Try, try, try again?

Differential Responses to Rejection & the Gender Innovation Gap

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Abstract

Women are underrepresented in STEM jobs despite making up over half of the college-educated workforce. This lack of representation extends to innovation, where it is well-known that women hold fewer patents than men. In this paper, we consider that the role differential attrition from the patent examination process is one contributor to the observed gender disparity in patent holders. To identify gender differences in the propensity to exit the application process, we evaluate the prosecution and outcomes of almost one million U.S. patent applications. We leverage variation in patent examiners' probabilities of rejecting applications to employ a quasi-experimental instrumental variables approach. Our results show that women who submit applications that are otherwise comparable to applications submitted by men are less likely to continue in the patent process after receiving an early-stage (but non-final) rejection of a patent claim. The importance of differential attrition appears to be sizable in magnitude: roughly half of the overall gender gap in awarded patents during this period can be accounted for by the differential propensity of women to abandon applications. We also provide suggestive evidence that institutional support is a significant channel that may lead to women's differential attrition. We find that the gender gap in patent application attrition is reduced when women-led applications have either the backing of firms or high-quality legal representation, consistent with a potential role for institutional support in mitigating gender disparities.

1 Introduction

By a variety of measures, women are underrepresented in innovation; in 2010, only 15.3% of all patents had at least one female inventor. This gap has narrowed over time as the number of female inventors has increased, but at the current rate, women will only achieve parity in patenting in 2092 (Milli et al., 2016). Women's differential participation in patenting is not driven solely by differences in education and occupation by gender; the gender gap in patents received is itself greater than the underrepresentation of women in STEM education and careers would suggest. Women comprise 28% of scientific and technical workers and only 12% of inventors on granted patents, despite making up over half of the workforce (Thébaud and Charles, 2018). Indeed, women are even less likely to receive patents than they are to pursue entrepreneurship (Toole et al., 2019). These facts suggest that even when women are well-positioned to contribute to innovation, they are underrepresented in formal records of innovation.

Participating in innovation has implications both for individuals' careers in the form of compensation and career trajectories, as well as for firm growth. Independent inventors may commercialize or sell patent rights, and within organizations, individuals who receive patents can see direct wage increases (Kline et al., 2019). Having a patent can also affect future employment by reducing the likelihood that an inventor will switch jobs (Melero et al., 2020). Patents are valuable for firms as well not only due to the intellectual property protection they provide, but also because of the signal that receiving a patent sends to investors. Startups that hold patents have higher sales and employment growth, and receiving a patent increases access to external funding from venture capital firms and banks (Gaulé, 2018; Farre-Mensa et al., 2020). Gender disparities in innovation can thus exacerbate differences in labor market outcomes between men and women at both the individual and firm level.

In this paper, we consider whether one causal factor that gives rise to the gender gap in patenting activity is the differential propensity to exit the patent application sequence after early-stage rejections. The patent prosecution process is a useful context in which to examine differential responses to rejection by gender, since there are a large number of patent applications from both men and women, as well as detailed data on and the iterative nature of patent review between patent examiner and applicant. Additionally, the patent process itself is an important setting in which to understand gender differences and identify potential policy interventions to increase the presence and success of women.

To answer this question, we use data from the United States Patent and Trademark Office (USPTO) on patent applications in the United States from 2002 through 2012. The final sample covers almost one million applications from US-based teams, both those that received patents and those that did not. The data include basic information on a patent application, including the technology class, the outcome of the application (whether a patent is issued), and innovators' full names, which we use to elicit gender. Importantly for our analysis, the USPTO data also include complete prosecution histories, which detail the entire application process. In particular, we can observe each step of the application and communication between the patent examiners and applicants, including rejections, amendments, and appeals. Most applications receive at least one rejection, coupled with feedback from a patent examiner, to which inventors must respond in order to continue their applications. Notably, patent applications are rarely categorically rejected by the USPTO. Rather, they are either implicitly or explicitly abandoned by applicants following what technically are appealable rejections issued by patent examiners (Lemley and Sampat, 2008). Thus, we consider innovators' tendencies to follow up on an application and amend their claims as a measure of persistence.

Estimating the causal effect of rejection on patent application is empirically challenging, given that the likelihood of receiving a rejection and the feedback that an inventor receives might be correlated with a host of unobservable application attributes also correlated with gender. We leverage the quasi-random assignment of applications to examiners to isolate the role of rejection. The intuition behind this strategy is that different examiners have different propensities to approve patents. More lenient examiners are more likely to grant a patent than are harsher[1] examiners, holding the quality of the proposed invention constant. In order to identify the causal effect of rejection on patent continuation, we use examiner harshness across all *other* applications in the same technological specialization and year as an instrument for patent rejection.

Our estimates using this IV strategy indicate that majority-female teams are 3.3-7.3 percentage points less likely to continue the patent process after receiving an initial rejection compared to male inventors. This differential effect by innovators' 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 females as compared to their male counterparts. This disparity in the continuation of applications from men and women accounts for more than half of the gender gap in granted patents, conditional on application. When restricting our attention only to applications filed by individuals, our estimates suggest that a rejection reduces the percentage of women applicants by 4.5 percentage points. This effect remains statistically significant when we examine the effect of the proportion of women inventors, or use indicators for whether the innovating team consists mostly or solely of female innovators.

Having shown significant gender disparities in attrition from application process, we then

[1]Consistent with other work in this domain (Farre-Mensa et al., 2020), we refer to more stringent examiners as being "harsh".

turn to a discussion of potential mechanisms that may explain. There are several potential reasons discussed in the literature that may explain why women are less likely to follow up than men after receiving a non-final rejection. In our view, these explanations can largely be considered either "institutional" or "behavioral" in nature. Behavioral explanations primarily relate to a rich literature in psychology and behavioral economics documents that women are more risk and competition-averse, which may in turn lead to differential attrition. In other words, women are more likely to opt out of settings in which their performance depends on competitive outcomes. Women's reluctance to enter competitions remains even when controlling for overconfidence, feedback aversion, and risk aversion (Buser et al., 2014; Flory et al., 2015). If the taste for competition is lower among women than among men, women may self-select into more routine inventive activities and tasks, rather than engage in risky, challenging projects.

While behavioral channels relate to differences in preferences or attitudes by gender, we can think of institutions as the "rules of the game" that govern organizations; the institutional framework shapes incentives, which in determine how skills and knowledge are deployed for maximum payoff (Williamson, 1979; North, 2005). Institutions can be broadly characterized as either 1) "public" institutions, or 2) private (decentralized/informal) institutions (Ingram and Silverman, 2002). Public institutions include laws, regulations and tax codes that may affect the labor market for inventors. Noncompete agreements and nondisclosure agreements, for example, are thought to hurt gender diversity among innovators. On the other hand, private institutions include societal norms, cultural norms, expectations and beliefs. Both types of institutions are particularly impactful for innovative ventures, as they suffer from the liability of newness (Stinchcombe, 1965) and must struggle against existing institutional arrangements (Aldrich and Fiol, 1994; Scott, 1995).

While data limitations prevent us from a complete accounting of mechanisms driving our treatment effect of interest, our analysis of mechanisms suggests that institutional channels are likely at play. We provide a few pieces of suggestive evidence that gender differences in institutional support is a likely mediator for the patent application attrition gap. To demonstrate the importance of institutions, we focus on three main institutional explanations: organizational/firm support, legal support, and macro-environmental support.

We first examine whether individuals and teams that submit an application with the support of a firm behave differently than unaffiliated inventors. We find that in the aggregate, firm-backed applications are considerably more likely to proceed beyond an initial rejection. This effect is even stronger for applications whose authorship is majority female; applications from half- and all-female applicant teams are 3.8 and 5.1 percentage points (respectively) more likely to follow up after receiving an initial rejection if they are affiliated with a firm than similarly situated male applicants. The positive effect of firm affiliation on female inventors' persistence in pursuing patents suggests that the provision of resources to inventors and organizational management of patent applications can help shrink the gender gap in persistence, and thus in patenting outcomes.

Another institutional barrier that women may face is access to high-quality legal representation (Sandefur, 2008). Existing research suggest that women are less likely than men to utilize formal legal processes to advance their interests within the workplace (Miller and Sarat, 1980; Quinn, 2000; Marshall, 2003; Quinn, 2015). In the patent context, factors contributing to this institutional deficiency may be information-based (the lack of awareness of the patent process) or the resource-based that are available as well as the difficulty and cost of the patent process. The process of obtaining a patent is a complex legal process – requiring property drafting and filing an initial application, and potentially then negotiating applications with government agents within the USPTO in order to finally receive legal protection for an invention. Even filing a patent application alone can be costly, with attorney fees alone costing $5,000 to $16,000 – before getting to the stage of amendment and reapplication (Fechner, 2019).

We test for the importance of access to legal representation by using the detailed information in the USPTO data on the lawyer/firm that represents a given innovator. Specifically, we evaluate whether using a lawyer to file a patent application has an effect on gender differentials in responses to rejection. Using measures of legal representation quality based on an industry database, we find that gender differences in access to representation are a significant driver of the gap. When female applicants are represented by one of the top general or IP-focused law firms, the gender differential in applicant attrition shrinks considerably.

Finally, drawing on recent research highlighting the importance of broader social context for gender diversity (Zhang, 2020), we examine whether the importance of the macro-institutional environments by examining industry and geographic heterogeneity in gender attrition disparities. The gender gap in patent examination attrition is significantly lower in states and industries in which women face lower levels of discrimination, as measured by industry and state-level gender earnings gaps. This finding is consistent with a large body of research documenting that regulation and norms governing diversity in the workplace are often geography-specific. For example, studies on diversity management have found that geographic context strongly shapes both regulatory and normative legitimacy of gender diversity in organizations (Nishii and Özbilgin, 2007; Klarsfeld, 2010; Christiansen et al., 2016).

Contributions

Our findings contribute to the existing literature on the gender innovation gap. Understanding where in the process of innovation women fall out and why this happens is essential in order to develop solutions that address the gender gap in innovation (Delgado et al., 2019; Cook, 2020). We build 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. Our results shed light on gender differences in entrepreneurship and innovation (Ding et al., 2006, 2013; Guzman and Kacperczyk, 2019) and highlight a potential driver of broader gender disparities in participation in these fields.

Our results also speak to the literature studying gender differences in organizations (Fernandez-Mateo and Coh, 2015; Brands and Fernandez-Mateo, 2017) and the role that institutional investments can play in addressing and shrinking performance gaps between men and women (Blau et al., 2010; Srivastava, 2015). Our findings suggest a channel through which organizations can effectively improve outcomes for women. Finally, we add to the literature studying gender differentials in response to rejection in other settings, such as politics (Wasserman, 2018), and crowdfunding (Kuppuswamy and Mollick, 2016) by showing how differential responses to rejection by gender contribute to variation in outcomes in the context of innovation.

2 Setting

We study gender differences in the patent application process in the United States. Patents in the United States are granted exclusively by the 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 directed to an art unit, which is comprised of patents of the same technological field. Then, the application is assigned to an examiner, who oversees the application for the remainder of its existence. The assigned examiner assesses the viability of inventor's claims and decides whether to accept the patent claims. Most applications (over 80%) are not immediately accepted.

Patent applications are not categorically rejected by the USPTO. An applicant may respond to an initial, or any subsequent, rejection by amending their claims. Rejections that occur after an initial rejection are typically categorized as 'final' rejections by USPTO. However, even when a final rejection is issued, an inventor can continue to submit amendments or appeals. Patent applications are only terminated when the inventor implicitly or explicitly abandons the application following what technically is an appealable rejection issued by the patent examiner (Lemley and Sampat, 2008).

Figure 2 provides a detailed summary of the patent prosecution process, for all-male and all-female teams, which constitute approximately 85% and 5% of our final sample, respectively. As we can see in the figure, men are far less likely to abandoned an application following an initial rejection, 13.5% compared to 21.9% for women.[2] The gap is even more apparent when examining responses to 'final' rejections–men are 9.3% more likely to respond compare to women.

Ultimately, approximately 60% of applications that received an initial rejection are awarded a patent. However, as men are more likely to respond to examiner's comments are each given round, there is a large discrepancy in the propensity of patent issuance for initially rejected applications—62.6% for men compared to 49.2% for women.

3 Empirical Framework

3.1 Data

This section focuses on the core data required for the main findings; we relegate a more detailed account to Appendix Table **??**. Table A1 presents the descriptive statistics.

We use data on patent applications from 2001-2012 from USPTO's Patent Application Information Retrieval (PAIR) database. The data include basic information on a patent application, such as technology class, art unit, firm assignment, and whether a patent was ultimately granted. Importantly for our analysis, the data also include complete prosecution histories, the identity of the examiner assign to the application,and applicant amendments and appeals.

Unfortunately, the gender of the applicant, which is crucial to our empirical design, 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. Particularly, we identify the frequency with which specific names are given to males and females born in the United States. For example, if there are 10,000 people with the name Carol, and 9,500 of whom are were women, then the name Carol would receive a female proportion of 95%. We use a 90% cutoff threshold and drop applications for which any inventors' names are assigned to both male or female less than 90% of the time, i.e., we exclude

[2]Figure 2 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.

unisex names such as Alex or Taylor. The final sample includes only applications for which we can assign gender to *all* inventors on the team. Additionally, we limit the sample to applications for which all inventors are based in the United States and that have ten or less inventors. Using this method, we are able to identify the gender of all inventors for 71% of applications. Our final sample includes 971,547 applications.

It is straightforward to define the gender of applications filed by a solo inventor. For applications submitted by research teams, however, we focus on several measures of gender composition: (1) whether the team is composed of 50% or more women (half-female), (2) whether it is composed of all women (all-female), and (3) the proportion of women on an application.

In addition, we use USPTO data on employer assignment, i.e., whether the application is backed by an organization, as well as the information for an attorney filing the application (if any). Finally, we complement the USPTO data with additional data sources including Compustat, which contains financial data on publicly traded firms, Vault's ranking for top law firms, and data from the American Community Survey, which we use to derive the gender wage gap by industry and state.

3.2 Empirical Strategy

Our goal is to identify the gender differential in responses to negative decisions made by patent examiners. A simple comparison of response rates between women and men, however, will fail to cleanly isolate gender differences. The main reason is that rejected application might systematically differ on unobserved variables such as patent quality, broadness, room for amendment etc. Thus, comparison of gender differences is plagued by omitted variable, leading to potentially biased estimates. Ideally, we would want to hold applications' observable and unobserved attribute fixed and randomize patent rejections across men and women.

To get closer to this (infeasible) experiment, we use an instrumental variable (IV) approach which introduces variation in the likelihood of receiving an initial rejection *regardless* application attributes. Particularly, we use the quasi-random assignment of patent examiners to applications. Our design is similar in spirit to several recent studies about the patent prosecution process, such as Sampat and Williams (2019) and Farre-Mensa et al. (2020). The intuition behind this approach is that examiner harshness directly affects the likelihood of receiving a rejection, but should be (conditionally) uncorrelated with applications' attribute: Within art units, the USPTO assigns examiners to applications based on availability and other internal factors.[3]

[3]Based on qualitative and empirical evidence: for example, 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

Our final sample includes 7,700 unique examiners. We define examiner leniency as the leave-one-out initial rejection rate of examiner by art unit-year (i.e., the proportion of initial rejections in all *other* applications reviewed by the examiner that year). Formally, we define harshness as:[4]

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

In this expression, e indicates the examiner assigned to an application a, n_e is the total number of applications seen by examiner e in art unit-year, k indexes the applications seen by examiner e, and ER_k, an initial reject, is equal to one if the applicant did not receive a patent when the first response was given by examiner e for patent application k. 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, it is difficult to imagine why examiner's rejection rate for *other* applications would be correlated with a specific application's unobserved attributes.

Nevertheless, following Sampat and Williams (2019), Figure 3 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 all the application information we have: art unit, year, number of applicants, gender, whether the application is associated with an employer or lawyer, etc. We find a strong relation of almost unity between harshness and actual rejection rate, suggesting that harshness significantly affects the probably of initial rejection. In contrast, we see an extremely weak relation between harshness and *predicted* rejection rate. This finding implies that there does not exist a consistent relationship between examiner's harshness and ex-ante rejection probability, which supports the validity of the exclusion restriction.[5]

Using examiner harshness as an instrument for rejection, the main specification is:

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

Where ut is the patent art unit X application year. Y_a is the outcome of interest, either whether

or substantive evaluation of an application before assigning it to an examiner.

[4]In Table A3, we discuss an alternative definition of examiner leniency, using the leave-one-out *patent* rejection rates.

[5]Following Righi and Simcoe (2017), in Table A2, we also test quasi-random assignment of applications to examiners with subclass fixed effects.

inventors continued the application following a rejection or whether the application was approved. $Initial\,Rej$ is a dummy for whether the application received an initial rejection, and $Female$ is an indicator for the prevalence of females in the inventors team, as described in Section 3.1.We instrument for $\widehat{Initial\,Rej}_a$ and $[Female \times \widehat{Initial\,Rej}]_a$ using $Harshness_e$ and $[Female_a \times Harshness_e]$, respectively. μ_{ut} are art unit X application year fixed effects. We cluster at the examiner X application year level, which as the unit at which treatment is assigned.

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. In other words, β_3 captures the gender *differential* in response to rejection.

4 Results

4.1 Main Findings

We begin our analysis by presenting suggestive evidence that persistence has a central role in explaining the gender innovation gap. Panel A of Table 1 presents the results of a simple OLS regression of the impact of gender on initial rejection rates, controlling for application art unit-year. The definition of female changes across columns: Column 1 provides an estimate for the effect of the proportion of women on an application; Column 2 defines female as equal to one if 50% or more of the inventors on an application are women; in Column 3, female is equal to one if 100% of inventors on an application are women (includes applications from solo women), and Column 4 includes only solo applicants and female is equal to one if the sole applicant is a woman.

We find suggestive evidence that teams with more women are marginally more likely to receive initial rejection compared to majority male teams. While 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 0.7 percentage points more likely to receive an initial rejection. Since inventor gender might be correlated with unobserved characteristics such as patent quality, we cannot completely rule out that examiners are discriminating against female inventors. Nevertheless, the above evidence suggests that discrimination, at least at the first office action stage, is not a major driver of the patent gender gap.

In contrast, as we observe in Panel B in Table 1, the presence of women on inventor teams is correlated with significant reductions in the probability of a patent being granted. For instance, as is shown in in Column 3, 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. Thus, the effect on final outcome is an order of magnitude larger than the effect of initial rejection. This difference in magnitudes is presented graphically in Figure A2.

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 submits roughly two amendments. This finding is consistent with our hypothesis that heterogeneous responses to persistence drive the innovation gender gap.[6]

Persistence by Gender: We now turn to our primary question, which studies heterogeneity by gender in innovators' responses to initial rejections. Table 2 presents our primary estimation results using the instrumental variable strategy presented in Equation 1. The definition of the Female variable changes across columns and is indicated in the last row of each column, similar to Table 1. We focus on two primary 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. This finding is consistent all of our specifications.

We begin by focusing on Panel A. These regressions capture the effect of receiving an initial rejection on submitting an initial amendment, the next step to keep a rejected patent application alive. As expected, mechanically, receiving an initial rejection increases the likelihood that applicant(s) subsequently submit an initial amendment in response. Column 4, for instance, shows that, in solo applications, female applicants are 4.5 percentage points (p.p.) more likely to abandon an application following an initial rejection compared to male applicants. Recall that because we are leveraging random variation in likelihood of initial rejection, these estimates avoid potential bias from unobservable application characteristics.

This pattern is consistent across specifications: Column 1 shows that the effect persists even when continuously evaluating share of women on the application. Similarly, Columns 2 and 3 provide estimates of the primary specification using different measures of female presence on inventor teams. In Column 2, we observe that when patents whose authorship is primarily female (patents in which 50% or more of the inventors on an application are women), and in Column 3, all-female teams. As expected, the estimated effect is larger in magnitude when comparing the

[6] To further investigate the concern that examiners themselves may be gender biased, we investigate whether examiners' propensity to reject female inventors changes with examiners' gender. We evaluate the interaction between examiner gender, applicant gender, and initial rejections. The results are presented in Table A4. Generally, we find no evidence that the examiner's gender has any bearing on the persistence gap between men and women.

effect of all-female teams to that of mostly-female team, 3.3 p.p. and 7 p.p., respectively.

In Panel B, we focus on whether this mechanism explains the overall gender disparities in patenting. We examine whether women are differentially deterred from ultimately *completing* patent applications after initial rejections by their assigned patent examiners. Successful patent grants may involve several examiner rejections of specific claims, followed by applicant amendments, before a patent is finally awarded. We find that, across specifications, the initial differential effects of initial rejection are amplified when examine patent issuance rates. For instance, Column 4 shows that, in solo applications, female applicants are 7.5 p.p. less likely to receive a patent following an initial rejection compared to male applicant. 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.

Similar to Panel A, the pattern is again consistent across specification: The differential effects of initial rejections on female and female-led application are magnified when examining patent issuance. The estimated effects when looking at mostly- and all-female teams are 5.9 p.p. and 10.4 p.p., respectively. We observe consistent magnitudes of differences between immediate (as measured by initial amendment submissions) and downstream (measured by patent receipt) gender differences across our measures of gender application composition. In all cases, the differential deterrence of women after initial rejection is larger for final patent completion than for completing the immediate next step of the process, and the differential response to initial rejections accounts for 55% to 70% of the gender gap in granted patents.

4.2 Drivers of Differential Attrition

We now turn to examining the mechanisms driving the differential responses between female- and male-led teams.[7] In particular, we focus on institutional support as a channel to moderate the gender innovation gap. Our main test is a triple-differences regression in which we estimate how the differential effect of initial rejection by gender changes as one varies the level of institutional support.

We operationalize institutional support in three ways: organizational support, legal advice, and institutional environment. Organizational support captures the benefits of an application being affiliated with a more supportive organization, such as access to resources, information, networks etc. We incorporate two measures of the level of institutional support. Most simply, we explore

[7] As mentioned above, we are unable to completely corroborate or reject behavioral explanations, such as overconfidence or risk-aversion.

whether an application is assigned to an employer. Next, to measure organizational experience, we calculate the (logged) number of previous application filed by the organization.

To estimate the effect of legal support, which can aid an applicant in making more informed decisions, we add a dummy variable for whether the application is supported by a lawyer, and whether the law firm representing the application is in the top 50 or 100 law firms in the US (according to Vault, the leading source for law firm ratings).

Finally, to capture the institutional environment more broadly, we also estimate the moderating impact of wage equity in the relevant industry and state.[8] 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 in formally in Appendix Table A6 and graphically in Figure 4. Figure 4 presents the estimated triple interaction between female (using the "All Female" definition), instrumented initial rejection, and the institutional variable of interest. Panel A presents the effect on initial amendment and Panel B on patent issuance. As is clear from Figure 4, institutional support substantially reduces the gender gap. For instance, looking at the first coefficient in Panel A, the effect of employer, we find that when an application is affiliated with an employer, the gender difference in propensity to file an initial amendment is mitigated by about 5 p.p. This pattern is consistent across the various measures of institutional support– the coefficients are always positive, and almost always statistically significant, implying that institutional support substantially mitigates the gender differential in responsiveness to rejection. Note, however, that while the gap decreases substantially, we still find significant difference in the attrition rates of male and female applicants.

Panel B presents a similar story. Institutional support mitigates not only the gap in responsiveness after an initial rejection, but also improves the overall gap in patent issuance between female- and male-led applications. Taking the first coefficient for example again, we find that when the application is supported by a firm, the differences in patent issuance rates between all female applications and all other applications are mitigated by 5.7 p.p. Again, the gender gap is substantially decreased, but it not completely negated, even when the application receives strong institutional support.

[8]Since the relevant industry is based on the firm supporting the application, we can only estimate the impact of the industry wage gap for applications assigned to a firm.

5 Discussion and Conclusion

In this study, we seek to identify the extent to which gender differences in deterrence after early setbacks contribute to the underrepresentation of women in innovation. To do so, we study how male and female inventors respond to rejection in the patent application process. We use an instrumental variables strategy that takes advantage of the quasi-random assignment of applications to patent examiners. We identify that gender differentials in responses to rejection contribute significantly to differential outcomes in patenting for women. Female inventors who receive rejections early in the application process are less likely to submit amendments in response to examiner feedback, and this results in the abandonment of their applications. We also explore the effects institutional support by evaluating how organizational support, legal guidance, and institutional environment mitigate the gender differential. We find that increased institutional support substantially mitigates, though not completely negates, the gender gap.

Our findings have implications for work on gender gaps more broadly. We identify a potential driver of the underrepresentation of women in the last steps of the innovative process– from filing a patent application to receiving the patent. As is clear in our data, gender gaps are substantial even prior to the application stage, as about 85% of patent application are filed by solo male inventors or all-male teams. While we cannot directly observe the steps leading up to patent filing, such as choosing a career or investing in potential patent, it seems plausible to think that differential attrition contributes to that gap.

Moreover, the main mechanism we study opens the door to potential interventions that policymakers can consider to begin addressing the gender gap in patenting, so that future innovations can better serve the needs of a diverse and varied world. 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.

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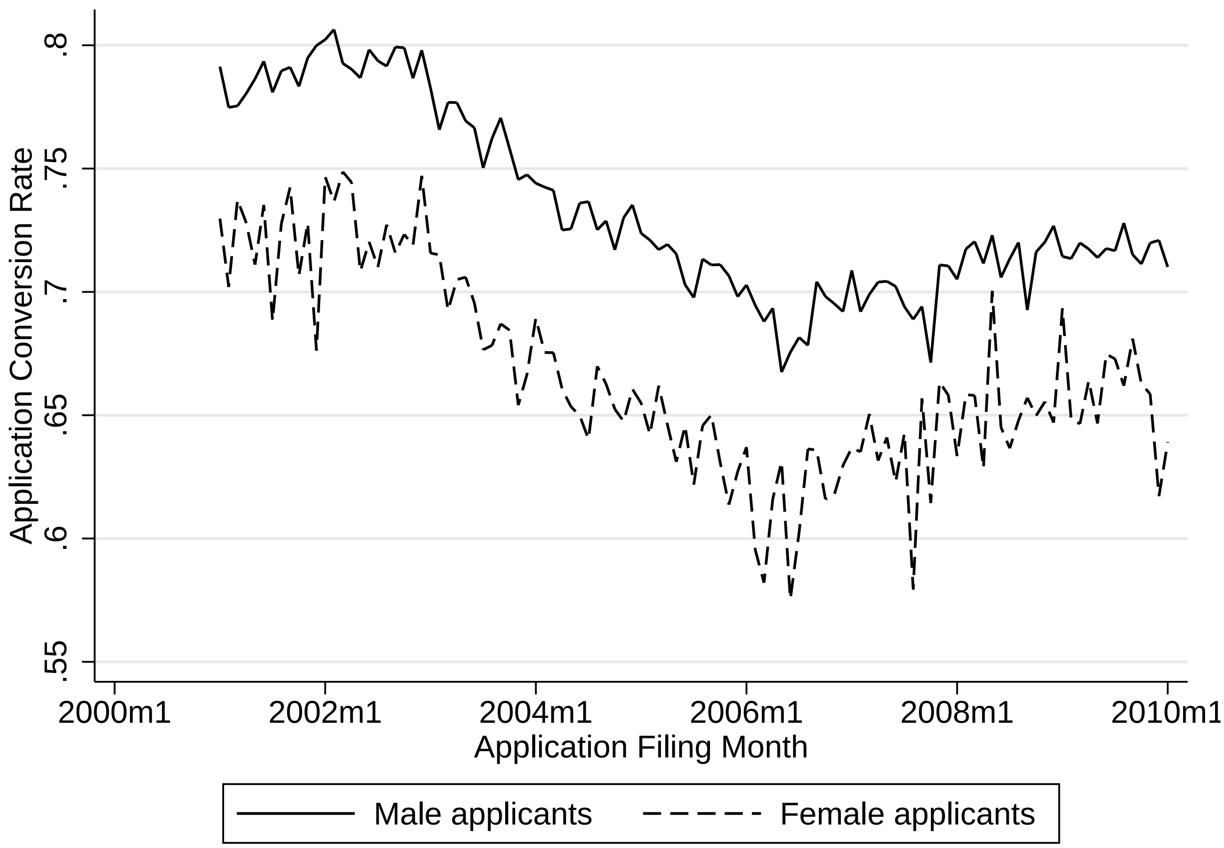
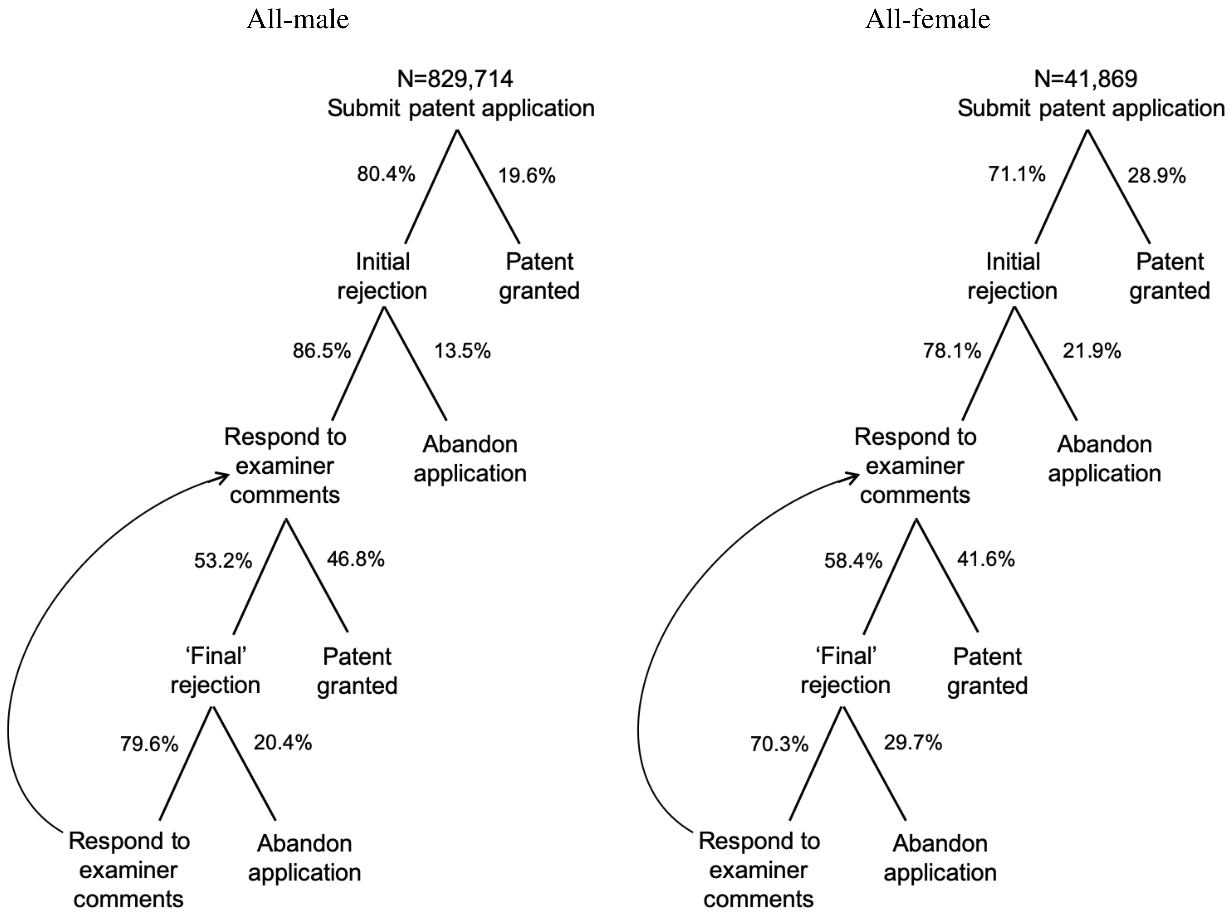
6 Figures and Tables

Figure 1: Application Conversion Rates by Gender



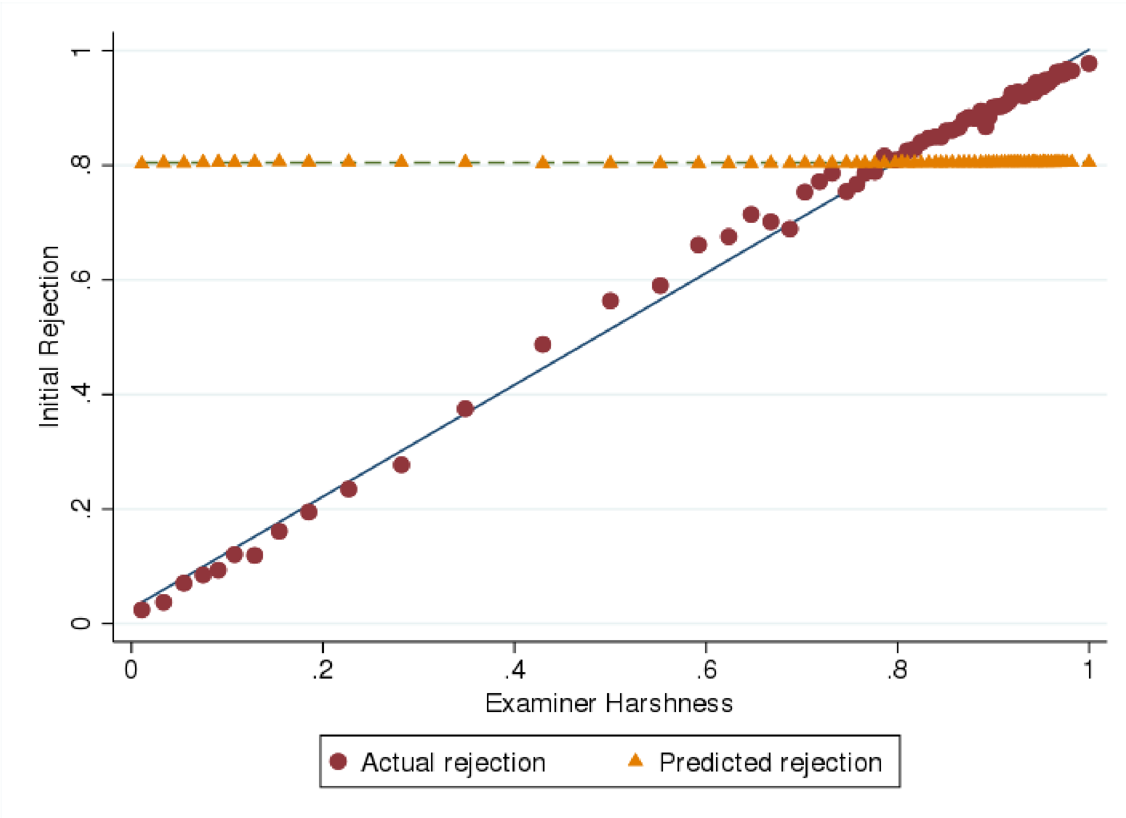
This figure shows the raw proportions of granted patents of total applications filed by applicants gender.

Figure 2: Evaluative Trajectory of Patent Applications



This figure 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.

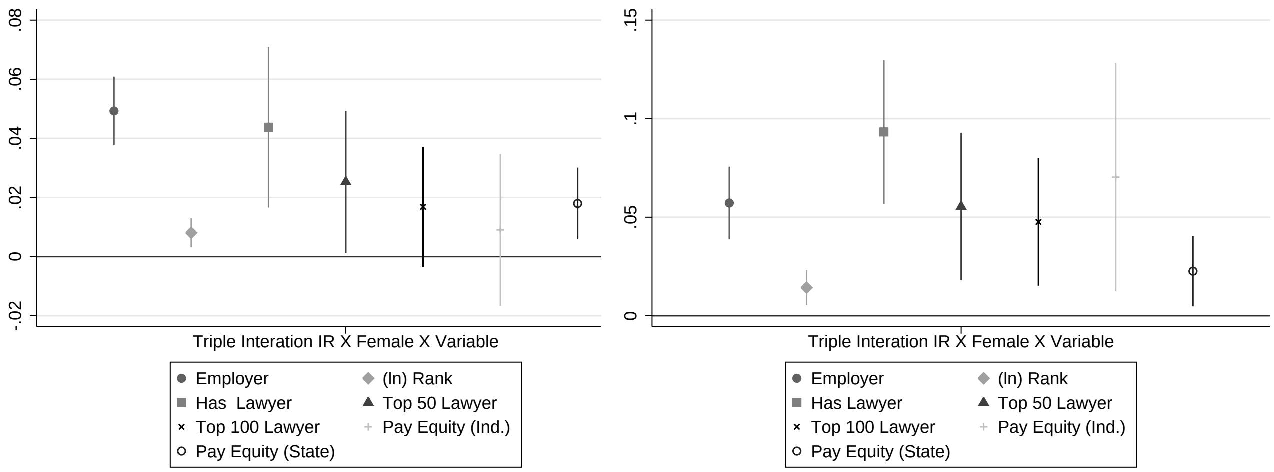
Figure 3: Distribution of Examiner Harshness by Initial Rejection (Residualized)



This figure relates examiner harshness to two variables: the actual initial rejection rate, shown in red, and the predicted rejection rate in yellow. By construction, the initial rejection rate is perfectly correlated with examiner harshness. Predicted rejection is based on observables that proxy for 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 4: Impact of Institutional Support on Differential Responses to Initial Rejection

Panel A: Effect on Initial Amendment | Panel B: Effect on Patent Issued



This figure present the estimation results of the triple integration 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 art unit-year. Female definition compares all-female teams to all other 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

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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

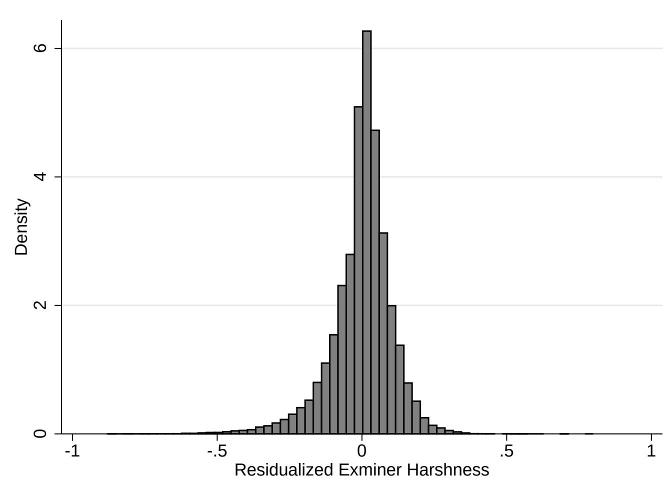
Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

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.

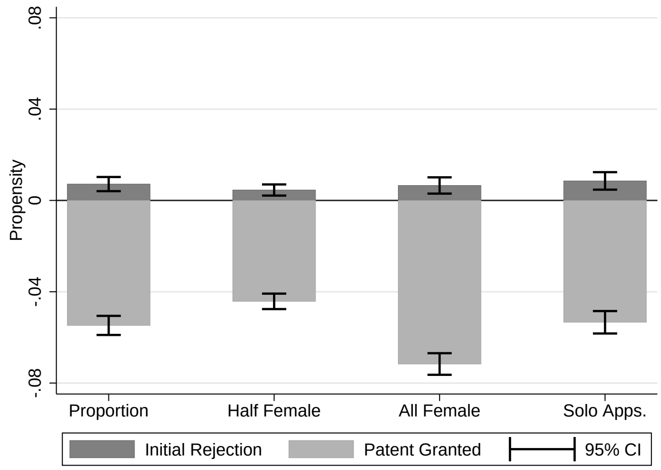
7 Appendix A: Additional Figures and Tables

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

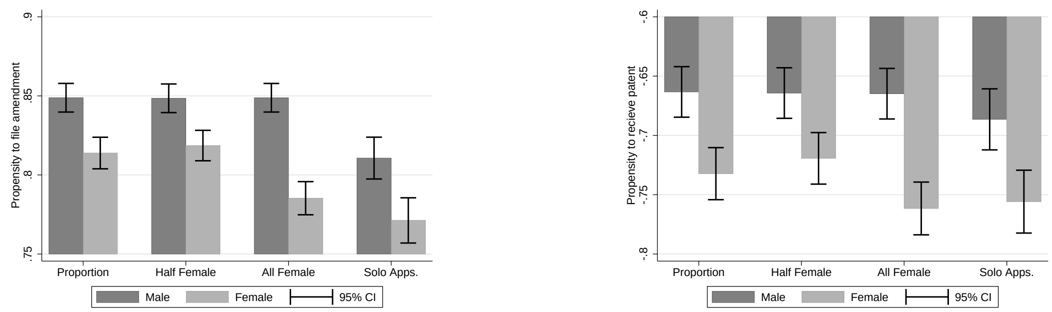


This figure shows the estimated coefficients and confidence intervals from four different regressions estimating the impact of gender on application outcome, where female definition is indicated below each bar.

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. 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	0.047*	0.041*	0.059**	0.058**
	(0.019)	(0.017)	(0.021)	(0.022)
Initial Rejection × Examiner Female	-0.037***	-0.038***	-0.036***	-0.039***
	(0.009)	(0.008)	(0.008)	(0.010)
Female × Initial Rejection	-0.083***	-0.069***	-0.135***	-0.097***
	(0.016)	(0.014)	(0.017)	(0.018)
Examiner Female	0.040***	0.040***	0.039***	0.043***
	(0.007)	(0.007)	(0.007)	(0.008)
Female × Examiner Female	-0.040**	-0.032*	-0.048**	-0.048**
	(0.015)	(0.013)	(0.015)	(0.016)
	Panel B: Patent Recieved			
Female × Initial Rejection × Examiner Female	0.155***	0.109***	0.152***	0.143***
	(0.044)	(0.038)	(0.045)	(0.046)
Initial Rejection × Examiner Female	-0.247***	-0.243***	-0.240***	-0.188***
	(0.027)	(0.026)	(0.026)	(0.026)
Female × Initial Rejection	-0.185***	-0.131***	-0.187***	-0.174***
	(0.035)	(0.030)	(0.035)	(0.037)
Examiner Female	0.235***	0.232***	0.230***	0.183***
	(0.025)	(0.025)	(0.024)	(0.024)
Female × Examiner Female	-0.127***	-0.085**	-0.114***	-0.110***
	(0.040)	(0.035)	(0.041)	(0.042)
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: 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.

Table A6: Impact of Institutional Support 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) Rank	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 applicant fixed effects and are clustered at the examiner-year level.

Table A7: Gender Differences in Patent Quality and Scope

	Panel A: Patent Scope			
	(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 B: 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 C: 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