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Inventor Gender and the Direction of Invention†

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Does who invents matter for what gets invented? An emerging literature shows that female scientists, inventors, and entrepreneurs are more likely to produce ideas, inventions, and companies that benefit women (Nielsen et al. 2017; Koning, Samila, and Ferguson 2019; Feng and Jaravel 2019). On the one hand, this link between the gender of the inventor and the "gender" of the invention might merely reflect occupational segregation and stereotyping (Goldin 2014; Hebert 2019; Tak, Correll, and Soule 2019): female inventors will sort into research areas that focus on women's needs. On the other hand, if female inventors bring to their work different types of knowledge, experience, and preferences, then the inventor-invention link may result from women discovering new, female-focused ideas that men would or could not. In this view, a rise in the share of female inventors will shift the supply of inventions toward the needs of women.

In this paper, we show that increasing the share of female inventors appears to shift the supply of inventions toward the needs of women. To do so, we use data on biomedical patents from Koning, Samila, and Ferguson (2019) that measure the gender of patent inventors, the gender focus of the patent, the diseases the patent addresses, and the technological approach used in the patent. We use this data to construct thousands of "market-level" disease-technology-year research areas. Similar to the approach taken in Azoulay et al. (2019), we then test whether research areas with a greater share of female inventors produce more female-focused inventions after accounting for disease-technology, disease-year, and technology-year fixed effects.

We find that a 10 percentage point increase in the share of female inventors yields 1.2 percentage points more female-focused patents. The positive coefficient suggests that, when women invent for women, they do not merely crowd out men, nor do they invent things that men would have otherwise invented. Notably, this effect holds only for lead female inventors. Areas with a greater share of female inventors in supporting roles do not produce more female-focused inventions. For gender to affect the supply of inventions, it appears that women must occupy positions of power.

While there has been a general increase in the number of female inventors, this growth has been markedly uneven. In the Surgery and Instruments technology subcategory, the share of women-led patents increased only slightly since 1990. Conversely, in the Drugs subcategory, the share trebled. Yet even within drugs, there is substantial variation in the share of female inventors by disease topic: some have zero female-led teams, and a few have more than 40 percent. Our estimate suggests that moving a disease-technology area from the average, 10 percent female led, to gender parity would result in 23.4 percent of inventions being female focused. As the average is 18.5 percent, this is a 25 percent increase.

Overall, our results suggest that increasing the diversity of inventors is likely to yield gains beyond improving the allocation of innovative talent (Bell et al. 2019). Even in 2010, there were areas of research that had essentially no women-run invention teams (Ding, Murray, and Stuart 2006). Our findings suggest these areas may be ripe with yet-undiscovered inventions that could benefit women. More generally, it appears that labor-market stratification and inequality may play a key role in shaping who benefits from product-market innovation.

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I. Data Description

Here we briefly describe the patent data we use in our analysis, which are from Koning, Samila, and Ferguson (2019). The data are an enriched version of the PatentsView-NBER patent dataset. They cover all biomedical patents (Category 3) granted between 1976 and 2010 and have measures of inventor gender, patent gender,[1] and patent disease topic. The latter two measures are generated by using a machine-learning algorithm applied to the text of each patent. Here, we restrict the data to patents from the two technology subcategories that cover 90 percent of all biomedical patents, (i) Surgery and Instruments and (ii) Drugs.

To build disease-technology-year area observations, we rely on the Medical Subject Headings (MeSH) present in the enriched patent data. These MeSH terms, similar to *Journal of Economic Literature* keywords, provide nested measures of the content of the patent. For example, the term "Cataract [C11.510.245]" is listed under "Lens Diseases [C11.510]," which is listed under "Eye Diseases [C11]," which is in turn listed under "Diseases [C]." To build disease-technology-year areas, we focus on all patents that match to a disease at least at the third numeric level of the MeSH tree (e.g., Cataract [C11.510.245]). We then aggregate the 505,152 matching patent-disease observations into 18,913 disease-technology-year observations. Our data contain 558 disease topics, two technology types, and 34 years. The average disease-technology-year area in our data has 28 patents.

For each area, we calculate the shares of female-led invention teams and invention teams with nonlead female members. We use the "authorship" order of inventors listed on the patent to measure whether an inventor is the team lead. Invention teams are female led 9.8 percent of the time. A further 13.4 percent have women inventors listed in other positions.

To calculate the share of inventions in an area that are female focused, we simply count the percent of patents that match to the "Female" MeSH term in the area. A patent that matches to this term is one that has text that covers "female organs, diseases, physiologic processes, genetics, etc." In the average area, about 18.5 percent of patents are female focused.

II. Uneven Rise of Female Inventors

We begin our analysis by documenting substantial growth and variation in the share of female-led invention teams across disease-technology-year areas. Here we focus on lead inventors, as prior work has documented that women are especially likely to invent for women when in positions of power (Nielsen et al. 2017; Koning, Samila, and Ferguson 2019). The variation we document is not just longitudinal but occurs within and across disease topics and technology subcategories.

Figure 1, panel A, shows that, even within disease topics, there is meaningful variation in the female-inventor share over time and across technology subcategories. The figure plots the percentage of female-led teams in an area net of disease fixed effects. While Surgery and Instruments patents and Drugs patents had similar female-inventor shares in the 1980s, the trends markedly diverge after 1990. By 2010, more than 15 percent of Drugs patents were female led, compared with less than 10 percent of Surgery and Instruments patents. This divergence is consistent with women having experienced especially hostile work environments in surgical fields (Conley 1999). Figure 1, panel B, plots kernel-density estimates for the share of female-led inventions across disease topics in 2010 and in technology subcategories. Even in 2010, the range includes disease topics with no lead female inventors and topics with 40 percent women-run teams. The distribution of female inventors across areas appears markedly uneven.

III. The Supply of Inventions

To test whether disease-technology-year areas with more women are more likely to invent for women, we estimate the following model using ordinary least squares:

$$
\begin{aligned}
(1)\qquad & \mathit{ShareFemaleFocused}_{dty} = \\
& \beta_1 \mathit{FemaleLeadInventor}_{dty} + \\
& \beta_2 \mathit{FemaleNonleadInventor}_{dty} + \\
& \delta_{dt} + \gamma_{dy} + \zeta_{ty} + \epsilon_{dty}.
\end{aligned}
$$

[1] We refer to the gender focus of the invention as a parallel to inventor gender. To be clear, our measure of patent gender comes from the patent's text, which nearly always references biological differences between the sexes.

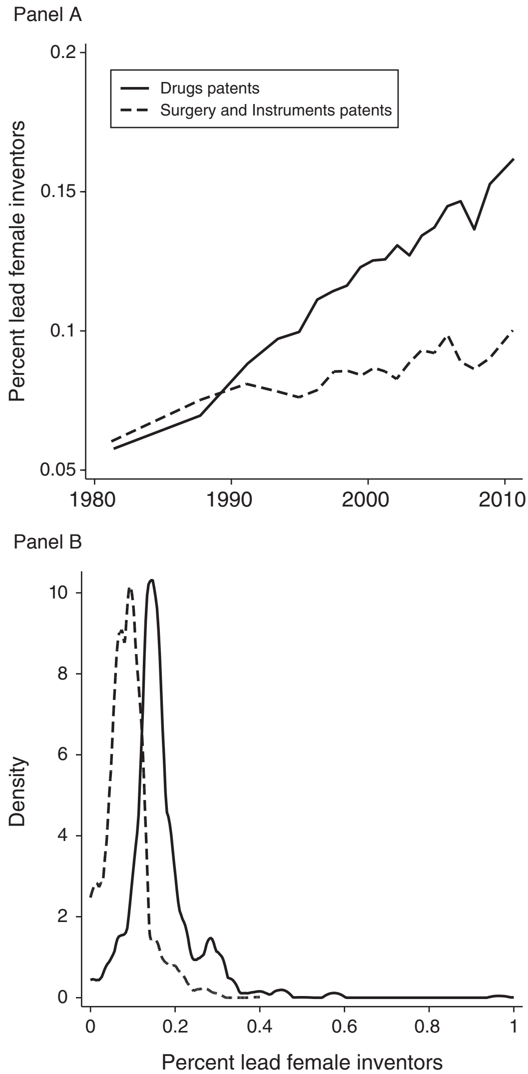

Figure 1. The Share of Female-Led Teams over Time and across Disease Areas

Notes: Panel A shows the average percentage of female-led teams in an area after accounting for disease-level fixed effects. Panel B shows the kernel-density estimate for female-led teams across disease areas in 2010. In both panels, the solid line is for Drugs patents and the dashed line is for Surgery and Instruments patents. Both are weighted by the number of patents in the disease area.

The dependent variable is the share of female-focused inventions, β_1 is the effect of increasing the share of female-led invention teams in an area, and β_2 is the effect of increasing the share of nonlead female inventors. We include the nonlead share as a point of comparison to test whether what matters is mere representation or whether it is representation coupled with positional power that grants more discretion. The model also includes fixed effects δ_{dt} for disease-technology, γ_{dy} for disease-year, and ζ_{ty} for technology-year pairs. In our most detailed model, we also include fixed effects for the number of patents in the area.

Our identifying variation comes from within-disease-year or within-technology-year changes. This identification strategy is an improvement over the standard disease-level fixed-effects models used to study shifts in the direction of science and innovation (Azoulay et al. 2019). That said, it does leave open the possibility that women inventors sort into technology-disease areas that increasingly focus on the needs of women, over and above any shifts occurring within the disease or the technology. While this is no doubt possible, prior work suggests some skepticism is warranted, given that the decision of whether, when, and where to innovate is often made with less than perfect strategic foresight (Azoulay, Liu, and Stuart 2017; Azoulay et al. 2019).

Table 1 presents our models regressing the share of female-focused inventions on the gender composition of the inventor pool. All models are weighted by the area's patent count, and we exclude areas with fewer than five patents to avoid overfitting the extreme share shifts that can occur in small populations (e.g., three women-led teams in a three-patent area). Doing so reduces our number of observations to 9,667. The online Appendix presents robustness checks, including checks that show that our results hold with unweighted regressions and with no count cutoffs.

Returning to Table 1, Model 1 includes only disease-technology fixed effects. We find positive estimates for both female-inventor-share variables ($p \leq 0.001$). In Model 2, we include disease-year fixed effects, which reduces the number of observations to those with multiple disease-technology years. In this model, the effect of nonlead female inventors shrinks and becomes insignificant. This suggests that areas that increasingly focus on women's needs do pull in more female inventors, but that this sorting does not extend to leadership positions. Model 3 includes the technology-year fixed effects and Model 4 the patent count fixed effects. In

Table 1—Effect of Female-Inventor Share on the Share of Female-Focused Inventions

	Percent female-focused patents			
	(1)	(2)	(3)	(4)
Percent female lead inventors	0.091 (0.022)	0.111 (0.039)	0.103 (0.043)	0.120 (0.045)
Percent nonlead female inventors	0.086 (0.018)	0.022 (0.032)	0.010 (0.036)	−0.025 (0.038)
Disease × technology fixed effects	Yes	Yes	Yes	Yes
Disease × year fixed effects		Yes	Yes	Yes
Technology × year fixed effects			Yes	Yes
Patent count fixed effects				Yes
Observations	9,667	5,656	5,656	5,320

Notes: The table shows disease-technology-year area observations. Estimates are weighted by the number of patents in the area. Areas with fewer than five patents are excluded. Standard errors are clustered at the disease and technology level.

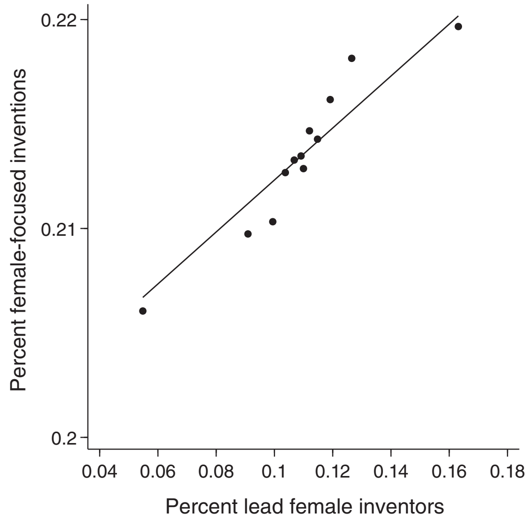

Figure 2. Binned Scatterplot of Female-Focused Inventions on Female Lead-Inventor Share

Notes: The figure shows the percentage of female-focused inventions after accounting for disease-technology, disease-year, technology-year, and patent count fixed effects. Estimates are weighted by area patent count; areas with fewer than five patents are excluded.

both, we find that areas with a greater share of female-led teams have more female-focused inventions ($p \leq 0.01$).

Finally, in Figure 2, we present a binned scatterplot of the areas' female-focus shares against their female-led teams' shares. The figure mirrors the specification in Model 4. We find a relatively clean linear relationship. Moving from 6 percent to 16 percent of patents' having a female-run team leads to about 1.2 percent more female-focused patents.

IV. Conclusion

Consistent with the view that female inventors bring with them different experiences, knowledge, and preferences, we find that research areas with more women produce a greater share of female-focused inventions. While many questions remain, we see these as promising areas for future research. Does this increase happen at the expense of male-focused research, or does it come at the extensive margin? Does this shift in direction stem from women having better information, or stronger motivation? What are the downstream impacts on female-focused products and women's health outcomes (McDevitt and Roberts 2014)?

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