REPORT

# Who do we invent for? Patents by women focus more on women's health, but few women get to invent

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## Invention and identity

Members of social groups may be more likely to patent inventions targeted toward their own group's needs and interests. Koning *et al.* examined US biomedical patents and found that although fewer women engage in commercial patenting compared with men, their patents are more likely to focus on women's health (see the Perspective by Murray). In an evaluation of biomedical articles, the researchers found that women were also more likely to make scientific discoveries that might lead to women's health patents. These findings demonstrate that a lack of representation among inventors translates into a lack of breadth in inventions.

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## Abstract

Women engage in less commercial patenting and invention than do men, which may affect what is invented. Using text analysis of all U.S. biomedical patents filed from 1976 through 2010, we found that patents with all-female inventor teams are 35% more likely than all-male teams to focus on women's health. This effect holds over decades and across research areas. We also found that female researchers are more likely to discover female-focused ideas. These findings suggest that the inventor gender gap is partially responsible for thousands of missing female-focused inventions since 1976. More generally, our findings suggest that who benefits from innovation depends on who gets to invent.

The inventor gender gap is well established. Although progress has been made, women are still less likely to enter STEM (science, technology, engineering, and mathematics) occupations, less likely to continue in scientific careers, and less likely to become inventors (*1*–*6*). Even today, only 35% of STEM scientists and 13% of U.S. patent inventors are women, suggesting that there are many "lost Curies," talented girls who never grow up to discover and invent (*7*–*9*).

Although the gap itself is cause for concern, its consequences may extend beyond the labor market (*10*). It is possible that women are more likely to invent for women, and if so, the dearth of female inventors may cause society to supply too few inventions that benefit women. Recent work suggests a shortage of projects, procedures, and products aimed at female patients' needs (*11*–*13*). Anecdotal evidence abounds that a disproportionate share of female-focused inventions—such as ovarian cancer tests, personalized breast cancer trials, and cataract-removal proce-

dures [cataracts are more common in women than in men (14)]—are invented and brought to market by women (15–17).

Yet, there is little systematic evidence on whether female-invented products are more likely to focus on the needs of women, especially in knowledge-intensive domains such as biomedicine. On the one hand, the lived experiences of female inventors may lead them to see opportunities to invent for people like themselves, specialize in clinical and disease areas that men may overlook, and invent with more knowledge of women's health (18, 19). On the other hand, medical inventors generally have extensive training in MD and PhD programs, which could eliminate knowledge differences between male and female researchers. Furthermore, inventions follow market demand (20). It could be that inventors, male or female, simply invent where the market pulls them.

We measured the gender of inventors and the sex focus of their inventions for all U.S. biomedical patents filed between 1976 and 2010. We found that in this field, inventions by women are more likely to focus on the medical needs of women. This pattern is strongest for all-female invention teams, holds over decades, and is present even within narrow areas of invention. This last finding suggests that the female inventor-invention link is both the result of women working in more female-focused research areas and female inventors identifying opportunities to invent for women regardless of the area in which they work. We also analyzed biomedical research articles between 2002 and 2020 and found that female-discovered ideas are also more likely to be female-focused. That upstream research ideas also exhibit a female inventor-invention link further suggests that the gender gap in who commercializes their ideas has contributed to the sex gap in what types of ideas become inventions.

The starting point for our analysis was a new measure for a patent's focus on the medical needs of men and/or women. We extracted the title, abstract, and start of the summary text from the 441,504 "Drugs and Medical" patents in the PatentsView-NBER (National Bureau of Economic Research) dataset. We then fed this text through the National Library of Medicine's Medical Text Indexer (MTI) (21).

The MTI algorithm uses machine learning to map text to the Medical Subject Heading (MeSH) terms that most likely reflect the text's content. More details are provided in supplementary text S1.

The MeSH ontology includes two tags for the sex focus of the patent. A patent's text gets the "Female" tag when it covers "female organs, diseases, physiologic processes, genetics, etc." There is a parallel "Male" tag. We refer to the 12.76% of patents that the MTI tagged "Female" as female-focused patents. Conversely, 13.27% of patents are male-focused. In supplementary text S2, we validate the MTI algorithm, showing that it works well with patent text and that its accuracy is unbiased with respect to inventor gender. In supplementary text S3, we show that although the female and male MeSH tags are a coarse measure of sex focus, they capture meaningful differences in the likelihood that a patent benefits women or men. For example, with word-embedding methods and clinical-trial data, we show that female- and male-tagged patents are roughly 400% more likely to describe inventions that would be evaluated by a female- or male-only trial. Furthermore, with data on disease incidence, we show that patents tagged as female address diseases that affect roughly twice as many women; we found a similar pattern for male-tagged patents and men. We measured inventor gender using a standard dictionary-matching process (supplementary text S4). Our last sample includes 430,060 patents with inventor-gender and sex-focus measures.

Our first set of analyses explored raw trends in the gender composition of inventors. We did so by splitting our data into two groups: patents with majority-female inventing teams (≥50% women) and patents with strictly more male inventors (>50% men). In Fig. 1, we show that women-invented biomedical patents are on the rise, growing from 6.3% in 1976 to 16.2% in 2010. Yet the 3014 inventions by female-majority teams in 2010 are still outnumbered by the 3347 patents invented by men nearly four decades earlier, in 1976. In total, male-majority teams generated 373,774 patents, whereas female-majority teams generated 56,286.

**Fig. 1 Total number of U.S. biomedical patents over time along with the number of patents with majority female (≥ 50% women) and majority male (> 50% men) inventor teams.**
The figure includes 430,060 patents from 1976 through 2010.

Trends in the sex focus of invention for male-majority teams are shown in Fig. 2A and those of female-majority teams in Fig. 2B, with the black solid line and gray dashed line showing the percentage of patents that are female-focused and male-focused, respectively. Male-majority teams invented more for men than for women in all but 1 year of our data (Fig. 2A), although the difference has shrunk. In 1976, patents by male-majority teams were 15% more male-focused (11.2%) than female-focused (9.7%); in 2010, patents by male-majority teams were 6.2% more male-focused (13.7%) than female-focused (12.9%). This narrowing follows efforts by the National Institutes of Health and National Science Foundation starting in the late 1980s to promote research on women's health (*22*). Overall, of the 373,774 patents invented by male-majority teams, 49,886 (13.3%) were male-focused, 46,453 (12.4%) were female-focused, and the rest were tagged as not sex-focused.

**Fig. 2 Percentage of U.S. biomedical patents that are male-focused and female-focused broken out by the gender composition of the inventor team.**
(**A**) The percentages for patents with majority-male teams (>50% men). (**B**) The percentages for patents with majority-female teams (≥50% women).

Female-majority teams are substantially more likely to invent for women and only slightly less likely to invent for men than are male-majority teams (Fig. 2B). In 1976, patents by female-majority teams were 7% more male-focused (12 versus 11.2%) and 37% were more female-focused (13.3 versus 9.7%) than patents by men. As with male-majority teams, by 2010, female-majority teams invented more often for both sexes. On average, of the 56,286 patents invented by female-majority teams, 8246 (14.7%) were female-focused, 7053 (12.5%) were male-focused, and the rest were not tagged as sex-focused. Compared with male-majority teams, female-majority teams are only 6% (12.5 versus 13.3%) less likely to invent for men but are 18.5% (14.7 versus12.4%) more likely to invent for women.

The inventor gender gap amplifies these invention sex gaps (Fig. 3). The number of female-focused minus male-focused patents invented by male-majority teams over time is shown in Fig. 3A. Such teams regularly invent more than 100 additional male-focused inventions per year. The same difference for female-majority teams is shown in Fig. 3B. Male and female inventors seem to have offsetting tendencies, but because there have been so many more male inventors, in aggregate invention has been skewed toward men's health (Fig. 3C). The rising share of female inventors, and their increased focus on the needs of women, has begun to close and in some years flip the invention sex gap.

**Fig. 3 The number of female-focused patents minus male-focused patents over time.**
(**A**) The gap for patents with male-majority inventor teams (>50% men). (**B**) The gap for patents with female-majority teams (≥50% women). (**C**) The gap when including both types of teams.

To further explore the magnitude and consequences of this female inventor-invention link, we turned to patent-level models that regress a patent's female focus on whether the invention team falls into one of four buckets: all female, majority (50% or more) but not all female, minority female, and all male (our excluded baseline). Our model includes fixed effects for the year interacted with the patent's subcategory (drugs, surgery and instruments, biotechnology, or other) and the patent team's size (*23*). Additional details and tables are provided in supplementary text S5. The estimates from this model, shown in black in Fig. 4A, show a clear dose-response relationship, increasing from 1.3 ± 0.16 (±SE) ($P < 0.001$) percentage points for minority-female teams to 2.4 ± 0.19 ($P < 0.001$) for majority-female teams, and to 4.6 ± 0.30 ($P < 0.001$) for all-female teams. These reflect relative increases of 10, 18, and 35% over the baseline female-focused invention rate of all-male teams.

**Fig. 4 The increased chance, in percentage points, that a female-invented patent or research article is female-focused, compared with a patent or article from an all-male invention team.**

The bars show robust 95 and 99% confidence intervals. (**A**) Estimates using the patent data. Black estimates come from a model fit by using OLS with year × subcategory and year × team size fixed effects. The gray estimates are from models that match teams with female inventors to all-male teams by using the patent's year, subcategory, team size, and disease focus. The full sample includes 430,060 patents; the largest matched sample includes 45,751 patents. (**B**) Estimates using the research article data. Black estimates are from models fit by using OLS with year × journal and year × team size fixed effects. The gray estimates are similar but also match teams with female scientists to all-male teams by using the article's year, team size, and disease focus. The full sample includes 2,062,695 articles published in the 1000 journals in PubMed with the highest commercialization impact factors from 2002 through 2020; the largest matched sample includes 119,650 papers.

These estimates are the result of two possible pathways. First, women might work in more female-focused research areas. Second, women might draw on different experiences and knowledge, regardless of their research area. If the first pathway is the main one, then the benefit to women of there being more female inventors will be concentrated in areas that are already female-focused (for example, additional pre-eclampsia treatments). If the second pathway matters more, then women would also see benefits in research areas without a strong prior sex focus (for example, female-focused atrial fibrillation treatments).

To isolate the within-research-area mechanism, we matched female-invented patents to male-invented patents using the patent's publication year, subcategory, team size, and the narrow MeSH level-four disease area most associated with the invention [for example, 1983 drug patents for atrial flutter (C14.280.067.248) with two inventors, or 1990 surgery patents for atrial fibrillation (C14.280.067.198) with three inventors]. The estimates in Fig. 4A in gray come from this matched sample, which is roughly 1/10th the size of our full sample and includes year × subcategory × team size × disease fixed effects. After tightly matching within research areas, just over half of the total effect remains, with effect sizes for minority, majority, and all-female teams of 0.67 ± 0.37 ($P = 0.36$), 1.3 ± 0.37 ($P = 0.002$), and 2.8 ± 0.55 ($P < 0.001$) percentage points, respectively. The female inventor-invention link stems equally

from women working in female-focused research areas and from women spotting opportunities in other research areas.

In the supplementary materials, we report additional analyses. In supplementary text S6, we show that inventions by women are not merely more sex-focused in general, which could be so if women work in applied areas in which anatomical sex differences are more central or if women are more likely to run sex and gender analyses (*24*). Instead, and consistent with Fig. 2, we found that teams with female inventors, as compared with all-male inventor teams, are neither more nor less likely to invent for men. Robustness checks are provided in supplementary text S7, including analyses showing that patents with all-female teams target diseases that affect 16% more women and are roughly 40% more likely to describe an invention that would be evaluated by a clinical trial that only enrolls women. Our within-disease-area findings hold if we instead rely on different matching criteria, multidimensional disease fixed effects, or lasso-style machine-learning methods (supplementary text S8), all of which further account for differences in which areas women and men invent.

In supplementary text S9, we show our exploration into heterogeneity in the female inventor-invention link. We found little evidence that the female inventor-invention link has consistently increased or decreased with time. We found suggestive evidence that all-female teams are 2.4 percentage points more likely to invent for women in non-corporate than in corporate settings, which is consistent with the idea that limited women's representation in corporate management leads firms to overlook female-focused research and development opportunities (*25*). We also show that all-female teams are 8.7 percentage points more likely to invent for women in the surgery subcategory, versus 2.3 percentage points in drugs. This last difference is consistent with the idea that the historical hostility toward women in surgery (*26*) has both involved men dismissing promising female-focused surgical ideas and women being especially likely to develop those ideas.

Overall, we found that women's biomedical inventions are more likely than men's inventions to focus on women's needs. That said, patents are a downstream outcome in the process of discovery and invention. Perhaps nascent female inventors discover ideas for both sexes equally, but gender stereotypes lead women to not patent their male-focused ideas (or men to not patent their female-focused ones). Differential selection into patenting, not differences in the knowledge and experiences that women bring to the discovery process, might be responsible.

To test for differential selection, we used data on the upstream research ideas that biomedical patents build on. Specifically, we analyzed 2,062,695 original biomedical research articles from the National Library of Medicine's PubMed database that are at risk of being commercialized and were published between 2002 (the first year we have data on the authors' gender) and 2020 (supplementary text S10). We again used the MeSH ontology's "Male" and "Female" check tags to asses articles' sex focus, but we did not use the MTI algorithm because articles in PubMed are assigned MeSH tags by human medical indexers.

Research teams with more women are more likely to discover for women (Fig. 4, A and B). There is again a clear dose-response relationship, with the effect increasing from 0.84 ± 0.08 ($P < 0.001$) to 3 ± 0.08 ($P < 0.001$) to 4.5 ± 0.12 ($P < 0.001$) percentage points for minority, majority, and all-female teams, respectively. As in Fig. 4A, the gray estimates in Fig. 4B involve matching and fixed effects to account for differences in men's and women's publishing rates in different narrow disease areas (supplementary text S11). Although the coefficients shrink, the differences are small and nonsignificant. Compared with the baseline female-focused publication rate, papers with all-female teams are about 12% more likely to focus on the health needs of women. Additional robustness tests are reported in supplementary text S12, including analyses that show that discoveries by women are not more likely to be male-focused, that our findings hold under alternative matching schemes, and that discoveries by all-female teams target diseases that affect 47% more women and are >40% more likely to describe an idea that would be evaluated by a clinical trial that enrolls only women.

These findings imply that many promising female-focused discoveries have yet to be commercialized because women are less likely to obtain patents (*1*, *27*). Rough calculations (supplementary text S13) suggest that if all the patents invented between 1976 and 2010 had been produced by men and women equally, then there would have been around 6500 more female-focused inventions. Even when we focused within research areas, thus holding constant the number of patents produced across areas, we still found that inventor gender equality would have resulted in just over 3500 more female-focused inventions. If research articles were produced equally by men and

women, then from 2002 to 2020 there would have potentially been 40,000 more female-focused discoveries. This suggests that there may still be many untapped market opportunities to invent for women—opportunities that could in turn improve women's health.

These estimates of the number of lost female inventions are suggestive. The primary goal of this study is to establish a link between the background of inventors and who might benefit from their inventions. We did not observe the counterfactual world in which there are more (or fewer) female inventors or scientists. Hence, the evidence presented here cannot tell us whether women's female-focused inventions could have instead been invented by all-male teams, or the extent to which female inventors might displace men from working on women's health, or whether women might instead pursue other, non–female-focused ideas if there were a greater share of female inventors and inventions. Our analyses also cannot tell us whether the gender mix of inventions is or ever has been socially optimal. Last, although recent work has found that demographic similarity between doctors and patients improves female and African American health outcomes (*19*, *28*, *29*), our analysis does not shed light on whether female-invented and -focused patents are more original or impactful. We see each of these limitations of the present study as a promising avenue for more research.

That research should not be limited to the differences between men and women nor to biomedicine. Our findings sketch a road map for future research on demographics and innovation. Reducing the barriers that disadvantaged groups face when working and inventing has accounted for a nontrivial share of economic growth over the past century (*30*). In virtually all cases, though, whether the population under study has been 19th-century Black inventors (*31*), early-20th-century Eastern European scientists (*32*), or some other group, the focus has been on how discrimination has reduced the overall level of innovation. By contrast, we found a robust and sizable connection between inventor gender and the sex focus of inventions. This is one step in showing how labor-market bias might spill over into product-market bias. Whereas earlier work on gender and innovation has focused on estimating biases against entrepreneurs and inventors while holding the underlying idea constant [for example, (*33*)], we hope that future work will focus on understanding bias against ideas that especially benefit historically disadvantaged groups (*34*). Our findings here suggest that inequities in who invents may lead to inequities in who benefits from invention.

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## Supplementary Material

### Summary

Supplementary Text

Figs. S1 to S8

Tables S1 to S50

References (*36*–*54*)

### Resources

File (aba6990-koning-sm.pdf)

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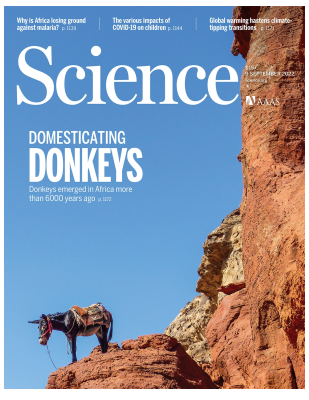


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