete sense as smaller companies cannot weather the turbulent economic environment; hence inventors dropped out of work, and patents got acquired by other companies while major companies stand and contributed relatively larger volumes of patents. If we compare men's and women's percentages, we see that women working in top assignees contribute a higher fraction in their corresponding gender invention pool. Women have less competition in their gender than men, but the swiftly increasing male inventor labor force should be concerned.

Meanwhile, a question lingers with the decreasing trend - are those top assignees' inventors really inventing less through time? The answer to this question is that the base of inventors increases vastly. With a stable growth rate in the expansion of those top assignees, their fraction is inheritably becoming lower. It is reasonable to assume that both genders have access to a similar number of resources among top assignees. For example, having better support in patent attorney usage, research funding, etc. Figure 5, displaying the growth rate change in the percentage of figures 3 & 4, shows that the change is stable within a fixed range, with women being a bit faster. This indicates that top assignees' women inventors are inventing more aggressively – refuting again that top assignees' inventors are not inventing less (note that this is an absolute less, not a relative less and we shall see this in a minute).

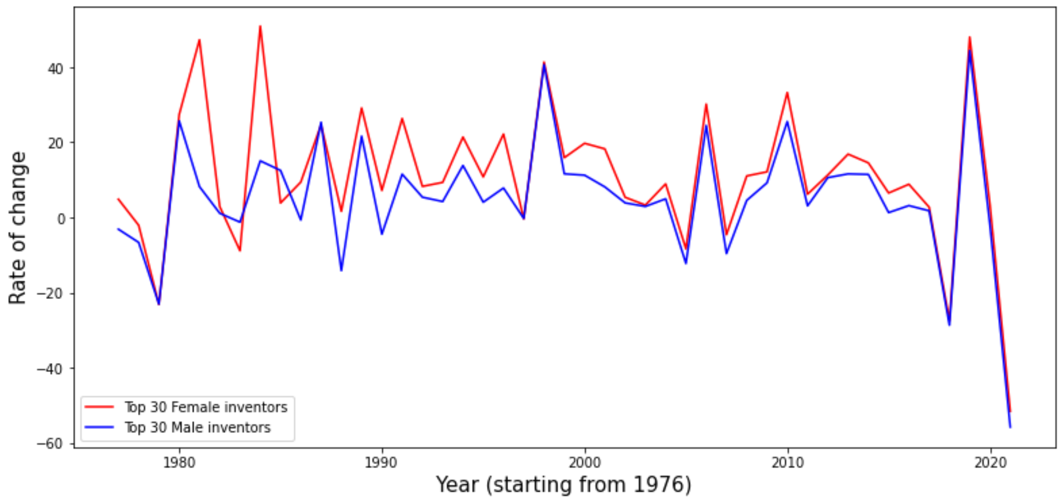

Figure 5: Percentage of patents created by Top 30 assignees' male inventors over the sum of the whole men inventors work force (1976 – 2021)

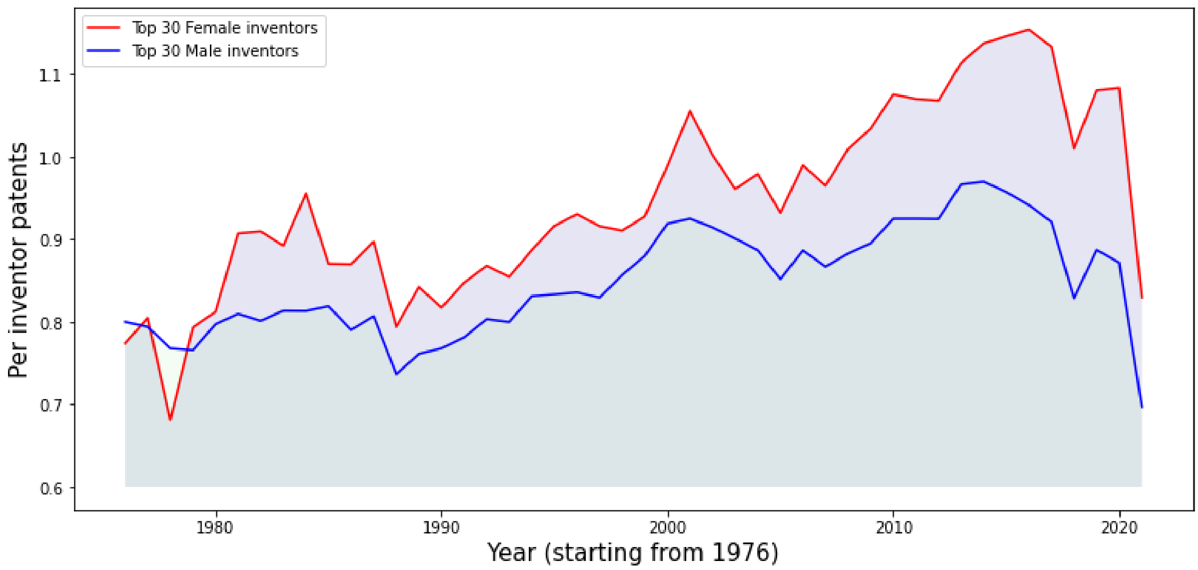

Figure 6: Per Inventor patents created by Top 30 assignees' male and female inventors over time

Digging deeper into productivity, Figure 6 shows the per inventor patent in the top 30 assignees' inventors for both genders. The per capita patents trend indicates that top assignees' women inventors have higher productivity compared with their male counterparts, and this productivity gap is widening. Numerically, women are on average 6% more productive than men, with a standard dev. of 8.4% and a median of 4.57%. This result becomes even more impressive, especially considering how women are at a disadvantage within a macro environment of gender disparity and can still be more productive. This result is also educative for companies in this field while making hiring or resource distribution decisions.

Figure 7 compares the growth rate of patents between female inventors who only stayed in the top 30 assignees, inventors switching at least once in their lives, and inventors who only stayed in non-top assignees. The Y-axis is this year's patents' growth compared with last year. This figure contains several interesting pieces of information: 1) Surprisingly, non-switchers from non-top companies have the highest growth rate but are more unresistant to economic recessions – yielding much fewer patents than switchers and top 30 workers. The high growth rate in recent years can be explained by the pressure of being more inventive to survive larger companies' lawsuits. 2) Switchers came second in terms of productivity in most years, as they have worked in both environments. They are also the group that performs the best during turbulent times. Possible explanations can be that one must be highly skilled to be able to switch, and the receiving assignee must provide a good number of resources to support. 3) Non-switchers in top-30 assignees had the least productivity, but they came second when it comes to recessions.

The sluggish trend in top companies could be explain by that they might have accumulated a significant number of important patents so less effort was needed since they are already advanced, or, it could also be that although the growth rate is slow, their patent may be of higher quality in terms of references and becoming standards. Overall, those trends did not vary much, indicating that a general trend in women's productivity exists. Those women productivity pattern echoes with previous research that for CS fields in particular, women are outperforming men in various dimensions.

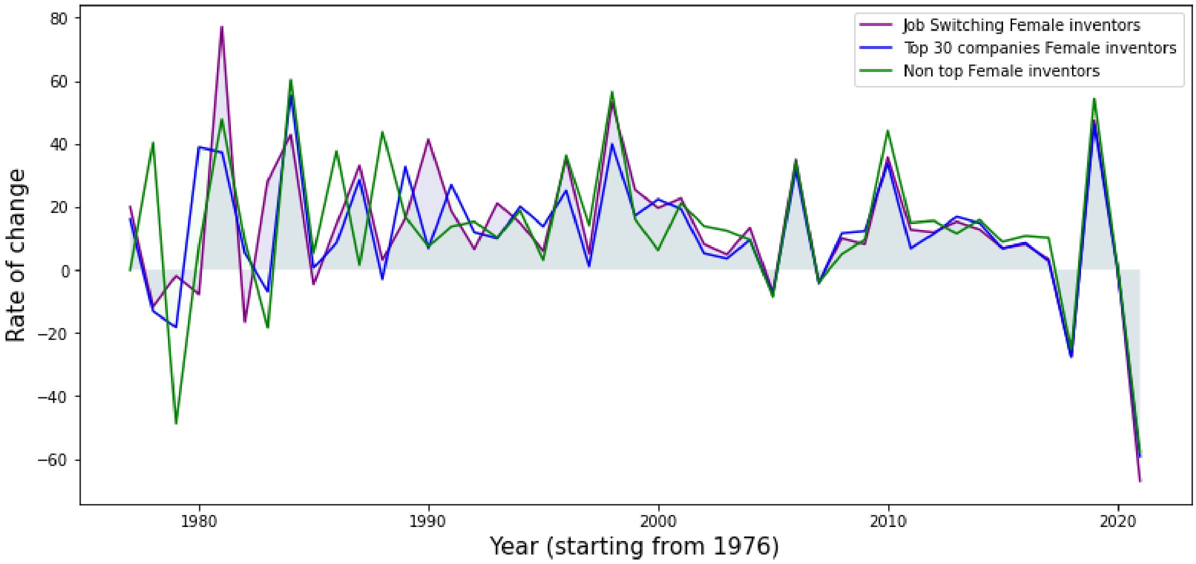

Figure 7: Growth rate of volume of patents created by Top 30 assignees' female inventors, Job Switchers, Non-top 30 female inventors

IV.iii. Patent Abstract and how it is related to women

After locating the exact position of patents that hits our gender library, a random sample was picked from multiple years to manual check if abnormal cases like the mother and daughter we've mentioned before occurs. Figure 7 shows the respective number of female-oriented patents invented by male and female inventors. On the left, the male trend increases before 2000, then decreased and fluctuated ever since. The maximum is at 244 patents and the next peak is at 192 patents in 2016. On the right, the female trend drops during 2000-2005, and then continuing to increase after 2005. Those are very informative results, on one hand, the overall volume of female orientated patents is decreasing; on the other hand, women themselves has become the central force of developing female orientated patents.

Section H is a smaller sample compared with Life sciences (our dataset is about 1/4 of Koning et al.'s). Due to the discipline-specific characteristics, electricity has fewer direct female-orientated patents. Still, this result is consistent with some of Koning et al.'s. Similarly, fewer women get to invent, and women's electricity inventions are more likely than men's inventions to focus on women, given the denominator of the number of female-majority teams. But life sciences have an increasing trend in female-focused patents by male-majority teams.

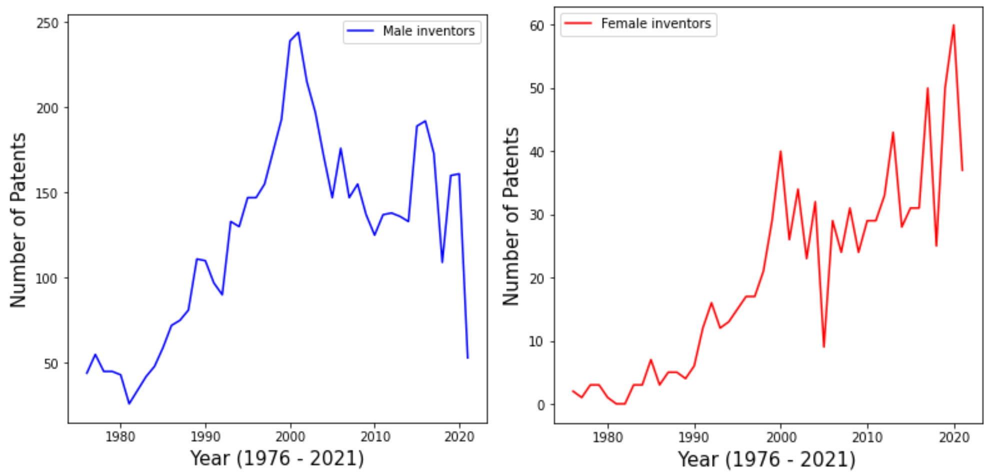

Figure 8: a. (left) Number of Male-focused patents invented by Male inventors

b. (right) Number of Female-focused patents invented by Female inventors

PART V. CONCLUSION AND DISCUSSION

This project has come to five central conclusions about Section H patents in the U.S.:

1. Although the gender gap within Section H patents is closing slowly, it remains large. This can be found from the trend that the percentage of women majority inventor teams within overall teams is still relatively low. The growth rate of patents from female majority teams does not catch up with the growth rate of men majority teams. If not fixed recently, it will take another 20 years until we eventually reach gender parity. Moreover, the current metrics that only looks at "at least one female on team" is insufficient, the female

majority rate is a better indicator.

2. Inventors from top assignees no longer play a dominant role in their corresponding gender invention pool as before 2000. Both trends are decreasing while women stay at a relatively high level. The reason is main from an expansion of the inventor workforce.

3. During recessions, job switchers yield the highest output, top assignees' inventors are more resilient but are slacker on ordinary days, non-top assignees' inventors suffer the most; in economic growth sessions, non-top assignees' inventors have the highest growth, job switchers come next, and top assignees' inventors are not as productive.

This conclusion comes highly novel and useful, since it provides guidance on which groups should receive the most attention during different times. Given a similar composition of institutional faculty, this conclusion may also be applied to the realm of higher education – extra funding is needed to persist innovation when schools do not possess high rankings.

4. Holding other factors constant, women are more productive than men in terms of volume growth and per inventor patents. Women has a high level of innovative potential and if supported with more resources they are bound to utilize it well.

5. Overall, electricity is not an industry with gender-oriented products. However, with our findings, we can observe the decrease in female-orientated patents with an increase in contribution directly from women. Combining with the results from life sciences, it is safe to conclude that women are more inclined to invent female-oriented patents.

There are a few suggestions derived from those conclusions:

1. Encourage female entry into patent-intensive STEM fields and careers and help them to stay.

From the perspective of productivity, greater inventor labor force participation rates among women scientists are associated with a greater number of innovations. Policies should be made to remove barriers for women to enter, for example, encourage companies/institutions to hire more female researchers in STEM or provide more funding for female teams. Academic institutions should provide scholarships and fellowships specifically for women to study patent-intensive STEM fields, collaborate with the industry to provide internships for girls studying STEM, and establish programs to support women advance to higher ranks in STEM research. This will not only promote gender equality but also will generate profit, especially in section H where Google, Microsoft and Amazon's cloud computation patents are located.

2. Encourage female-centered inventions both from men and women.

Such acts may not reverse the decreasing trend in a short time but will be useful to lessen the gender gap and make more people become aware of diversity. Furthermore, all levels of associations on the patenting chain should work to address sociocultural issues and bias that hinders inventors to step forward on female-specific patens. Especially given that part of the examination was done by AI, which makes the task of examination easier while challenging.

3.Targeted resources should be provided to females, especially female majority teams and non-top assignees' inventors for research in recessions. The complexity and cost of patenting process should both be reduced.

The USPTO should increase women's access to critical patenting resources. To be more specific, such resources include grant facilities and grant windows that provide awards specifically for women's research and innovation, research funding and deduction of application fees, maintenance fees, lawyer advisory service fees, etc. Non-top inventors are the most productive but most vulnerable group in hard times so they need this resource much more than the others. Moreover, given women's time challenges balancing work and family, the whole chain of patenting (USPTO, companies, etc) should be more efficient and applicant-friendly. For individuals, the direct lesson from conclusion 3 is that if one is looking for high performance, then top companies should not be their consideration; if one wants stability and resilience, it is best to enter top companies.

4. Improve the collection and use of sex-disaggregated data. Encourage more gender-related IP policy research.

The USPTO should continue to use the sex-disaggregated data currently collected through the patent application to systematically analyze and track progress over time in applications by gender, as a means of understanding trends and whether efforts to address gender specific barriers are bearing results. Plus, relevant administration should commission research on national IP policies and laws, that may discourage female patenting or erode gender parity. Targets should be set on specific contents that might generate negative consequences and measures should be proposed to rectify them.

There are some room to improve within this project:

1. Data: the inventor gender data is not complete, which means we are missing a small proportion of people; the assignee data contains a large fraction of individual inventors, although intuitively, their ability to invent most of the time does not exceed those who belong to organizations due to lack of equipment and other reasons, it would be too fast to conclude that their contribution is not worth considering.

2. Quality and Contribution: In this project, I assume individuals have an equal share in one patent but this

does not describe those individuals' contributions well. Inventors do not share the same amount of workload in reality, and the quality of patents differs.

3. Another drawback is that we are unclear about subsidiaries, and we even have several inventors who switched more than 100 times during their inventing life of less than 10 years– which can only be explained by inventing in a top assignee, but the patent was assigned to one of its subsidiaries for tax or other purposes.

The next steps of this project can be that:

1. Investigate the gender gap during the chain of patenting process.

If we break down the patenting chain, we may see various channels of gender gap. The gender gap starts as an inventor starts the application, then, prosecution, appealing, will also become gender filters. This process is relatively harder to track since the prosecution data containing replies and queries are not public. Moreover, when AI comes into play as examiners, how can we make sure that the AI don't automatically label men's patent as "with higher quality"?

2. It would be useful to build discipline-specific gender word libraries or algorithms that detect special words' surroundings. In this project, I found that there are no ready-made libraries to borrow from and abnormal cases interfere with identification precision. I was lucky to have a relatively small number of texts to eyeball through, but this will not always happen.

3. Taking patent quality into account to further measure both genders' impact. Quality can be measured by citations similar to the publication from STEM careers and we can see how various levels of citation correlates to gender compositions as well as productivity.

At the end of the day, everyone loses from the gender gap in innovation, and we should work together to bridge it.

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