Attrition and the Gender Innovation Gap: Evidence from Patent Applications *

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Abstract

We consider the role of differential responsiveness to rejection as a contributor to the innovation gender gap. Leveraging the prosecution histories and outcomes of almost one million U.S. patent applications and the quasi-random assignment of applications to examiners, we show that women are 3.3-7.3 percentage points less likely to continue in the application process following an early-stage rejection. Male-female disparities in the propensity to abandon applications accounts for more than half of the overall gender gap in issued patents. We document suggestive evidence of differential resources and environmental constraints being potential contributors to the attrition gap.

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1 Introduction

By a variety of measures, women are underrepresented in innovative activity in the United States. In 2020, only 20% of all patents had one or more female inventors (Toole et al., 2020). This disparity in patenting (and innovative activity more generally) has important implications for gender inequality, since innovators receive direct benefits from patenting activity in the form of increased wages (Kline et al., 2019) and improved career trajectories (Melero et al., 2020). Moreover, the underrepresentation of women in patents may have adverse consequences for the distribution of benefits from innovation more broadly (Bell et al., 2019). Research teams including women are significantly more likely to produce female-focused innovations (Koning et al., 2021).

While the underrepresentation of women in innovation and patenting is now well-documented, the specific drivers of this disparity are not well understood (Jensen et al., 2018; Sarada et al., 2019). Understanding the sources of gender differences is important because different explanations for the innovation gap have policy implications. For example, bias against female innovators will have a very different policy response than gender differences in the quality of applications submitted for patent protection.[1]

In this paper, we study a novel channel driving the gender patent gap: the differential tendency to exit the patent application process after receiving an initial rejection. To quantify the importance of this channel, we utilize a unique feature of the patent prosecution process, which is that applications are never categorically rejected (and indeed most applications are ultimately accepted), but rather abandoned by applicants following what are appealable rejections issued by patent examiners (Lemley and Sampat, 2008). Using detailed data from the United States Patent and Trademark Office (USPTO), we find that women are less likely to follow up on applications after receiving initial negative feedback as compared to male applicants. Female inventors' increased propensities to exit the application process after an early-stage rejection explain approximately half

[1] To offer a preview: we find no evidence of either gender discrimination or gender differences in patent application quality.

of the gender gap in patent issuance rates.

To address the concern that the quality or content of a patent application is correlated with gender, we employ an instrumental variables (IV) strategy that leverages the quasi-random assignment of applications to patent examiners, who differ in their tendency to approve patents.[2] We show that drawing a more stringent (or "harsher") examiner increases the probability of receiving an initial rejection, independent of patent quality or other ex-ante application/inventor characteristics. We thus use the exogenous variation in patent rejection rates that arises from quasi-random assignment to examiners to approximate random exposure of marginal patent applications to early-stage application rejections.

Our central finding is the gender differential in attrition within the patent application process is an important contributor to the gender innovation gap, as measured by granted patents. Majority-female teams of inventors are 3.3-7.3 percentage points less likely to continue the patent process after receiving an initial rejection compared to male inventors (a reduction of about 4.5% to 8.5%).[3] The effects we document are robust to alternative definitions of female-majority research teams (e.g., solo vs. all-female teams), as well as alternative specifications. The quantitative importance of this channel for the overall gap in patents is sizable: gender disparities in application continuation account for more than half of the overall gender gap in issued patents. In contrast, we do not find consistent evidence of alternative explanations, such as discrimination within the administrative process or male-female differences in application quality.

We then consider the mechanisms driving the attrition gap. We find suggestive evidence that resource constraints and environmental factors are primary reasons that women are more likely to exit the application process sooner than men.[4] For example, the gender attrition gap decreases

[2] In particular, some examiners are more "lenient," and tend to accept more applications than others. Similar designs are used in previous work in this domain – see for example, recent work by Melero et al. (2020), Sampat and Williams (2019), and Farre-Mensa et al. (2020). Note that in 2019, the assignment of examiners to patent applications was no longer random. This is not a problem for our study, given that we examine applications through 2012.

[3] This differential effect by innovator gender is magnified when examining whether a patent is ultimately issued; we find that an initial rejection differentially reduces the probability that a patent is granted by 5.9-10.4 percentage points more for women.

[4] We note at the outset that we cannot provide an exhaustive accounting of all potential mechanisms, but instead on

substantially when applications are sponsored by firms or managed by high-quality legal support. These results suggest a role for increased access to information, resources, and representation during the patent prosecution process. Similarly, we find that the gender gap is significantly smaller in US states and industries with lower gender wage disparities, which we interpret as highlighting the role of institutional environment (Williamson, 1979). None of these factors, however, completely accounts for the gender gap in attrition.

Our findings contribute to the growing intersection of the economics literature concerning gender disparities and innovation. A growing body of scholarship documents gender gaps in persistence (Rask and Tiefenthaler, 2008; Ellison and Swanson, 2018). In both academic competitions and grant applications, women are more likely than men to drop out after losing or being rejected (Buser and Yuan, 2019). By showing how differential responses to application rejections contribute to gender patent outcome differences, we also add to the literature documenting gender differentials in response to negative shocks in other settings, such as medical practice (Sarsons et al., 2021), political campaigns (Wasserman, 2018), and financial performance (Kuppuswamy and Mollick, 2016).

We also contribute to the literature on the innovation and its implications for entrepreneurship and science more generally (Ding et al., 2006, 2013; Guzman and Kacperczyk, 2019; Ley and Hamilton, 2008). Understanding where in the process of innovation women exit and why this happens is essential in order to develop solutions that address the gender gap in innovation (Delgado et al., 2019; Cook, 2020). This research builds on prior work identifying a gender gap in the conversion of applications to granted patents (Jensen et al., 2018) by examining how a key feature of the patent process, the receipt of rejections and subsequent need for correspondence with patent examiners, drives differing outcomes for male and female inventors. We thus suggest a channel through which organizations can effectively improve outcomes for women.

one for which our data is well-equipped. For instance, we do not explore behavioral explanations relating to women's innate preferences, such as risk and competition aversion (Niederle and Vesterlund, 2007; Flory et al., 2015; Buser et al., 2014).

2 Setting

To study gender differences in the innovation process, we examine the U.S. patent application process. Patents are granted exclusively by the U.S. Patent and Trademark Office (USPTO), which handles over 300,000 patent applications annually (Frakes and Wasserman, 2017). An application consists of a set of claims delineating the legal rights that the inventor is seeking. The application also includes disclosure of existing patents material to the patentability of the invention ("prior art"). An application submitted to the USPTO is first assigned to an art unit, which comprises patents of the same technological field. Then, the application is assigned to an examiner, who oversees the complete application process. The assigned examiner assesses the viability of inventor's claims and decides whether to accept the patent's claims.

Figure 1a provides a detailed summary of the patent prosecution process for applications with all-male and all-female authorship, which constitute approximately 85% and 5% of our final sample, respectively. Most applications—over 80%—are not immediately accepted. An applicant may respond to an initial or any subsequent rejection by submitting an appeal or an amendment. Patent applications are only terminated when the innovator implicitly or explicitly abandons the application following what technically are appealable rejections issued by patent examiners (Lemley and Sampat, 2008).

Notably, there are persistent differences between men and women's application conversion rates, as shown in Figure 1b. Similarly, we observe significant differences in "exit" from the application process.[5] As we see in Figure 1a, male applicants are far less likely to abandon an application following an initial rejection (13.5% compared to 21.9% for women).[6] Ultimately, approximately 60% of applications that receive an initial rejection are awarded a patent. However, as men are more likely to respond to rejections, this conversion rate varies significantly by gender—

[5]We define "exit" or "attrition" as any outcome that does not result in a patent being granted, since application denials are non-final.

[6]Figure 1a also suggests than women are less likely to receive an initial rejection compared to men (71.1% compared to 80.4%). This finding, however, is not robust to the inclusion of patent art-unit and time controls, as evident in Table 1, in which we find a much smaller differential in the *opposite* direction.

62.6% for men compared to 49.2% for women.

3 Empirical Framework

3.1 Data

We use data on patent applications between 2001 and 2012 from the Patent Office's Patent Application Information Retrieval (PAIR) database. The data include basic information, such as technology class, art unit, firm assignment, and whether a patent was ultimately granted. The data also include complete prosecution histories for all submitted patents. Importantly for our analysis, we can observe each step of the application and communication between the patent examiners and applicants, including rejections, amendments, and appeals.[7]

Gender is not an explicit field in the USPTO data. Following Jensen et al. (2018), we impute applicant gender using the gender distributions of first names of all baby names since 1880, obtained from the U.S. Social Security Administration. We use a 90% name-cutoff threshold, dropping applications for which any inventors' names are identified as either male or female less than 90% of the time. The final sample includes includes 971,547 (71% of applications), for which we can assign gender to *all* inventors on the team. While our analysis is straightforward for solo-inventor applications, for applications submitted by research teams, we focus on several measures of gender composition: (1) teams composed of 50% or more women (half-female), (2) teams composed of all women (all-female), and (3) the proportion of women on an application.

We also use USPTO data on the organizations supporting the application (if any), and on the attorney filling the application. We complement the USPTO data with additional data sources: Compustat data, which contains financial data on publicly traded firms; Vault's ranking for law firms; and the 2000 Decennial Census, which we use to derive the gender wage gap by industry and state.

[7] A more detailed account of the data is provided in the Supplemental Materials.

3.2 Empirical Strategy

Our goal is to identify the gender differential in responses to application rejections. However, a simple comparison of response rates between women and men fails to cleanly isolate gender differences because applications may systematically also differ on unobserved variables such as patent quality, broadness, room for amendment, or any other traits correlated with applicant gender. To address this empirical challenge, we use an instrumental variable (IV) approach which leverages variation in the likelihood of receiving an initial rejection *independent* of application attributes – namely, the quasi-random assignment of patent examiners to applications. Our design follows the work of Sampat and Williams (2019), Kuhn and Thompson (2019), and Farre-Mensa et al. (2020).[8] The main intuition is that examiner harshness directly affects the likelihood of receiving a rejection, but should be (conditionally) uncorrelated with applications' attributes – including gender or gender correlates. Within art units, the USPTO assigns examiners to applications based on availability and other internal factors.[9]

Our final sample includes 7,700 unique examiners. We define examiner leniency as the leave-one-out initial rejection rate of an examiner by art unit-year (i.e., the proportion of initial rejections given to all *other* applications reviewed by that examiner that year). Formally, we define harshness as:

$$Harshness_{ae} = \left(\frac{1}{n_e}\right)\left(\sum_{k\neq a}^{n_e} ER_k\right)$$

In this expression, e indicates the examiner assigned to an application a, n_e is the total number

[8] When treatment effects are heterogeneous (i.e., they affect different individuals differently), an instrument identifies a local average treatment effect (LATE). This means that our 2SLS estimates identify the effects of patents only for the subpopulation of men and women whose patent applications are affected by their examiners' leniency. Applications that are clearly low-quality will be rejected even by lenient application examiners (these applicants are "never-takers," in the standard econometrics nomenclature). Applications that are high-quality will be approved even by tough examiners (i.e., "always-takers"). The subpopulation of applicants that will respond to the leniency instrument is thus the group of applicants with proposed innovations of marginal quality. As such, the leniency instrument identifies the effect of initial rejection on marginal innovators. Our IV approach thus provides a local average treatment effect.

[9] Both Lemley and Sampat (2012) and Frakes and Wasserman (2014) conducted a series of interviews and confirm that there is no deliberate selection of examiners or substantive evaluation of an application before assigning it to an examiner.

of applications seen by examiner e, k indexes the applications, and IR_k, an initial reject, is equal to one if the application was initially rejected by the examiner. Appendix Figure A1 shows that distribution of the instrument, controlling for year and art unit.

For examiner harshness to be a valid instrument, it must satisfy two main conditions. First, variation in harshness must affect rejection probabilities (the *relevance assumption*). Second, the instrument must be uncorrelated with applications' observed and unobserved attributes (the *exclusion restriction*). Given the institutional details, examiner's rejection rates for *other* applications are unlikely to be correlated with a specific application's unobserved attributes.

Figure 2 provides evidence consistent with both of these assumptions. Examiners' harshness is plotted on the horizontal axis, and vertical axis shows *actual* initial rejection rates and *predicted* rejection rates using numerous application characteristics, such as art unit, year, number of applicants, gender composition, and several other observables. We observe a strong relationship (almost unity) between harshness and actual rejection rate, suggesting that harshness significantly affects the probability of initial rejection. In contrast, we see an extremely weak relation between harshness and predicted rejection rate based only on observables. This finding suggests there is not a consistent relationship between an examiner's harshness and ex-ante rejection probability, which supports the validity of the exclusion restriction.[10]

Using examiner harshness as an instrument, the main specification is given by:

$$Y_a = \beta_1 \widehat{IR}_a + \beta_2 Female_a + \beta_3 [\widehat{Female \times IR}]_a + \mu_{ut} + \varepsilon_{aut} \tag{1}$$

Here, ut is the patent art unit X application year. Y_a is the outcome of interest, either whether inventors continued the application following a rejection or whether the application was approved. IR is a dummy for whether the application received an initial rejection, and $Female$ is an indicator for the prevalence of women in the inventors team, as described in Section 3.1. μ_{ut} are art unit X

[10] Following Righi and Simcoe (2019), in Appendix Table A2, we also test quasi-random assignment of applications to examiners with subclass fixed effects.

application year fixed effects. We cluster at the examiner X application year level, which as the unit at which treatment is assigned. We instrument for $\widehat{IR}_a$ and $[\widehat{Female \times IR}]_a$ using $Harshness_e$ and

$[Female_a \times Harshness_e]$, respectively. The main coefficient of interest is β_3, which estimates the likelihood of women to either amend an application or obtain a patent compared to men, conditional on receiving an initial rejection.

4 Results

4.1 Main Findings

We begin by presenting suggestive evidence that differential attrition from the patent application process plays an important role in explaining the gender innovation gap. Panel A of Table 1 estimates a simple OLS regression (without the instrument) of the impact of gender on initial rejection rates, controlling for application art unit-year. As described in Section 3.1, the definition of female changes across columns. We find that majority-female teams are only marginally more likely to receive an initial rejection. Though statistically significant, the effects are small in magnitude. For instance, in Column 3, which compares applications filed by all-female to not-all-female teams, we find that female inventors are only 0.7 percentage points more likely to receive an initial rejection.

In contrast, Panel B of Table 1 suggests that gender is strongly correlated with reductions in the probability of a patent being granted. Column 3 shows that applications filed by all-female teams are 7.2 percentage points less likely to eventually receive a patent. We observe similar magnitudes across all specifications. In short, gender's correlation with final outcome is an order of magnitude larger than the effect of initial rejection. This difference in magnitudes is presented graphically in Appendix Figure A2.

While we cannot completely rule out that examiners are discriminating against female innovators, the above evidence suggests that examiner discrimination, at least at the first office action stage, is not a major driver of the innovation gender gap.[11] We interpret this as suggestive evidence that a gender gap in application conversion rates exists and, more importantly, that this gap is not driven by differences in initial rejection rates; women's higher rates of initial rejection do not alone explain the significantly different rates of patent receipt, especially given that the median application only goes through two amendments.

We now turn to our primary analysis, which causally identifies the heterogeneous response in innovators' responses to initial rejections by gender. Table 2 presents the results using the IV strategy presented in Equation 1. We focus on two outcomes: 1) whether an applicant/team proceeds to the next step of the application, i.e. files an amendment, and 2) whether the application is eventually granted a patent. Collectively, the results demonstrate that women and majority-female teams are significantly *less* likely to continue in the patent process if they receive an initial rejection compared to their male counterparts and are thus less likely to ultimately receive a patent.

Panel A captures the differential gender effect of rejection on submitting an initial amendment, which is the next step to keep a rejected application in contention for a granted patent. We find that women and majority-female teams are significantly *less* likely to continue in the patent process if they receive an initial rejection compared to their male counterparts. For instance, Column 4, shows that, in solo applications, female applicants are 4.5 percentage points (p.p.) more likely to abandon an application following an initial rejection. Columns 1, 2, and 3 provide similar, statistically significant, estimates; Women are 3.9 p.p., 3.3 p.p., and 7.3 p.p. less likely to follow up after receiving an initial rejection.

In Panel B, we examine whether women are differentially deterred from ultimately completing patent applications after initial rejections. We find that, across specifications, the initial differential effects of initial rejection are amplified when examining patent issuance rates. For instance, Column 4 shows that, in solo applications, female applicants are 7.5 p.p. less likely to

[11] This result also suggests only small gender differences in patent application quality that do not drive our results on responsiveness or application conversion. To further corroborate these underlying similarities, we examine the relation between gender on measures of patent quality; we do not find consistent differences for either initial applications or for granted patents.

receive a patent following an initial rejection compared to male applicants. Given that solo female applicants are 4.5 p.p. more likely to drop out immediately (Panel A) – i.e., without refiling an amended application – our results suggest that 60% of the overall gender patent granting gap is explained by women's differential deterrence when an examiner makes her initial determination.

This pattern is again consistent across specifications: The differential effects of initial rejections on female and female-led application are magnified when examining patent issuance. In addition, we observe consistent differences between immediate (as measured by initial amendment submissions) and downstream (measured by patent receipt) gender differences across our measures of gender application composition. The gender differential in response to initial rejections accounts for 55% to 70% of the gender gap in granted patents.

4.2 Quality Differences in Applications

A natural concern for our design is that gender is related to invention/patent quality, and differences in patent application quality are captured in the $Female \times IR$ term. While this concern does not affect our estimation strategy per se, this confound has important implications for the interpretation of the coefficients. We thus examine the severity of this potential confounder, and provide evidence to suggest that gender is *not* merely a proxy for patent quality.

First, as we note above, we do not observe that women are more likely than men to be rejected at the first office action stage when poor quality applications are filtered out. Second, we fail to find consistent evidence for gender differences in patent application or granted patent quality and scope (see Appendix Table A6). Third, to attempt to control for patent quality, we include additional application characteristics, such as number of innovators, and number of claims. The main results remain statistically significant and qualitatively similar, though they become larger and noisier (see Appendix Table A7). Moreover, in order to control for unobservable differences between applications, we run a similar specification with innovator-level fixed effects; again, the main results are robust to this exercise (see Appendix Table A8). This test provides some evidence against negative selection in patent application. While none of these tests conclusively rule out differences in quality as a confounder to our interpretation of gender differences in application attrition, taken together, these results suggest quality is unlikely to drive our results.

4.3 Drivers of Differential Attrition

We next focus on resources and environmental factors as a channels to moderate the gender innovation gap (Czarnitzki et al., 2016). While we cannot fully control for these factors, our main test is a triple-differences regression in which we estimate how the differential effect of initial rejection by gender changes as we varies the levels of available resources and environment.

We look at three factors that might affect resources and environment: organizational support, legal advice, and institutional environment. Organizational support captures the benefits of being affiliated with an organization, such as access to resources, information, networks etc. We incorporate two measures of the level of organizational support: (1) Whether an application is assigned to an employer, and (2) Organizational experience, based on the (logged) number of previous applications filed by the organization.

Next, to estimate the effect of legal support, we code whether the application is managed by a lawyer, and whether the law firm is in the top 50 or 100 law firms in the US (according to Vault.com). Finally, to capture environmental factors, which we think about as general attitudes toward women and social norms, more broadly, we also estimate the moderating impact of wage equity in the relevant industry and state.[12] Formally, we define wage equity as 1 minus the ratio of average female wage to the average male wage in the industry or state. Large wage gaps, i.e. men earning substantially more than women will lower the measure towards zero, and when the wage gap decreases our measure approaches 1.

The results are presented formally in Appendix Table A5 and graphically in Figure 3. Figure 3 presents the estimated triple interaction between female (using the "All Female" definition),

[12] We can only estimate the impact of the industry wage gap for applications assigned to a firm.

instrumented initial rejection, and the variable of interest. Panel A presents the effect on initial amendment and Panel B on patent issuance. We find that institutional support substantially mitigates the gender innovation gap. For instance, looking at the first coefficient in Panel A, the effect of an employer, we find that when the application is affiliated with an employer, the gender differences in propensity to file an initial amendment are mitigated by about 5 p.p. This pattern is consistent across the various measures of support–the coefficients are always positive, and almost always statistically significant, implying that access to resources and supportive environment substantially mitigate the gender innovation gap. Note, however, that while the gender gap decreases, we still find significant differences in the attrition rates of male and female applicants.

Panel B presents a similar story. Institutional support reduces the gender gap in responsiveness not only at the first amendment stage, but it also reduces the overall difference in patent issuance across female- and male-led applications. Taking the first coefficient again, we find that when the application is supported by a firm, the differences in patent issuance rates across male- and female-led teams are mitigated by 5.7 p.p. Again, the gender gap is substantially decreased, but it is not completely negated.

5 Discussion and Conclusion

In this project, we identify and estimate a novel channel driving the gender innovation gap: the differential tendency of male and female inventors to exit the patent application process after receiving a rejection. We study how male and female inventors respond to rejection in the patent application process using the quasi-random assignment of patent examiners as instrumental variables. We find that female inventors who receive early rejections are far less likely to submit amendments and subsequently receive a patent. We find suggestive evidence that access to resources and favorable institutional environments can substantially, though not completely, mitigate the gender gap.

Our results have important policy implications. We find that the gender attrition gap drops by half when women have the backing of a firm when applying or have legal representation. These results (the latter in particular) suggest an actionable implication– in fact, the USPTO recently began a program in which unaffiliated inventors without an attorney can access resources and information about the process, along with access to free legal representation. More generally, if women differentially benefit from the provision of institutional support, then one way to address the gap may be to offer more resources and information to patent applicants.

More broadly, our findings suggest that even in the last steps of innovation– between the filing of a patent application and receiving a patent– differential responsiveness can lead to a significant gender gap. Given that an individual who is in the position to apply for a patent has already invested significant resources and time in acquiring relevant skills and develooping a new innovation, one might anticipate that fallout at this stage is trivial. As we show, gender gaps are substantial prior to the application stage, as about 85% of patent applications have all-male authorship. This work identifies that even holding selection into innovative and entrepreneurial contexts fixed, gender variation in the process of innovation itself is a sizeable contributor to gender gaps. Our analyses identify this area as a fruitful one for future research.

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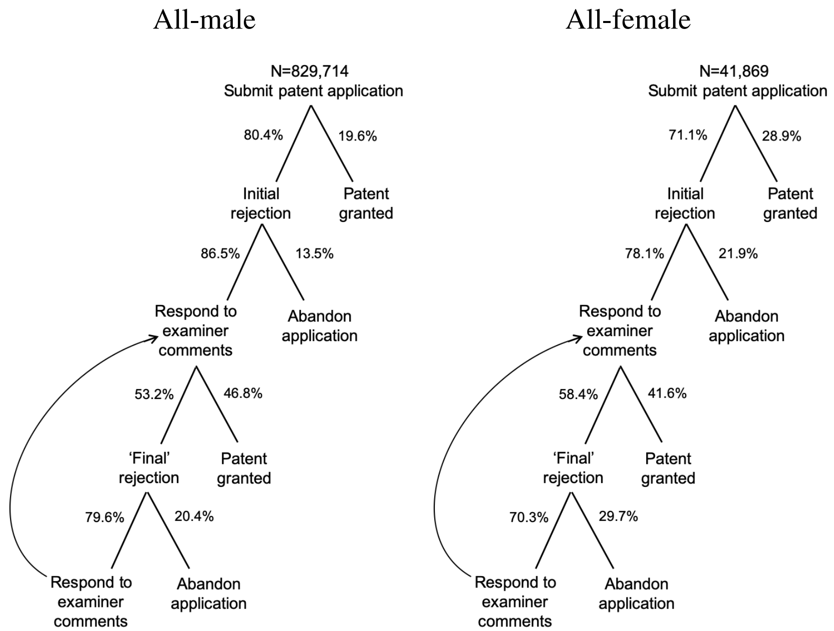
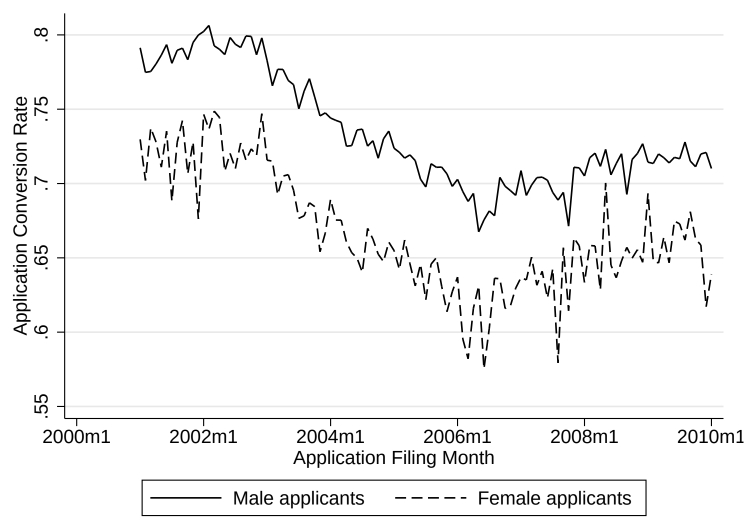
Figures and Tables

Figure 1: The Patent Application Process

(a) Evaluative Trajectory of Patent Applications



(b) Application Conversion Rates by Gender



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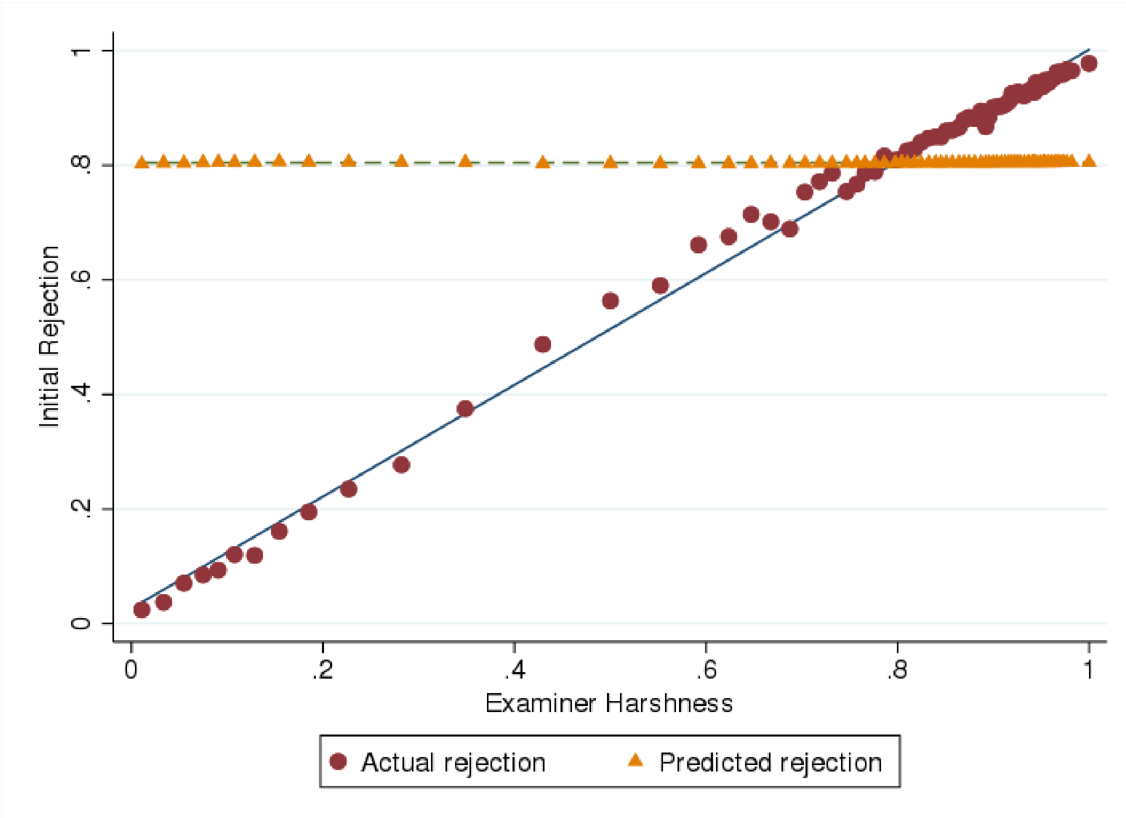
Panel (a) shows the raw proportions of applications that progress through each stage of the patent process for applications from all-male and all-female inventors or teams. Applications from single-gender teams or solo individuals account for almost 90% of all applications in our sample. Panel (b) shows the raw proportions of granted patents of total applications filed by applicants gender.

Figure 2: Distribution of Examiner Harshness by Initial Rejection (Residualized)

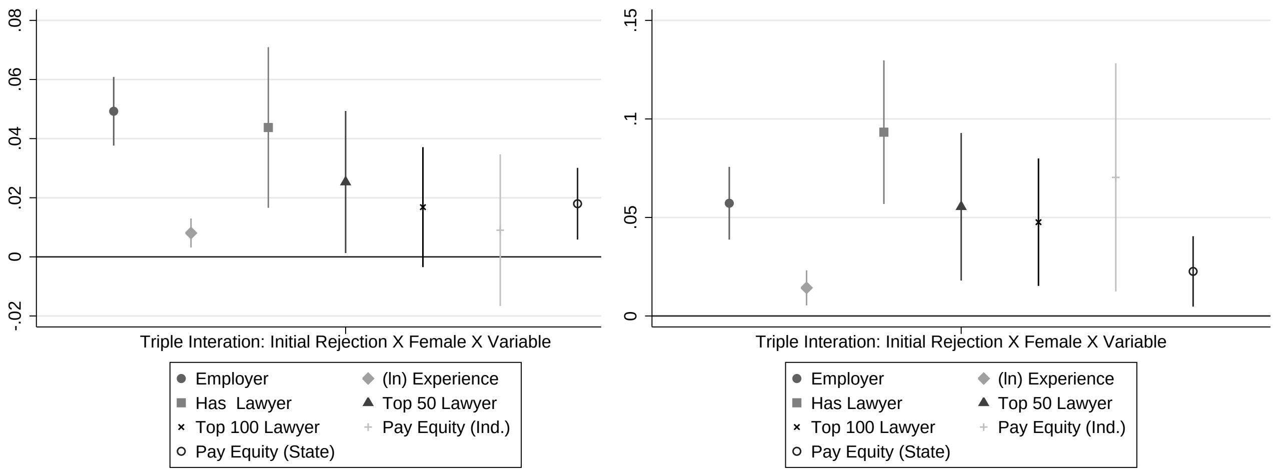


This figure relates examiner harshness to two variables: the actual initial rejection rate, shown in red, and the predicted rejection rate in yellow. The initial rejection rate is correlated with examiner harshness. Predicted rejection is based on observable characteristics that may be correlated with quality (the number of inventors on an application, the proportion of female inventors, whether the application is assigned to an employer and who that employer is). Together, these variables explain 40% of the likelihood of initial rejection (R^2=.40).

Figure 3: Impact of Access to Resources and Environmental Factors on Differential Responses to Initial Rejection

Panel A: Effect on Initial Amendment

Panel B: Effect on Patent Issued



This figure present OLS estimates relatating initial amendment (Panel A) or patent issuance (Panel B) to a triple interaction between initial rejection, and indicator for female-led application, and the relevant institutional variable as indicated below the graph and the 90% confidence interval. We instrument for initial rejection using examiners' leave-out mean initial rejection rate for all other applications within an art unit-year cell. "Female" applications defined as all-female inventor teams. All regressions include art unit-year and applicant fixed effects and are clustered at the examiner-year level.

Table 1: Motivating Evidence - Effect of Gender on Patent Application Outcomes (OLS)

	(1)	(2)	(3)	(4)
Panel A: Effect of Gender on Initial Rejection				
Female	0.007	0.005	0.007	0.009
	(0.002)	(0.001)	(0.002)	(0.002)
Dependent Var. Mean	0.80	0.80	0.80	0.77
Panel B: Effect of Gender on Patent Granted				
Female	-0.055	-0.044	-0.072	-0.053
	(0.002)	(0.002)	(0.002)	(0.003)
Art Unit x Year FE	X	X	X	X
Dependent Var. Mean	0.70	0.70	0.70	0.69
Observations	971547	971547	971547	461147
# of Clusters	36851	36851	36851	36727
Female Definition	Proportion	Half Female	All Female	Solo

Standard errors in parentheses

The dependent variable mean shows the mean value of initial rejection and patent granted in the sample, respectively. All regressions include art unit-year fixed effects and are clustered at the examiner-year level.

Table 2: Effect of Initial Rejection on Patent Application Continuation (IV)

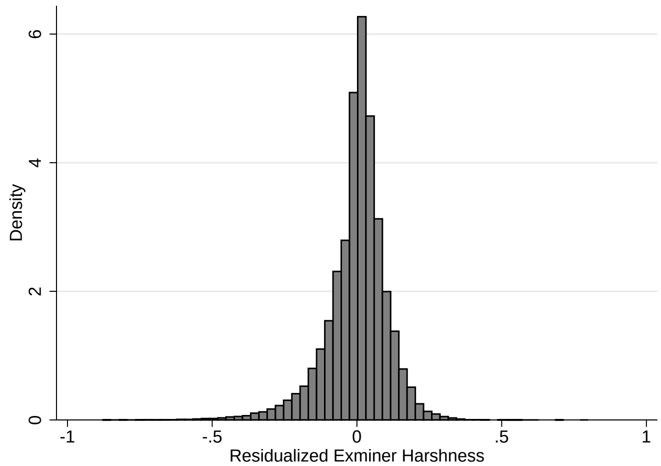
	(1)	(2)	(3)	(4)
	Panel A: Initial Amendment			
Female × Initial Rejection	-0.039	-0.033	-0.073	-0.045
	(0.003)	(0.003)	(0.004)	(0.004)
	Panel B: Patent Recieved			
Female × Initial Rejection	-0.074	-0.059	-0.104	-0.075
	(0.005)	(0.004)	(0.006)	(0.006)
Observations	971547	971547	971547	461147
# of Clusters	36851	36851	36851	36727
Female Definition	Proportion	Half Female	All Female	Solo

Standard errors in parentheses

Each estimate based on OLS relating an indictor variable for an initial amendment to a patent application (Panel A) or a patent issuance for an application (Panel B) to an interaction term of "Female applications" and whether an application receives an initial rejection. Definitions of the Female variable are denoted below each column and are described in the text. We instrument for initial rejection using examiners' leave-out mean initial rejection rate for all other applications within art unit-year. All regressions include art unit-year fixed effects and are clustered at the examiner-year level.

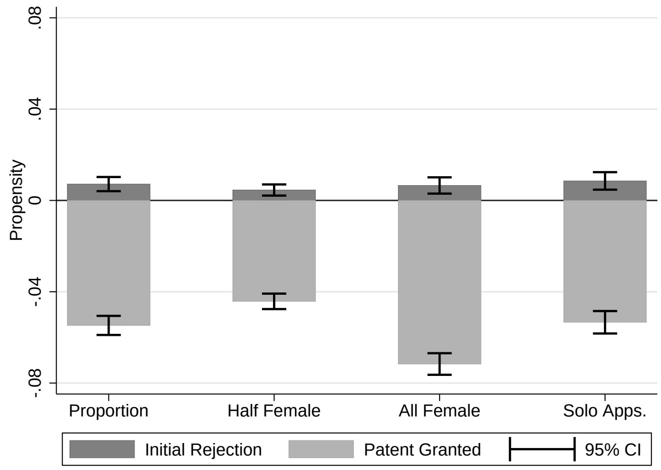
Supplementary Material: Appendix A - Additional Figures and Tables

Figure A1: Probability of Initial Rejection by Examiner Harshness



This figure shows the distribution of patent initial rejection rates, residualizing by the full set of art-unit-by-application-year fixed effects.

Figure A2: Effect of Gender on Application Outcomes

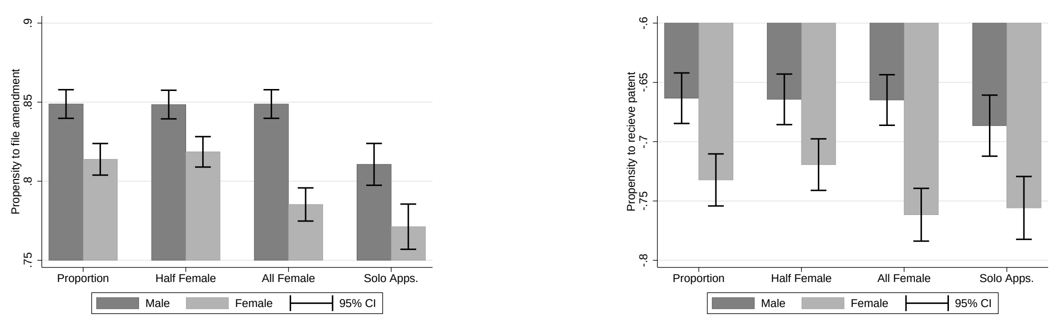


This figure shows the estimated coefficients and confidence intervals from four different regressions estimating the impact of gender on application outcome, where female definition is indicated below each bar.

Figure A3: Effect of Gender on Application Outcomes

Effect on Initial Amendment

Effect on Patent Issuance



This figure shows the estimated coefficients and confidence intervals from eight different regressions (four in each panel) estimating the impact of differential responses by gender of (instrumented) initial rejection on initial amendment and patent issuance. Female definition is indicated below each bar.

Table A1: Summary Statistics

	Mean	SD	Min	Max
Applications (N=971,547)				
All-US Inventors	1	0	1	1
Patent Issued	0.70	0.46	0	1
Using Attorney	0.95	0.21	0	1
Employer Assigned	0.63	0.48	0	1
Number of Team Members	2.04	1.37	1	10
Solo Inventors	0.47	0.50	0	1
Solo Female Inventors	0.038	0.19	0	1
Proportion of Female Team Members	0.088	0.19	0	1
>=1 Woman on Team	0.21	0.40	0	1
>=50% Women on Team	0.096	0.29	0	1
All-Female Team	0.009	0.09	0	1
Number of Initial Rejections	1.15	0.92	0	12
Number of Initial Appeals	1.10	1.13	0	19
Number of Final Rejections	0.52	0.78	0	12
Number of Final Appeals	0.56	1.03	0	23
Proportion of Applications that receive Initial Rejections	0.80	0.40	0	1
Proportion of Applications that submit Initial Amendments	0.69	0.46	0	1
Proportion of Applications that receive Final Rejections	0.38	0.49	0	1
Proportion of Applications that submit Final Amendments	0.32	0.47	0	1

Table A2: First-Stage Results

	(1) Initial Rejection	(2) Initial Rejection	(3) Initial Rejection	(4) Initial Rejection
Examiner Harshness	0.709***	0.694***	0.709***	0.695***
	(0.004)	(0.004)	(0.004)	(0.004)
Proportion of Female			0.003*	0.002
			(0.001)	(0.001)
Affiliated With Employer			-0.007***	-0.006***
			(0.001)	(0.001)
Top 100 Lawyer			0.011***	0.011***
			(0.001)	(0.001)
Art Unit x Year FE	X	X	X	X
Subclass x Year FE		X		X
F-stat	36669.90	30538.25	9256.51	7691.45
Observations	969752	943594	969752	943594
# of Clusters	36851	36851	36851	36851

This table reports the results of two different versions of the first-stage equation of our IV (2SLS) analysis. We use the initial rejection rate (for applications in the same art unit and year) of the assigned patent examiner to predict whether the focal application will receive an initial rejection. Column 1 includes only art unit-year fixed effects, Column 2 adds characteristics of the application and applicants that may proxy for quality, and Column 3 adds subclass-year fixed effects. The inclusion of subclass FEs has very little impact on the coefficient on the instrument, which varies from 0.709 to 0.695 after the inclusion of subclass controls. This represents a less than 2 percent change in magnitude and suggests that neither subclass nor our proxies for application quality and characteristics predict whether the application receives a rejection. Additionally, we use the Kleibergen-Paap *rk* Wald *F* statistic and identify that examiner harshness is a good instrument for rejection.

Table A3: Effect of Initial Rejection on Patent Application Continuation: Alternate Definition of Harshness IV

	(1)	(2)	(3)	(4)
	Panel A: Initial Amendment			
Female × Initial Rejection	-0.055***	-0.046***	-0.095***	-0.058***
	(0.008)	(0.007)	(0.009)	(0.010)
	Panel B: Patent Received			
Female × Initial Rejection	-0.116***	-0.086***	-0.109***	-0.099***
	(0.019)	(0.017)	(0.020)	(0.020)
Observations	971547	971547	971547	461147
# of Clusters	36851	36851	36851	36727
Female Definition	Proportion	Half Female	All Female	Solo

In the eight separate regressions displayed in this table, we instrument for initial rejection using examiners' leave-out mean *overall* rejection rate for all other applications within art unit-year. This alternate definition of harshness allows us to check that our results are robust and not reliant on exclusively defining harshness in terms of the rate of giving initial rejections. Definitions of the Female variable are denoted below each column and are described in the text. All regressions include art unit-year fixed effects and are clustered at the examiner-year level.

Table A4: Heterogeneity by Examiner Gender (IV)

	(1)	(2)	(3)	(4)
	Panel A: Initial Amendment			
Female × Initial Rejection × Examiner Female	-0.006	-0.003	0.002	0.002
	(0.007)	(0.006)	(0.009)	(0.009)
Initial Rejection × Examiner Female	-0.002	-0.002	-0.003	-0.001
	(0.002)	(0.002)	(0.002)	(0.003)
Female × Initial Rejection	-0.040***	-0.034***	-0.078***	-0.049***
	(0.005)	(0.004)	(0.006)	(0.006)
Examiner Female	0.001	0.001	0.001	0.001
	(0.002)	(0.002)	(0.001)	(0.002)
Female × Examiner Female	0.003	0.003	-0.001	-0.003
	(0.004)	(0.003)	(0.004)	(0.004)
	Panel B: Patent Recieved			
Female × Initial Rejection × Examiner Female	-0.005	-0.003	0.011	0.014
	(0.012)	(0.010)	(0.013)	(0.014)
Initial Rejection × Examiner Female	-0.036***	-0.036***	-0.037***	-0.030***
	(0.006)	(0.006)	(0.006)	(0.007)
Female × Initial Rejection	-0.073***	-0.059***	-0.109***	-0.081***
	(0.009)	(0.007)	(0.009)	(0.010)
Examiner Female	0.016***	0.016***	0.017***	0.013**
	(0.005)	(0.005)	(0.005)	(0.005)
Female × Examiner Female	0.004	0.006	-0.001	-0.006
	(0.009)	(0.007)	(0.009)	(0.010)
Observations	816168	816168	816168	392474
# of Clusters	30300	30300	30300	30197
Female Definition	Proportion	Half Female	All Female	Solo

This table examines whether examiner gender affects determinations of initial rejection, and if there is any interaction between examiner and applicant gender. Each column reports coefficients from a separate regression. An observation is a patent application. We instrument for initial rejection using an examiner's leave-out mean initial rejection rate for all other applications within art unit-year. We find that female examiners are no more or less likely than male examiners to lead to differential outcomes for male vs female applicants. It does appear that applications reviewed by female examiners are less likely to convert to granted patents, but this does not vary based on the gender of the applicants. Examiner Female is a dummy variable for whether patent examiner is a female. All regressions include art unit-year fixed effects and are clustered at the examiner-year level.

Table A5: Impact of Access to Resources and Environmental Factors on Differential Responses to Initial Rejection

	(1) Initial Amendment	(2) Initial Amendment	(3) Patent Issued	(4) Patent Issued
	Panel A: Persistence Gap by Firm Assignment			
Female × Initial Rejection × Employer	0.038***	0.049***	0.039***	0.057***
	(0.005)	(0.007)	(0.009)	(0.011)
Observations	969752	969752	969752	969752
# of Clusters	36851	36851	36851	36851
Female Definition	Half Female	All Female	Half Female	All Female
	Panel B: (Log) Number of Previous Patents			
Female × Initial Rejection × (Ln) experience	0.001	0.008***	0.008**	0.014***
	(0.002)	(0.003)	(0.004)	(0.005)
Observations	388368	388368	388368	388368
# of Clusters	36373	36373	36373	36373
Female Definition	Half Female	All Female	Half Female	All Female
	Panel C: Lawyer Assigned to Application			
Female × Initial Rejection × Has a Lawyer	0.050***	0.044***	0.083***	0.093***
	(0.013)	(0.017)	(0.018)	(0.022)
Observations	969752	969752	969752	969752
# of Clusters	36851	36851	36851	36851
Female Definition	Half Female	All Female	Half Female	All Female
	Panel C: Top 50 Law Firms			
Female × Initial Rejection × Top 50 Lawyer	0.016*	0.025*	0.045***	0.055**
	(0.009)	(0.015)	(0.015)	(0.023)
Observations	969752	969752	969752	969752
# of Clusters	36851	36851	36851	36851
Female Definition	Half Female	All Female	Half Female	All Female
	Panel D: Top 100 Law Firms			
Female × Initial Rejection × Top 100 Lawyer	0.023***	0.017	0.048***	0.048**
	(0.008)	(0.012)	(0.014)	(0.020)
Observations	969752	969752	969752	969752
# of Clusters	36851	36851	36851	36851
Female Definition	Half Female	All Female	Half Female	All Female
	Panel E: Pay Equity by Industry			
Female × Initial Rejection × Pay Equity	0.008	0.009	0.040*	0.070**
	(0.009)	(0.016)	(0.022)	(0.035)
Observations	322467	322467	322467	322467
# of Clusters	35909	35909	35909	35909
Female Definition	Half Female	All Female	Half Female	All Female
	Panel F: Pay Equity by State			
Female × Initial Rejection × Pay Equity	0.008	0.018**	0.019**	0.023**
	(0.005)	(0.007)	(0.008)	(0.011)
Observations	969752	969752	969752	969752
# of Clusters	36851	36851	36851	36851
Female Definition	Half Female	All Female	Half Female	All Female

Definitions of the Female variable are denoted below each column and are described in the text. We instrument for initial rejection using examiners' leave-out mean initial rejection rate for all other applications within art unit-year. All regressions include art unit-year and are clustered at the examiner-year level.

Table A6: Gender Differences in Patent Quality and Scope

	Panel A: Patent Scope (Pre-Publication)			
	(1) Count of Ind. Claims	(2) Count of Ind. Claims	(3) Min. Word Count	(4) Min. Word Count
Female × Initial Rejection	0.152	0.243	8.391**	5.572
	(0.120)	(0.174)	(3.449)	(5.613)
Observations	759778	759778	758954	758954
# of Clusters	35753	35753	35753	35753
Female Definition	Half Female	All Female	Half Female	All Female
	Panel B: Patent Scope (Post Grant)			
	(1) Count of Ind. Claims	(2) Count of Ind. Claims	(3) Min. Word Count	(4) Min. Word Count
Female × Initial Rejection	0.135*	0.339***	0.974	2.771
	(0.076)	(0.115)	(3.648)	(6.077)
Observations	561037	561037	560031	560031
# of Clusters	35207	35207	35181	35181
Female Definition	Half Female	All Female	Half Female	All Female
	Panel C: Citations			
	Patent Cited	Patent Cited	No. of Citations	No. of Citations
Female × Initial Rejection	-0.029***	-0.049***	-2.017***	-2.978***
	(0.007)	(0.008)	(0.147)	(0.149)
Observations	971547	971547	971547	971547
# of Clusters	36851	36851	36851	36851
Female Definition	Half Female	All Female	Half Female	All Female
	Panel D: KPST			
	Top 10% F10/B5	Top 10% F10/B5	Top 10% F5/B5	Top 10% F5/B5
Female × Initial Rejection	0.002**	0.001	0.004	0.009
	(0.001)	(0.002)	(0.010)	(0.014)
Observations	363402	363402	363402	363402
# of Clusters	23058	23058	23058	23058
Female Definition	Half Female	All Female	Half Female	All Female

Definitions of the Female variable are denoted below each column and are described in the text. Outcomes are denoted above each column. We instrument for initial rejection using examiners' leave-out mean initial rejection rate for all other applications within art unit-year. All regressions include art unit-year and are clustered at the examiner-year level.

Table A7: Effect of Initial Rejection on Patent Application Continuation: Controlling for Patent Quality

	(1)	(2)	(3)	(4)
	Panel A: Initial Amendment			
Female × Initial Rejection	-0.062*	-0.046*	-0.162***	-0.103**
	(0.025)	(0.019)	(0.035)	(0.038)
	Panel B: Patent Received			
Female × Initial Rejection	-0.285***	-0.221***	-0.382***	-0.307***
	(0.040)	(0.031)	(0.056)	(0.059)
Observations	734893	734893	734893	321696
# of Clusters	35731	35731	35731	35512
Female Definition	Proportion	Half Female	All Female	Solo

Definitions of the Female variable are denoted below each column and are described in the text. We instrument for initial rejection using examiners' leave-out mean initial rejection rate for all other applications within art unit-year. All regressions include art unit-year, innovators state fixed effects, number of innovators, and controls for patents scope based on number of independent claims and word count. Regression are clustered at the examiner-year level.

Table A8: Effect of Initial Rejection on Initial Amendment and Patent Issuance (with Applicant Fixed Effects)

	(1)	(2)	(3)
	Panel A: Initial Amendment		
Female X Initial Rejection	-0.016*	-0.015**	-0.031***
	(0.009)	(0.006)	(0.010)
Initial Rejection	0.940***	0.940***	0.939***
	(0.005)	(0.005)	(0.005)
Observations	612411	612411	612411
# of Clusters	36334	36334	36334
	Panel B: Patent Granted		
Female X Initial Rejection	-0.074***	-0.059***	-0.105***
	(0.005)	(0.005)	(0.006)
Initial Rejection	-0.682***	-0.683***	-0.683***
	(0.012)	(0.012)	(0.012)
Observations	892484	892484	892484
# of Clusters	36582	36582	36582
Art Unit x Year FE	X	X	x
Inventor FE	X	X	X
Female Definition	Proportion	Half Female	All Female

Definitions of the Female variable are denoted below each column and are described in the text. We instrument for initial rejection using examiners' leave-out mean initial rejection rate for all other applications within art unit-year. All regressions include art unit-year and applicant fixed effects and are clustered at the examiner-year level.

Supplementary Material: Appendix B - Data Appendix

In this section, we describe the data used in our analysis in greater detail. As described in the main text, we start with the nearly two million utility patent applications filed on or after March 2001 that were published by July 2012 from the USPTO's Patent Application Information Retrieval (PAIR) database. We then focus on a subset of 1.4 million applications that received a final disposition– that is, those that were granted or abandoned by July 2012. We infer innovators' genders by constructing a gender distribution of each name from the U.S. Social Security Administration. One potential limitation of this approach is that does not reliably identify the gender for non-American individuals. For this reason, we restrict our main sample to applications for which all inventors are based in the United States. We also exclude applications for which we cannot identify the gender of *all* innovators. We drop applications from teams composed of more than 10 individuals.

Because an examiner's decision on an application is never final (i.e., applicants can respond), we briefly describe how we define "failed" applications for the purposes of measuring attrition. The USPTO formally considers an application abandoned if the inventor fails to respond to an action letter from the assigned examiner within six months. For the purposes of this paper, we define abandoned application as those which inventors are no longer pursuing. This includes a broader set of applications than those that are formally abandoned, as it captures applications for which a lack of response followed examiner communication other than an action letter. Given that we restrict our sample to applications that are at least 8 years old, we are confident that this assumption accurately captures the set of applications which are no longer being pursued.

To examine mechanisms underlying our main effect, we combine the USPTO data with additional sources. First, to examine whether differences in the employment of inventors matters, we leverage data on employer "assignment", which indicates that an employer will assume the ownership right to the patent if granted. Our implicit assumption is that this is an indication of an employer's support of an application. In addition to recording an indicator for whether an application is employer-assigned or not, we also calculate a firm's prior experience in the patenting process using the number of previous patent applications from that firm (over the period of our sample).

We also take advantage of Compustat – a database of financial, statistical and market information on active and inactive global companies throughout the world – to add additional information about employers. We use firm name to match employers who appear as assignees in the patent data with Compustat records. We first attempt to match records directly using NBER name-standardization procedures (i.e., Derwent standardization). For unmatched names, we then use the data provided by Dorn et al. (2020), who match granted patents to Compustat based on online search results. We leverage matches found through this process to identify the employer information for unsuccessful patent applications assigned to firms as well. Using Compustat data provides us with the relevant industry in which the assigned firm operates, which we then use in our analyses.

We use this industry ID to match assignee data to the 2010 American Community Survey (ACS) on NAICS codes.[13] For each industry, we calculate the average hourly wage differential for individuals ages 18 to 65. We use this data to calculate the average wage gap by industry. Naturally, we can only conduct this exercise for patent applications assigned to an employer. Similarly, we calculate the average hourly wage gap in the state at which the patent was filled for *all* applications.

The USPTO data identify if a patent application was managed by a lawyer and provide the contact information, including name and mailing address, for the attorney, if applicable. To identify the law firm associated with a given application, we use this "correspondence information". We match firm names with the list of top law firms as they appear on the 2019 Vault.com's lists of Top 100 Law Firms and Top 50 IP Law Firms, which are constructed based on assessments of lawyers at peer firms.

Finally, as part of our robustness checks, we also identify examiners' genders. As we did

[13] We use 3-digits NAICS codes to match the data sets. Where needed, we manually convert the NAICS codes to 1997 NAICS equivalent codes.

with applicants, we use examiners' first names to identify their genders. Examiners are identified by unique IDs, and examiners' first and last names are also present in the data. In total, there are 7,700 unique examiners who appear in our sample, and we are able to identify gender for 6,397 of these individuals. The majority of examiners are male, as just 27.9% of examiners are identified as female. The average examiner reviews 125 applications between 2001 and 2012. Male and female examiners see similar numbers of applications each year, with female examiners being assigned to slightly more applications than male examiners over our 12 year period (means of 138.6 and 123.3 for female and male examiners respectively).

In the Online Appendix, we examine whether the main result are driven by patent quality and fail to find a consistent relationship. In order to construct these tests, we use several pieces of data. First, to proxy for patent scope, we use data on patent text, such as number of independent claims in the patent, as well as number of words in initial patent application and grant patent (if applicable), Previous research shows that number of words are negatively correlated with patent scope (Kuhn et al., 2020) and vice versa for number of claims. Second, we use data on patent citations, excluding examiner added citations. Finally, we use Kelly et al. (2021) measure of technological innovation, which uses text analysis to compute similarity to previous compared to subsequent work.

Supplementary Material: Appendix C - Robustness Checks and Additional Tests

This appendix discuss the exhibits present in Appendix A. Table A2 present the first stage of the instrumental variable regressions. We find that the assigned examiner's prior rate of rejection has a significant and robust effect on the likelihood of the focal application receiving an initial rejection. The effect of examiner harshness consistently statistically meaningful, with F statistics well-above the threshold of 104.7 (Lee et al., 2020).

Following Righi and Simcoe (2019), we also test the quasi-random assignment of applications to examiners by estimating our first-stage regression with and without subclass-fixed effects. This allows us to test whether the technology an application deals with is correlated with examiners' propensities towards rejection. Table A2 presents these results. We find that adding subclass-year fixed effects has very little impact on the coefficient on the instrument.

Table A4 examines how the *examiner's* gender affects responsiveness to rejection. The triple interaction between the gender of the applicant, initial rejection (instrumented), and examiner gender estimates whether female innovators respond differently to initial rejections when the assigned patent examiner is a women. We do not find any consistent or statistically significant impact of the examiner's genders on an applicants' propensity to file an initial amendment or receive a patent.

Table A6 evaluates differences in patent quality. While quality is hard to measure (or measure), we use several proxies: 1. patent scope, as measured by number of words and independent claims, both when filling the application and when the patent is granted (if applicable), 2, Whether the patent received any citation, and if so, the number of citations. 3. Kelly et al. (2021) measures of patent innovation.

In general, we fail to find consistent evidence of differences in quality between male-led and female-led patents. For instance, while we do find some statistically significant effects on patent scope, the result go in opposite directions, which suggests that woman use more words (narrower scope) and their applications include more independent claims (wider scope). The only difference we find is that patents with female authorship receive less citations.

Table A7 attempts to control for quality by adding additional controls. In particular, we include innovators' state dummies, the number of innovators, and information about the textual characteristics at the time of filing the patent (count of depend claims, count of independent claims, average number of words, minimal number of words, etc.). Our estimates remain statistically significant and become larger in magnitude and noisier.

Table A8 present the main regression results when including an applicant fixed effect. This specification helps control for unobserved differences at the innovator level. For instance, this controls for an individual's general ability, intelligence, or creativity, which may relate to patent quality. Since the USPTO does not provide a unique identifier for each innovator, we use a disambiguation method based on applicants' name, state of residence, and art unit. Our main results are robust to the inclusion of innovators' fixed effects.