TRY, TRY, TRY AGAIN?
PERSISTENCE AND THE GENDER INNOVATION GAP

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Abstract

We document that 85% of patent applications in the United States include no female inventors and ask: why are women underrepresented in innovation? We argue that differences in responses to early rejections between men and women are a significant contributor to the gender disparity in innovation. We evaluate the prosecution and outcomes of almost one million patent applications in the United States from 2001 through 2012 and leverage variation in patent examiners' probabilities of rejecting applications to employ a quasi-experimental instrumental variables approach. Our results show that applications from women are less likely to continue in the patent process after receiving an early rejection. 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 explore why this may be the case and provide evidence that the gender gap in outcomes is reduced for applications that are affiliated with firms, consistent with a role for institutional support in mitigating gender disparities.

1 Introduction

By a variety of measures, women are underrepresented in innovation, and 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 would 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. 2017). 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 are 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.

If, conditional on having an innovative contribution, women do not patent at the same rates as men, women's inventions may be lost, with negative implications for potential inventors as well as the progress of innovation. This can have distributional consequences; innovation comes from expertise, but also from exposure to contexts that could benefit from innovation and situational awareness. For example, female-led patent teams and teams including women are significantly more likely to produce female-focused innovations (Koning et al. 2019). If women are less likely to participate in innovation, the female population may lose out differentially.

Work exploring the causes of the gender gap in innovation has primarily focused on the pipeline for innovators and bias in evaluation processes. The gender gap in patents could be, among other things, a result of the lack of gender diversity in science and technology and biases that women face in innovative fields with respect to career advancement and access to resources. Conditional on studying STEM subjects, female college graduates are less likely to transition to STEM jobs (Sassler et al. 2017), and female academic scientists are less likely to patent due to having more limited professional networks. (Ding et al. 2006). Prior research has found that the small proportion of women who do participate in innovation are subsequently disadvantaged by biased evaluations of their accomplishments and capabilities as compared to similarly qualified men (Ridgeway and Correll 2004; Ding et al. 2013). This has measurable implications for innovation and individuals' careers; one third of the gender gap in financing for entrepreneurs is due to venture capitalists' reliance on negative stereotypes in the face of uncertainty (Guzman and Kacperczyk 2019).

These findings provide important insight into the dynamics that affect who enters and succeeds in innovation and entrepreneurship. However, these explanations overlook another channel that arises when one considers the fact that innovation is a setting in which failure and rejection are a part of the process (Kline and Rosenberg 1986; Holmstrom 1989). In fact, tolerance for failure can even enable more significant innovations (Tian and Wang 2014). If women and men differ in the extent to which they continue to pursue innovative activities after facing rejection- whether due to support, resources, or other drivers- their innovative trajectories may also look quite different. In other words, if women who acquire the skills and resources to invent respond differently to rejection than male inventors, the set of successful inventors will be disproportionately male even conditional on the initial pool of ideas. Work in other domains suggests that women are less likely than men to consider a job opportunity at a firm that has previously rejected them (Brands and Fernandez-Mateo 2017), and women are less likely than men to create a crowdfunding campaign following an initial failed crowdfunding attempt (Kuppuswamy and Mollick 2016). Whether similar dynamics are at play when considering innovation remains an open question.

In this work, we focus on the role of gender differences in responses to rejection, which we describe using the term "persistence," in driving the gender gap in innovation in the context of patenting. There are a number of reasons why women may be less likely to follow up than men after receiving a rejection. For example, female inventors may have less familiarity with the patenting process and interpret a rejection as a signal that their idea is not worth pursuing further. It could be that women are interested in following up on their applications but lack the resources- time, money, or information- to do so (Ceci and Williams 2011). Or, it may be that women are more likely to interpret negative feedback as an appraisal of their quality and thus lose confidence in their inventions (Cech et al. 2011). Women might believe, correctly or not, that they face bias from evaluators and thus feel there is less value in responding to a rejection. Finally, it could be that women's ideas are of differing quality from men's ideas, and knowledge of their quality leads women to invest less in pursuing their innovations. We do not attempt to provide an exhaustive accounting of why this may be the case, nor do we make an argument about the innate differences between women and men. Rather, we explore potential drivers of this gap by leveraging our empirical strategy to remove concerns about quality and bias.

Specifically, we explore how resources and information affect patent outcomes by examining the effects of patent attorneys and firm affiliation. Many inventors elect to use patent attorneys to manage their applications. Lawyers can be an important source of information for inventors regarding how to write their applications and respond to comments from examiners so as to increase the chances of patent receipt. We also examine the outcomes of patent applications that are associated with firms. Firm assignment indicates that a firm will assume the ownership right of the patent, and is generally accompanied by financial support and guidance through the patenting process.

Patent prosecution is an excellent context in which to examine responses to rejection due to the large number of patent applications from both men and women, the availability of detailed data, and the iterative nature of patent review. 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. We use newly available data from the United States Patent and Trademark Office (USPTO) on patent applications in the United States from 2001 through 2012. The final sample covers almost one million applications from individuals and teams based in the United States- both those that received patents and those that did not. The data include key information about a patent application, including the technology class, if application is associated with a firm, the outcome of the application (whether a patent is issued), and innovators' full names, which we use to elicit gender. We can also see each application's prosecution history, which details each step of the patent process. 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 (Lemley and Sampat 2008). 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. The likelihood of receiving a rejection and the feedback that an inventor receives might be correlated with a host of unobservable application attributes. 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.

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

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.

We next explore the effect of using a lawyer on responses to rejection and ultimate patent outcomes. We find that lawyers are more likely to push an application forward following the receipt of a rejection, but that there is no consistent variation in this effect by gender. That is, female inventors do not benefit differentially from using an attorney to represent their applications and as such, attorneys do not shrink the gender gap in patent continuation and receipt. This result suggests that differences in information about the patenting process are not a key driver of the gender gap that we observe.

We then 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.

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

To identify differences in responses to rejection as one channel that may contribute to gender disparities in rates of innovation, as well as under-representation in the science and technology labor market generally, we examine how men and women respond to first-time rejections within the patent process. Patents in the United States are granted by the the U.S. Patent and Trademark Office (USPTO). We begin with an overview of this setting, and how it provides the components of a natural experiment relevant to understanding gender differences in responses to rejection in this high-stakes setting.

Between 300,000 and 500,000 patent applications are filed at the USPTO annually (Frakes and Wasserman 2017). Application fees vary depending on the applicant, type of patent application, the application's level of complexity, and other features of the application, but the total cost of fees paid to USPTO are a minimum of roughly \$500 (excluding any attorney fees) (USPTO 2016b). Each application makes a set of claims delineating the legal rights that an inventor is seeking. This includes disclosure of "prior art," or existing patents material to the patentability of the invention. An application submitted to the USPTO is first directed to an art unit, which comprises patents of the same technological field. Within an art unit, a supervisory examiner quasi-randomly[2] assigns the application to a specific examiner, who oversees the application for the remainder of its existence. The assigned examiner first assesses the viability of an inventor's claim. She compares the prior art with the claims provided on the patent application, often conducting an interview with the applicant or the applicant's attorney. On the basis of the examiner's evaluation, she will write a "first office action" (FOA) letter that either accepts or rejects the claims. Some applications are accepted in their entirety during the examiner's initial examination. Most (over 80%) are not immediately accepted, with some or all of the claims failing to meet the requirements for patentability.

Patent applications are not 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). This includes at the FOA stage; most patent applications are rejected in the first interaction with the examiner. An applicant will typically then respond to an initial rejection by amending the claims. The examiner will then again either allow the claims in the amendment or reject them. That second rejection is typically categorized as a "final" rejection; however, at times, an application receives more than one initial rejection or more than one final rejection. However, even when a "final rejection" is issued, an

[2]Based qualitative and empirical evidence: for example, Frakes and Wasserman (2014) conducted a series of telephone interviews and confirms that supervisors do not make any substantive evaluation of an application before assigning it to an examiner. Additionally, Sampat and Williams (2019) (as well as our analysis) provide empirical evidence that, conditional on year and art unit, assignment of applications to patent examiners is plausibly random.

innovator can still attempt to convince the patent examiner that he/she is entitled to a patent wia the submissions of an amendment or appeal.

Receiving a rejection in the initial stage of the review process is not necessarily an indication that the innovation is of poor quality; in fact, over 60% of applications that are initially rejected eventually result in patents. As such, completing the patent prosecution process (i.e., the process of process of drafting, filing, and negotiating with the USPTO over patent rights) can require many months of work to remedy purported defects in an initial application and continue to try to convince examiners that a patent should be granted. Given the nature of the patent prosecution process, it can take several years from an application filing to the point at which a final patentability decision is made (Frakes and Wasserman 2014). Thus, the majority of patent applications require effort, patience, and persistence from the inventor in order to generate a "Notice of Allowance," which occurs when an examiner decides an applicant is entitled to patent protection for an invention. Our study examines whether, after receiving an initial rejection, women are more likely to exit the back-and-forth between applicant and examiner that is typically required for a patent to ultimately be granted. We measure responses to rejection by examining whether applicants follow up on early-stage administrative decisions by the USPTO.

Figure 1 provides a summary of the patent prosecution process and shows the raw proportions of applications in our sample, separated by gender of applicants, that proceed through each stage. Note that Figure 1 reports raw proportions without controls for application art units or time. "Initial" and "final" are used to describe the stages of rejection; however, as stated above, a single application can receive multiple initial rejections and final rejections to which the inventor(s) can respond with an amendment or appeal. Initial rejections are those that a patent application receives prior to an initial acceptance of some of the application's claims; some applications receive more than one initial rejection. Similarly, final rejections are those that the patent application receives following an initial acceptance of claims and prior to being granted the patent. At any point of time, the applicant can cease to respond to the examiner's communication.

As is evident in Figure 1, following both initial and final rejections, female applicants are far less likely to respond to the examiner's comments than male applicants. This difference affects which applications subsequently receive a patent; 63.6% of applications from male applicants that receive an initial rejection eventually go on to receive a patent, while for applications from women, that proportion is only 49.2%. Note that once controls are introduced in subsequent analyses,(3) the differential in rates of initial rejection by gender disappears when we include controls. For the purposes of this paper, we consider applications for which inventors did not respond to an office action to be those which the inventors are no longer pursuing. This is a broader set of applications than those that are formally identified as abandoned in the patent data, as it captures applications for which a lack of response followed examiner communication other than an action letter.

3 Empirical Framework

3.1 Data

To study differential responses to rejection between men and women in the patent prosecution process, we use individual patent application data over the course of 12 years from the Patent Office's Patent Application Information Retrieval (PAIR) database. The PAIR data cover all utility patent applications that were filed on or after March 2001. Our analysis focuses on applications that were filed from this date through 2012. We evaluate on non-provisional utility patent applications, which are formal applications for new processes, machines, and manufacturing systems (USPTO 2016a). Utility applications are the most common patents issued by the USPTO and make up over 90% of all patents issued annually. USPTO application records include basic information on a patent application, including the technology class, art unit, firm assignment, and the outcome of the application (whether a patent is issued). Importantly for our analysis, the data also include complete prosecution histories, including the examiner assigned to review an application, which we use to implement our identification strategy. The PAIR data also includes the date and sequence of application filing, each examiner rejection, applicant amendments and appeals, and final patent allowances.

Note that the gender of the applicant is not an explicit field within the USPTO data. We follow the same process as Jensen et al. (2018) to impute the gender of an applicant. We use publicly available data on the gender distributions of first names, in our case, downloaded from the U.S. Social Security Administration (SSA), to identify the frequency with which specific names are given to males and females born in the United States. There are 97,310 unique names in the SSA data, for which we construct a gender distribution by name. For example, if there are 10,000 people with the name Carol, 9,000 of whom are were women and 1,000 male Carols, then the name Carol would receive a female proportion of 0.9. We match these names to the 271,000 unique patent applicant names from the USPTO data to assign gender to patent applicants. We use a 90% cutoff threshold and drop applications for which any inventors' names are assigned either male or female less than 90% of the time (a proportion of less than 0.9). We only include applications for which we can assign gender to *all* inventors on the team. Using this method, we are able to identify the gender of all inventors for 71% of applications. Additionally, to ensure confidence in our gender identification of names, we limit our sample to applications for which all inventors are based in the United States. We focus on a few different measures of gender composition: (1) whether an application 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. We also conduct analyses in which we restrict attention to only applications submitted by individuals.

We use this same process to identify the gender of patent examiners. Each application is assigned to an examiner. 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. We are able to identify gender for 6,397 of these individuals. The majority of examiners are male, with just 27.9% of female examiners appearing in our data. 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).

We drop applications from teams composed of more than 10 individuals. In the remaining sample, we examine all applications, both those submitted by individuals and from inventor teams (composing 47% and 53% of our sample, respectively). We also use other information collected by the USPTO to test for heterogeneity and examine mechanisms underlying our results. Each application is associated with a correspondent, who is most often the attorney managing the patent application but may also be the inventor(s) if they elect not to use an attorney. It is not immediately clear in the data whether a lawyer is involved with a given application. However, by parsing the text of the correspondence name and address in the application data, it is possible to identify which applications are processed by lawyers. For example, if the correspondence name and address for one application are "Orrick and Partners" and "1234 Freedom Tower" respectively, one can reasonably assume that the application was managed by a law firm. Using natural language processing techniques, we identify that 94.5% of applications are managed by lawyers. The majority of lawyers and law firms appear infrequently in the data; the median lawyer submits two applications and receives only one patent.

Using the USPTO's data on assignment of application rights, we can tell whether an inventor is connected to a firm or is applying solo. The majority of applications (63%) are associated with firms. A firm "assignment" indicates that a firm will assume the ownership right if granted, and is thus an indication of firm backing of an application.[3,4] Data on firm assignment is manually entered by applicants, and there is no post-processing standardization applied to firm names. As a result, employer names exhibit a great deal of variation and errors. For example, two applications that are assigned to the same company could have firm names that are "Apple, Inc" and "Apple Corporation of California," respectively. To accurately identify firms and evaluate effects by firm

[3]Legally, the "original applicant is presumed to be the owner of an application for an original patent, and any patent that may issue therefrom, unless there is an assignment." (Graham et al. 2015)

[4]When an inventor or team of inventors apply for a patent, they are presumed to be the owner of the patent. Applicants can assign their idea to an organization or entity, generally the company for which they worked when they produced the idea.

size, we use natural language processing techniques to standardize employer names. Using this approach, we reduce the number of unique firms in the application assignment data from 109,952 to 77,093.

The core of our analysis focuses on almost one million applications. Table 1 provides summary statistics for the sample. As is clear from this table, the majority of applications result in patents. By all measures, women are underrepresented in applications, both on teams and as solo applicants. Also evident is the frequency of rejections in the applications process; the mean number of initial rejections received is greater than one.

3.2 Empirical Strategy

The goal of our study is to cleanly identify heterogeneous responses from men and women to negative decisions made by patent examiners, particularly at the First Office Action (FOA) stage of the patent application process. In other words, we identify gender differences in the likelihood that an applicant "persists" after having initial patent claims rejected (an *initial rejection*). We operationalize "persistence" in this setting as the likelihood of continuing with the patent prosecution process following a rejection at the first stage. While a fraction of patents will be granted based on the original claims, many more will involve adjustments to the application.

In other words, we examine whether, after receiving an initial rejection (the modal outcome in terms of an examiner's initial decision), women are differentially likely to submit an amendment responding to the points raised in the rejection. The ideal experiment to identify gender-specific responses to patent denials would be to randomize patent denials at the first instance across men and women, thus ensuring that successful applicants and their inventions do not differ systematically from unsuccessful ones ex-ante. Gender differences at the next stage would then indicate differential selection out of the patent prosecution process.

We model the relationship between receiving an initial rejection and continuing the patent prosecution process (including final receipt of a patent) as follows:

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

In this setup, a indexes a patent application, and ut the patent art unit*application year. Y_a is the outcome of interest, either whether 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 are interested in identifying the coefficient estimate for β_3, which tells us how likely women are to either amend an application or finally obtain a patent, conditional on receiving a rejection at phase one of the examination process, relative to men. In other words, β_3 captures the gender *differential* in response to rejection.

A simple comparison of how women compare to men in terms of continuing with the application process after an initial rejection will fail to cleanly isolate gender differences in responses to rejection independent of gender differences in application characteristics. That is, a comparison of gender-specific means may yield biased estimates because whether or not an application receives a rejection is likely correlated with application characteristics, many of which are largely unobservable. If, for example, men file applications for more incremental innovations that are inherently more easily obtained, they may receive rejections that have more straightforward, easy to address comments, and thus they may appear more persistent following a rejection. To estimate the effect that gender differences in persistence have on exit from the application process, we need variation in initial patent outcomes that is unrelated to other determinants of patents, such as the merit of a given application.

We use an instrumental variables (IV) strategy that leverages exogenous variation in the likelihood of receiving a rejection at the first step in the application review process. To obtain this type of exogenous variation, we use the quasi-random assignment of applications within the USPTO's review process to get as close as possible to the ideal experiment. The intuition behind this approach is that examiner harshness directly affects the likelihood of receiving a rejection, and it is also not correlated (as we show) with application quality and potential outcomes. The USPTO assigns examiners to applications quasi-randomly, and examiners differ systematically in their propensity to approve patents at any stage. Some examiners are more lenient and are more likely to grant patents, while others are more stringent and give a greater proportion of rejections. Thus, the variation in examiner harshness allows us to isolate the effect of rejection on application continuation. 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).

We define examiner leniency as the leave-one-out initial rejection rate of examiner by art unit-year (i.e., the proportion of all *other* applications for which a decision of initial rejection is made by a given examiner in each art unit-year). A higher value of harshness indicates that an examiner gives more rejections.[5,6]

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

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. We construct this measure for each application, so for a given application, the harshness measure captures how stringent the assigned examiner is based on all other applications she reviews. This measure of harshness avoids any bias from the current application. Figure 2 shows that examiner rejection rates at the initial decision stage vary substantially within year and art unit.

When we use this instrument to study the likelihood of patent continuation (responding to a

[5]We construct examiner harshness based on art unit-year because applications are assigned to examiners with art units in a given year.

[6]In Table A1, we discuss an alternative definition of examiner leniency, using the leave-one-out patent rejection rates; that is, how harsh an examiner is when it comes to actually granting a patent. The main results are robust to using the alternative definition.

rejection), one key insight is that examiners who are more likely to reject applications (those who are "harsher") are also those who give *more stringent* rejections. A useful analogy is to the process of academic publishing; referees who are more likely to reject submissions are also those who, when they write a review, are more likely to suggest substantial revisions. Similarly, when we compare the responses to rejections received from more lenient versus harsher patent examiners, we are examining how applicants react to incremental versus more significant comments.

Using examiner harshness as an instrument, we can then cleanly estimate heterogeneity in patent prosecution persistence:

$$Y_a = \beta_1 \widehat{InitialRej}_a + \beta_2 Female_a + \beta_3 [Female \times \widehat{InitialRej}]_a + \mu_{ut} + \varepsilon_{aut} \tag{2}$$

where we instrument for $\widehat{InitialRej}_a$ and $[Female \times \widehat{InitialRej}]_a$ using $Harshness_e$ and $[Female_a \times Harshness_e]$, respectively.

Before proceeding, we provide evidence in favor of a strong first-stage relationship. We report results of the first stage of our IV specification and examine the effect of the assigned examiner's harshness on the likelihood of rejection in Table 2. An examiner's prior rate of rejection has a significant effect on the likelihood of receiving an initial rejection, robust to the inclusion of covariates that measure characteristics of the application and applicants. In each of these specifications, the effect of examiner harshness on rejection is statistically meaningful, with F statistics well-above the threshold of 104.7 (Lee et al. 2020).

To satisfy the exclusion restriction, the only channel through which an examiner's stringency should affect outcomes is through the receipt of a rejection, and there should be no relationship between the assigned examiner's rejection rate for *other* applications and a patent application's potential outcomes. In our context, it is difficult to imagine how an examiner's harshness could affect patent outcomes other than through the likelihood that an application receives a rejection. Thus, any concern about identification would come from the harshness of the assigned examiner being correlated with omitted variables that affect the likelihood of following up after rejection or ultimately receiving a patent. Additionally, it is important to note that in our study, as we are interested specifically in the *differential* response of male and female applicants who are assigned to equivalently harsh examiners. That is, we do not examine the effect of patent rejection or receipt on potential outcomes like commercialization; instead, we identify the gender-specific effect of harshness on application continuation and receipt. As such, our design is even less vulnerable to these concerns regarding identification.

Following the advice of Righi and Simcoe (2017), we test our assumption of quasi-random assignment of applications to examiners by estimating our first-stage Ordinary Least Squares regression with and without subclass-fixed effects. This allows us to test whether the observed technology an application relates to is correlated with examiner characteristics. Table 2 presents these results. We find that adding subclass-year fixed effects in Column 3 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 do not predict whether the application receives a rejection.

We further examine the relationship between an application's quality and how harsh the assigned examiner is in Figure 3, which relates examiner harshness to the *actual* initial rejection rate, shown in red, and the *predicted* rejection rate in yellow. We calculate the mean initial rejection rate for each examiner, residualized by Art Unit-by-application year fixed effects. When we relate this measure of examiner "leniency" to initial rejection, by construction, we observe a strong relationship. We predict rejection based on a number of application covariates that may be related to quality, like the number of inventors on an application, the proportion of female inventors, whether the application is assigned to an employer, and the employer's patenting track record. Together, these variables predict 40% of the variation in initial rejection rates. This figure provides indirect support of a strong first stage relationship, as well as of the exclusion restriction and suggests there is no visible relationship between examiner harshness and predicted rejection. Drawing a harsher examiner increases the probability of initial rejection, regardless of patent quality or other ex ante characteristics.

We do not directly examine the question of whether examiners exhibit gender bias in this work. However, for our IV approach to be valid, the key issue is not whether examiners exhibit gender bias, but rather, whether gender bias is related to an examiner's leniency. That is, for a given examiner, there should be no relationship between her likelihood of issuing rejections and her gender-specific differential in harshness. This is most directly a concern if harshness and gender bias are positively related. If, for example, examiners who are harsher as measured by our leave-out mean rejection rate are also more likely to reject applications from women than applications from men, then male and female applicants may respond differently to harsher examiners because their experiences of interacting with said examiners differ more significantly than if they were interacting with a more lenient examiner. To address this concern, we calculate the gender differential in rejection rates for each examiner by finding the difference in the focal examiner's rejection rate for applications from men and applications from women. We then plot this against the examiner's overall harshness. We do this using two definitions for female applications: those that have majority and all-female authorship. Figure 4 displays our results. Importantly, there is no consistent relationship between an examiner's harshness and her gender differential in rejection. Harsher examiners are not systematically more likely to reject applications from female inventors. As such, our results on the effects of harsher examiners cannot be driven by across-harshness variation in gender rejection rates.

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 3 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 4, which restricts attention to applications filed by individuals, we find that female inventors are 0.9 percentage points more likely to receive an initial rejection. This coefficient estimate thus suggests that women are only 1.16 percent more likely than men to have their initial claims rejected (evident from dividing 0.009 by the mean of 0.77). This effect is even smaller for all other specifications. Since innovator gender might be correlated with unobserved characteristics such as patent quality, we cannot rule out that examiners are discriminating against female innovators. Nevertheless, the above evidence suggests that discrimination, at least at the first office action stage, is not a major driver of the innovation gender gap.

In contrast, observing Panel B in Table 3, we see that 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 receive a patent compared to applications filed by *all other* applicants. We observe similar magnitudes across all specifications. This suggests that there exists a gender gap in application conversion rates. More importantly, 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. Instead, this gap arises in subsequent stages of the patent application. This finding is consistent with our hypothesis that heterogeneous responses to persistence drive the innovation gender gap.

To further investigate the concern that examiners themselves may be biased and may apply more stringent requirements to female applicants, we use the same process as explained in Section 3.1 to impute the gender of patent examiners using first names. To investigate whether examiners exhibit gender bias and how this interacts with the examiners' own genders, we evaluate the interaction between examiner gender, applicant gender, and initial rejections. Results are presented in Table A2. We find no evidence that the examiner's gender has any bearing on the persistence gap between men and women.

Persistence by Gender: We now turn to our primary question, which studies heterogeneity by gender in innovators' responses to initial rejections. This approach allows us to directly compare male and female inventors' persistence in a unified regression framework. We evaluate this using the full sample of patent applications.[7] Table 4 presents our primary results. Each column indicates an estimation using the instrumental variable strategy in Equation 2. The definition of Female changes across columns and is indicated in the last row of each column, similar to Table 3. 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 1 summarizes the negative relationship between the presence of women on applications and innovation across our entire sample: for every 10% increase in women on an application, the likelihood of abandoning an ap-

[7] In Table A3, we conduct the same analysis but limit our sample to applications from individuals who apply completely independently; that is, applications that do not use attorneys and that do not indicate firm assignment. This sample represents applications for which we can reasonably assume 1) the inventor is handling communication with the examiner directly, and 2) there is no outside sponsorship of the patent application by an organization. Our results remain consistent.

plication following a rejection increases by up to 3.9 percentage points (p.p.). Recall that because we are leveraging random variation in likelihood of rejection at this stage, these estimates avoid potential bias from unobservable application characteristics. The coefficients on initial rejection in these analyses provide a baseline against which to compare the differential effect for women. Almost 85% of applications from men (in Columns 1-3) submit amendments after receiving initial rejections.

Columns 2 and 3 provide estimates of the primary specification using different measures of female presence on inventor teams. These estimates again indicate that women are less likely than men to continue in the patent process following an initial rejection in the patent examination process. 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) receive an initial rejection, these applications are over 3 p.p. less likely to continue with the application process than applications whose authorship is majority male.[8] Finally, all-female teams are over 7 p.p. less likely to continue with a patent application after an initial rejection. Given the coefficient on Initial Rejection which indicates a baseline response rate of 85% , these estimates represent a 3.8-8.5% reduction in the likelihood of submitting a response for majority and all-female teams.

In Column 4, we limit our sample further to only applications submitted by individual inventors. This approach, while reducing our sample size, provides arguably the cleanest estimate of gender persistence disparities in this innovation setting. Examining individual inventors allows us to avoid issues related to selection in team composition. The estimates in Column 4 are similar in magnitude to our other specifications, and suggest that a woman who applies for a patent is 4.5 p.p. less likely than a man who is facing an equally stringent examiner to amend her application if her initial set of patentability claims is rejected at the initial stage.

Given that the proportion of female applicants is low to begin, with just 15% of applications having at least one female inventor and only 4.3% of applications coming from all-female teams

[8] in Table A4, we limit our sample to only mixed-gender teams and find consistent results.

or solo women, these estimates represent a significant reduction in the number of women who remain in the patent application process. The monotonic negative relationship between the fraction of woman on an application and persistence provides compelling evidence that women are differentially deterred from continuing in the patent process after an initial rejection. This also indicates that the *intensive* margin of female representation matters when it comes to patent outcomes.

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. As is expected, receiving an initial rejection reduces the likelihood of receiving a patent, for both male and female applications. We start by examining the differential effect of a rejection on applications in which over 50% of inventors are women, as presented in Column 2. These applications are 5.9 p.p. less likely to receive patents than similarly situated patent applications with majority male inventors. Given that these teams were 3.3 p.p. more likely to drop out immediately (Panel A) – i.e., without refiling an amended application – our results suggest that 55% of the overall gender patent granting gap is explained by women's differential deterrence when an examiner makes her initial determination.

The effect of rejection on patent receipt is magnified when we look at outcomes for all-female teams and solo female inventors in Columns 3 and 4. These inventors are 10.4 p.p. and 7.5 p.p. less likely to be granted patents than all other applications and applications from solo male inventors, 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.

We find that the effect of the *first* rejection on gender differentials in patent continuation is greater than the the effects of subsequent rejections. That is, after receiving one rejection and subsequently continuing the patent process by responding with an amendment, female teams are less likely to drop out following another rejection in the process. These results are shown in Table A5.

This is interesting from a policy perspective; it may be that one way to address the gap in responsiveness to rejection is by providing resources to applicants about how to respond to an initial rejection, or information regarding the frequency of initial rejections. If female applicants are less likely to respond after receiving a rejection, it may be because they interpret an initial rejection as a signal of their quality. In this context, knowing that more than 80% of applications receive an initial rejection could help these applicants set their expectations and better interpret feedback from examiners. Bol et al. (2018) find a similar (gender aspecific) effect among early-career grant recipients and identify the provision of information as a potential solution.

4.2 Drivers of Differential Persistence

We turn now to sources of heterogeneity in women's differential responses to rejection in the patent prosecution process relative to men. First, we evaluate whether using a lawyer to file a patent application has an effect on gender differentials in responses to rejection. 95.4% of applications use lawyers to manage their patent applications. When an application is prosecuted by a law firm, this means that the inventor(s) pay a lawyer to manage the application process. The lawyer typically helps draft the patent application, handles all communication with the patent examiner at the United States Patent and Trademark Office, and solicits input and information from the inventor as needed. (USPTO 2020) The assistance of a lawyer is resource intensive, as patent attorneys' hourly billing rates range from $300 to over $700 depending on attorney experience and geographic location (Quinn 2015). Patent attorneys are particularly specialized professionals who are required to be registered "patent practitioners" to represent patent applicants before the USPTO. Registered patent practitioners are “individuals who have passed the USPTO’s registration exam and met the qualifications to represent patent applicants before the USPTO.” (USPTO 2020)

Table 5 presents our results. We begin by evaluating the net effect of using a lawyer on patent outcomes; that is, are applications prosecuted by lawyers differentially likely to respond to rejections, and does using a lawyer affect the gender gap in persistence? The Columns 1-2 display our aggregate results using differing definitions of female applications; when comparing applications using a lawyer to those that do not, on average applications prosecuted by lawyers are more likely to respond after receiving initial rejections (Initial Rejection×Lawyer). Female applicants who use lawyers are still less likely to proceed with their applications following the receipt of a rejection (Female×Initial Rejection), and the added benefit of using a lawyer is not greater for female applicants than for male applicants.

We next explore the variation in these effects by attorney experience. The median attorney who appears in the data only represents one successful patent, and an attorney at the 75th percentile (as measured by the number of patents received) has represented two successful patent applications. However, the distribution of successful patent applications is highly skewed, with the top 1% of attorneys managing over 300 granted applications. Applications from the top 25% of attorneys also make up the majority of our data; more than 90% of applications that use lawyers employ an attorney in the top 25%.

When we break down the aggregate effects by looking separately at the bottom 75% patent attorneys and the top 25% of attorneys, it is evident that more prolific lawyers are also more successful. As indicated in Columns 3-4, the median attorney has a positive effect on the likelihood of patent continuation Initial Rejection×Lawyer) when applications using attorneys in this range are compared to applications that do not use an attorney. This effect is positive and significant, with attorneys boosting the likelihood of response to rejection by over 11 percentage points. When we examine the differential effect of using an attorney for female applicants, the results are less clear. For applications whose authorship is 50% or more female, there is a positive effect of using an attorney on application continuation. However, this effect disappears when we focus on applications from all-female applicant teams and solo female inventors (Column 4). These results suggest there is no clear differential benefit of using an attorney for female applicants compared to male applicants.

Columns 5-6 show results for the top 25% of lawyers. Applications associated with more successful lawyers (those who have successfully prosecuted more applications) are more likely to follow up after receiving a rejection than applications that do not use attorneys. This effect is greater in magnitude than the benefit of using an attorney with less experience, as top attorneys increase the likelihood of responding to rejection by almost 30 percentage points for applications assigned to the most stringent examiners. Regardless of how we define the presence of women on an application, being affiliated with a lawyer with a better track record of patent completion does not affect the gap between male and female responses to rejection. The net effect for women (the summation of three coefficients, Female $\times$ Initial Rejection $\times$ Lawyer + Female $\times$ Initial Rejection + Female $\times$ Lawyer, displayed at the bottom of the table) remains negative.

Next, we consider whether applying for a patent with the support of an employer (rather than independently) affects women's greater tendency to exit the patent process after an initial rejection. When an inventor or team of inventors apply for a patent, they are presumed to be the owner of the patent. Applicants can assign their idea to an organization or entity, generally the company for which they worked when they produced the idea. Firm assignment indicates that a firm will assume the ownership right if granted, and is thus an indication of firm backing of an inventor team. Firm support of an application is often accompanied by financial support as well, with the firm paying for patent counsel. Additionally, many firms have internal processes to manage patent applications, and the individual inventor is less likely to be driving decisions regarding whether or not to continue in the application process. These analyses compare outcomes for applications that are associated with firms with applications from unaffiliated inventors, who are likely not receiving any financial or other support from organizations. Examining applications that are affiliated with firms compared with those that are not allows us to examine how access to resources and the handling of patent applications by professional experts affects gender gaps in innovation outcomes

Table 6 explores the effect of firm assignment on patent outcomes for majority and all-female applications. Columns 1-2 demonstrates that in the aggregate, working within firms does offset women's differential deterrence after an initial rejection. First, we observe that firm-backed patent applications are considerably more likely to proceed beyond an initial rejection (as indicated by Initial Rejection×Firm), and that this effect is greater for women (as seen in the coefficients on Female×Initial Rejection× Firm). That is, female applicants benefit *more* from firm affiliation than male applicants.

In Columns 3-6, we examine differential effects by firms' patenting track records. We sort firms based on the number of patents they have received to understand the effects of firm experience on outcomes. Given that the patent application process requires an understanding of the norms and techniques to successfully navigate both the initial application and subsequent communication with an examiner, experienced firms may differ substantially from novice firms in the support they provide to inventors. A small number of firms account for the majority of patent applications and granted patents in our data. In all, we have about 77,000 unique firms; the 770 companies that make up the top 1% of patent recipients account for 69.2% of all applications and 69% of all granted patents. The median firm receives just one patent, with the 75th percentile firm having just two patents.

Columns 3-4 evaluate outcomes for applications that are assigned to firms from the 1%-75% in terms of the number of patents received, relative to applications that are unaffiliated with firms. Columns 5-6 do the same for applications affiliated with firms in the top quartile. We find that there is a consistently positive effect of employer affiliation on the responses to rejection, regardless of firm size. Both male and female inventors are more likely to submit initial amendments when their application is assigned to a firm (Initial Rejection×Firm). This effect is of similar magnitudes for both sets of firms (11.7-14.7 percentage points).

For both types of firms, there is an additional positive effect for teams that are majority female, and this differential effect is greater for all-female teams. Relative to women and majority-female teams applying independently, female innovators from firms are significantly more likely to continue the patent application process after a receiving a rejection. Moreover, examination of the coefficients on Female×Initial Rejection×Firm suggests that the added persistence benefit for women applying as part of a firm exceeds that of men applying in firms. That is, being affiliated with a firm improves outcomes for female innovators more than for male innovators.

However, depending on the firm, majority-women application teams backed by firms are still less likely to either appeal or amend their applications after a rejection compared to majority-men teams backed by firms. This result requires the summation of three coefficients, Female×Initial Rejection×Firm + Female×Initial Rejection + Female×Firm, and is displayed below each column. Interestingly, applying for a patent while working at one of the the bottom 75% of firms appears to eliminate the persistence gap between women and men-led teams, while being at a firm that has received more patents has a relatively smaller effect and does not erase the gender differential completely.

These results suggest that firms can play a role in ameliorating the gender gap in innovation, potentially by providing information and resources to inventors. It may also be that the benefit of firm affiliation is actually that the inventor ceases to be the decision maker regarding whether or not to proceed with an application, as that judgment now lies with the employer. However, the fact that there still remains a gap in persistence between men and women at some firms indicates that firm support is not a panacea, and further work is required to understand the dynamics at play in this setting.

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. Female inventors' differential responses to rejection account for more than 50% of the gender gap in patent receipt, conditional on application. The gender gap in responsiveness to rejection widens as the presence of women on inventor teams increases, indicating that the *intensive* margin of female representation affects how patenting teams respond to rejection.

To examine how the gender gap in patent receipt can be mediated, we explore the effects of access to information on women's differential persistence. We do this by evaluating how using a lawyer to prosecute a patent application and having the support of a firm affects the gender gap in response to rejection. We find that using a lawyer increases the likelihood of submitting an amendment following a rejection for applications from both male and female inventors. However, there is no consistent effect of using a lawyer on the gender differential in response to rejection, which suggests that having the guidance of a lawyer and the information that comes along with patent counsel does not remedy the problem we identify.

When we consider the effect of having patent rights assigned to a firm on outcomes, we see that firm assignment increases responsiveness to rejection for all applications. This increase is greater for applications that come from female inventors and teams of 50% or more women. That is, having the support of a firm, which generally encompasses financing the application and any associated costs and managing the application process, helps shrink the gap between how male and female inventors respond following an initial rejection. These findings provide suggestive evidence that the provision of resources and potentially distancing inventors from the decision of whether or not to continue an application can play a key role in increasing women's success in the patent application process.

Our findings have implications for work on innovation and gender gaps more broadly. First, we identify a potential driver of the underrepresentation of women in entrepreneurship. Women's differential rates of patent receipt can contribute to the gender gap in access to financial resources as well as a disparity in opportunities for women to commercialize their inventions. We also identify a novel dimension of differences in persistence by gender; women are not only less likely to follow up on rejections than men, but they are also less likely to follow up on harsher rejections than more lenient rejections.

One limitation of this study is that we do not have access to communications between examiners and patent applicants. In ongoing analyses, we are evaluating the full text of examiner communications for a sample of applications to validate that harsher examiners provide more claims objections and rejections in their initial rejections than examiners who are more lenient. We are also not able to directly observe the mechanisms that drive the differential outcomes we observe. However, we leverage the available data to try to, at a minimum, rule out potential explanations.

We identify a number of opportunities for further research. Our findings follow the prosecution of a focal application to show that women are more likely than men to exit the patent application process after receiving a rejection. This implies that female inventors' ideas are lost or at best, underutilized, but it is not clear whether these inventors themselves are discouraged from innovation as a whole. In ongoing work, (Subramani 2020) tracks individual inventors over time and investigates the effect of a prior patent application rejection on subsequent innovative activity. Further, the patent application setting serves as a rich context in which to study firm bias and the dynamics that influence firm investment in employees, particularly given the repeat presence of a large number of companies in the data.

This work makes an important contribution by opening the black box of gender disparities in innovation and identifying a key reason for this gap. We focus on how differential responses to rejection by gender, a previously unexplored mechanism, contributes to the underrepresentation of women in innovation. Our findings highlight the potential implications of women's decreased likelihood to convert applications into patents for both the direction and landscape of innovation as well as individuals' career trajectories and firm outcomes. We suggest 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.

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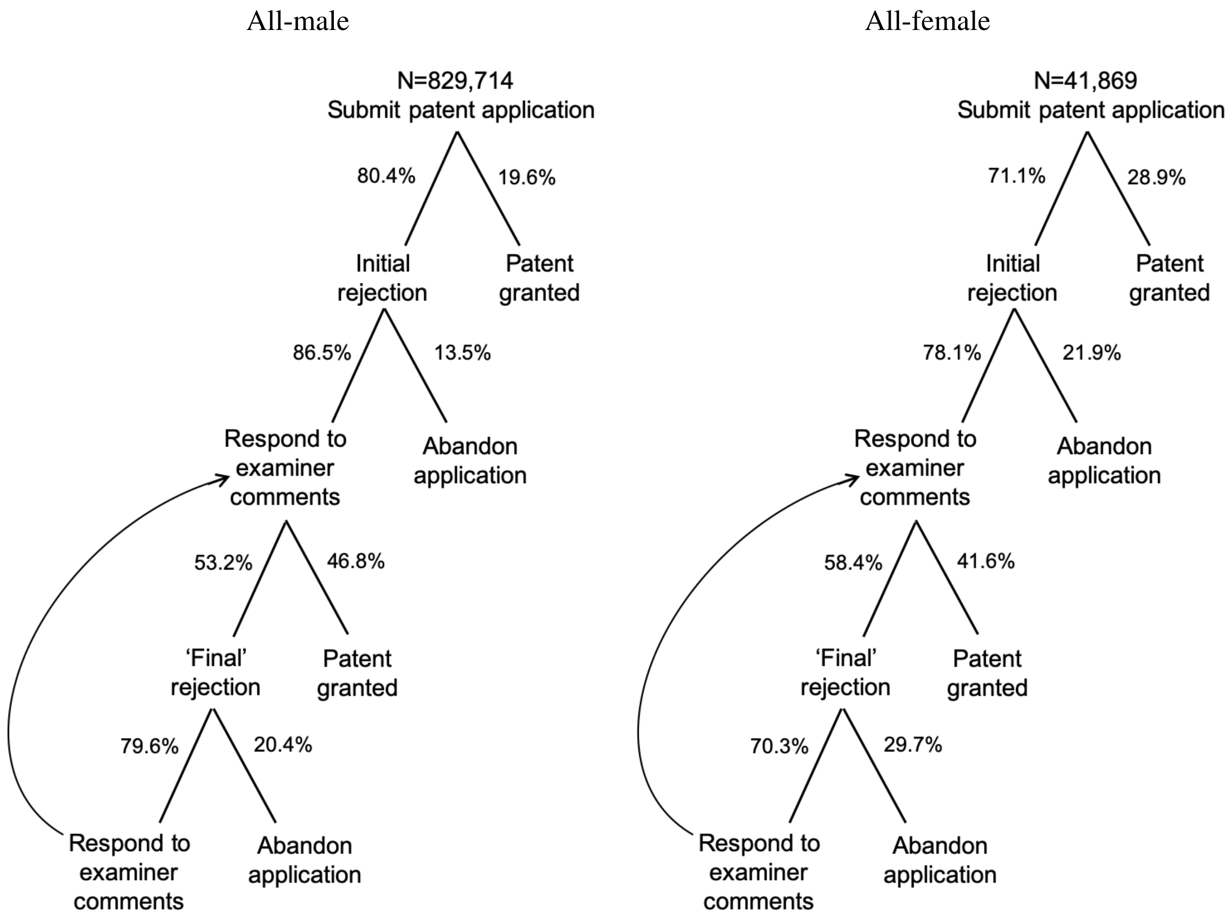
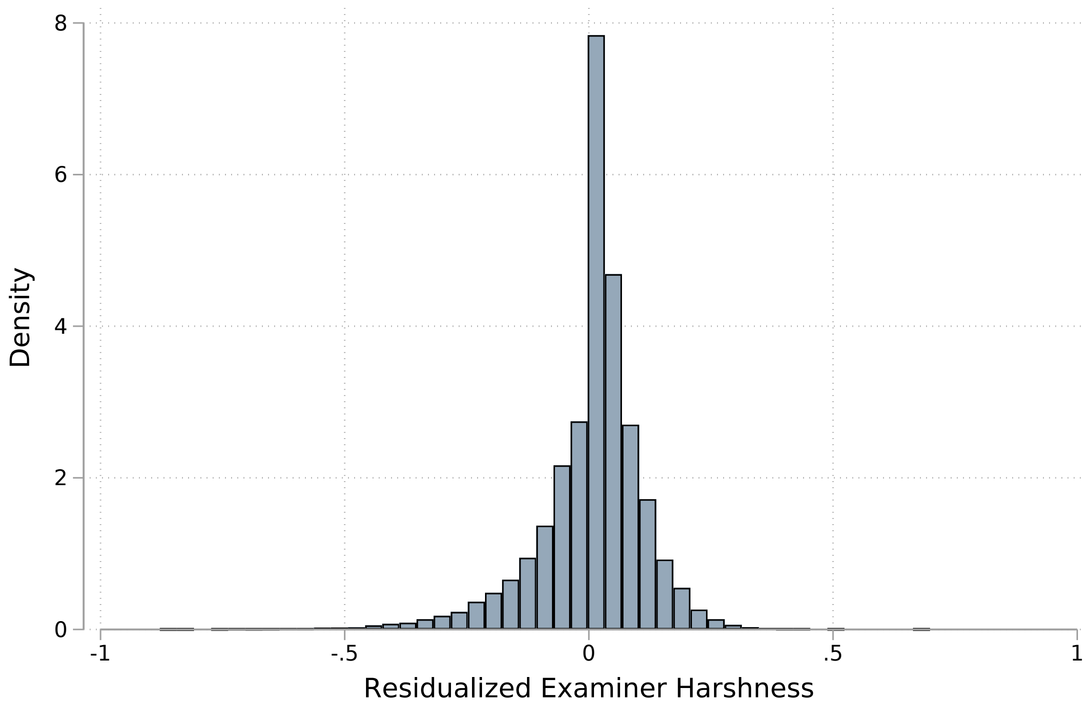
6 Figures and Tables

Figure 1: Evaluative Trajectory of Patent Applications



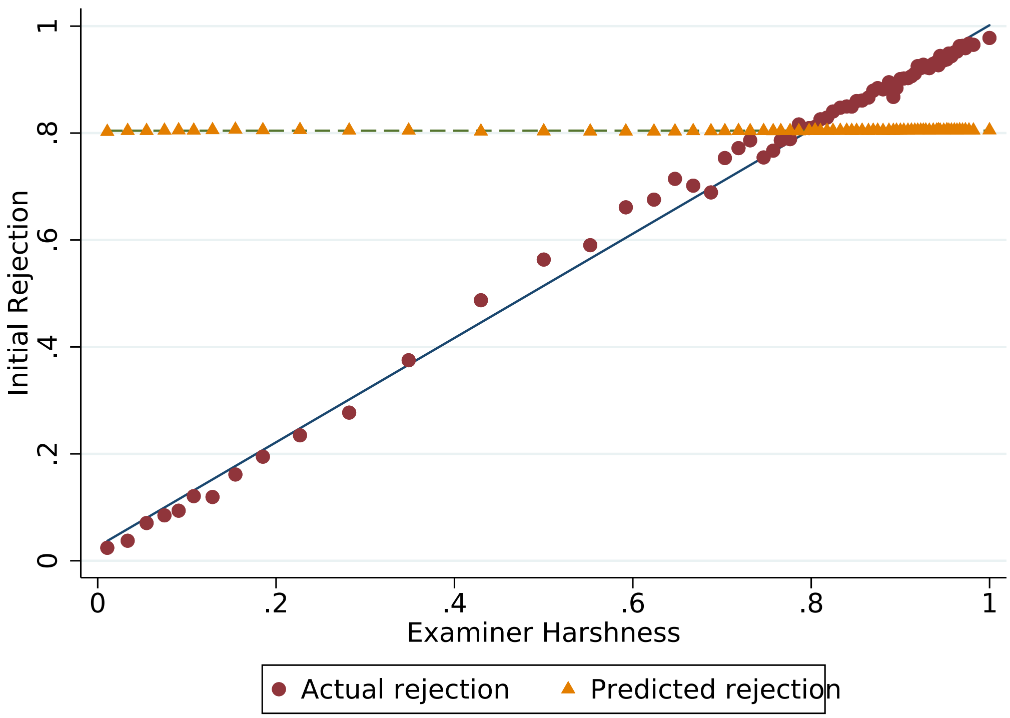
This figure shows the raw proportions of applications that progress through each stage of the patent process for applications from all-male and all-female inventors or teams. Applications from single-gender teams or solo individuals account for almost 90% of all applications in our sample.

Figure 2: 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.

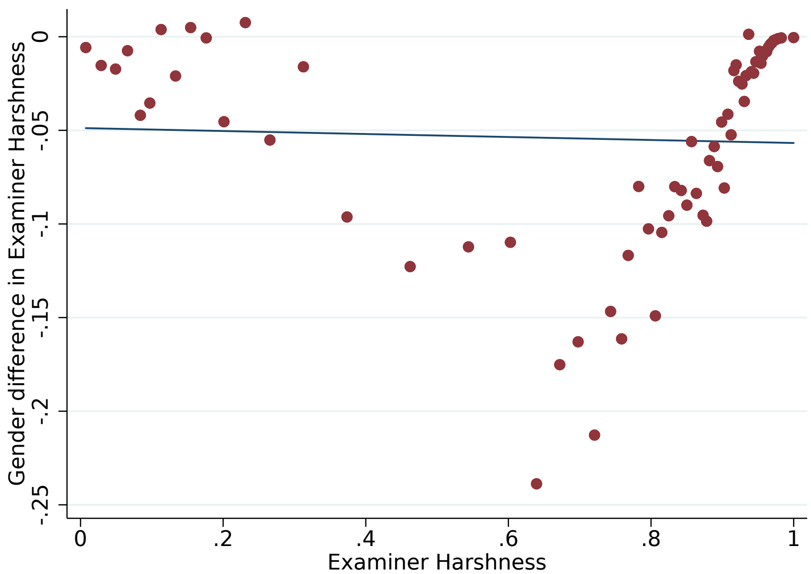
Figure 3: Distribution of Examiner Harshness by Initial Rejection (Residualized)



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: Gender Gap in Examiner Harshness

Comparing applications from female inventors with applications from male inventors



This figure plots the differential in examiner harshness by the gender of patent applicants against the examiner's own harshness. The Y axis measures the gap in rejection rate for a given examiner by applicant gender ($\text{harshness}_{\text{male\_applicant}}$-$\text{harshness}_{\text{female\_applicant}}$). A negative value indicates that the examiner gives more rejections to applications from female inventors than male inventors, and vice versa. These differentials are arranged in order of the focal examiner's harshness. These figures indicate that there is no consistent relationship between how harsh an examiner is and her gender differential in harshness.

Table 1: 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 2: First-Stage Results

	Application receives initial rejection		
	(1)	(2)	(3)
IV: Patent examiner harshness	0.694***	0.709***	0.695***
	(175.08)	(192.17)	(175.09)
Proportion of female inventors		0.00209	0.00133
		(1.42)	(0.89)
Using attorney		-0.0119***	-0.0112***
		(-7.75)	(-6.99)
Affiliated with employer		-0.00535***	-0.00504***
		(-7.03)	(-6.43)
Art Unit x Year FE	X	X	X
Subclass x Year FE			X
R^2	0.475	0.442	0.475
F-stat	30651.9	9265.1	7680.6
Observations	945373	971547	945373
# of Clusters	36851	36851	36851

t statistics in parentheses

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

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 3: 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 4: Effect of Initial Rejection on Patent Application Continuation (IV)

	(1)	(2)	(3)	(4)
Panel A: Effect of Initial Rejection on Initial Amendment				
Female X Initial Rejection	-0.039***	-0.033***	-0.073***	-0.045***
	(0.003)	(0.003)	(0.004)	(0.004)
Initial Rejection	0.849***	0.848***	0.849***	0.811***
	(0.005)	(0.005)	(0.005)	(0.007)
Panel B: Effect of Initial Rejection on Patent Granted				
Female X Initial Rejection	-0.074***	-0.059***	-0.104***	-0.075***
	(0.005)	(0.004)	(0.006)	(0.006)
Initial Rejection	-0.663***	-0.664***	-0.665***	-0.686***
	(0.011)	(0.011)	(0.011)	(0.013)
Art Unit x Year FE	X	X	X	X
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.

Table 5: Effect of Lawyer on Initial Amendment Submission (IV)

	Attorney		Attorney 1-75		Attorney 75+	
	(1)	(2)	(3)	(4)	(5)	(6)
Female × Initial Rejection × Lawyer	0.023	0.006	0.056**	0.026	0.024	0.008
	(0.014)	(0.017)	(0.026)	(0.032)	(0.014)	(0.017)
Initial Rejection × Lawyer	0.283***	0.284***	0.114***	0.119***	0.292***	0.293***
	(0.007)	(0.006)	(0.011)	(0.011)	(0.007)	(0.006)
Female × Initial Rejection	-0.045***	-0.061***	-0.044***	-0.058***	-0.045***	-0.062***
	(0.014)	(0.017)	(0.014)	(0.017)	(0.014)	(0.017)
Female × Lawyer	-0.017*	-0.023**	-0.034*	-0.026	-0.017*	-0.023**
	(0.010)	(0.011)	(0.019)	(0.021)	(0.010)	(0.011)
Art Unit x Year FE	X	X	X	X	X	X
Observations	971547	971547	75002	75002	914959	914959
# of Clusters	36851	36851	24381	24381	36851	36851
Female Definition	Half Female	All Female	Half Female	All Female	Half Female	All Female
$\beta_1 + \beta_3 + \beta_4$	-0.039	-0.078	-0.022	-0.058	-0.038	-0.077

Standard errors in parentheses

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

Specifications 2 and 3 group lawyers based on the number of patents the lawyer has received, where 1-75 represents the bottom 75% of lawyers by number of patents granted and 75+ represents the top 25% of patent-receiving attorneys. 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.

Table 6: Effect of Firm Affiliation on Initial Amendment Submission (IV)

	Employer Assigned		Emp 1%-75%		Emp 75%+	
	(1)	(2)	(3)	(4)	(5)	(6)
Female × Initial Rejection × Firm	0.038***	0.051***	0.070***	0.091***	0.038***	0.055***
	(0.005)	(0.007)	(0.010)	(0.013)	(0.005)	(0.007)
Initial Rejection × Firm	0.120***	0.121***	0.117***	0.120***	0.147***	0.147***
	(0.002)	(0.002)	(0.004)	(0.004)	(0.002)	(0.002)
Female × Initial Rejection	-0.043***	-0.070***	-0.044***	-0.069***	-0.043***	-0.072***
	(0.004)	(0.006)	(0.005)	(0.006)	(0.004)	(0.006)
Female × Firm	-0.007**	-0.010***	-0.013***	-0.012**	-0.006**	-0.010***
	(0.003)	(0.003)	(0.005)	(0.006)	(0.003)	(0.003)
Art Unit x Year FE	X	X	X	X	X	X
Observations	971547	971547	424344	424344	885432	885432
# of Clusters	36851	36851	36339	36339	36851	36851
$\beta_1 + \beta_3 + \beta_4$	-0.012	-0.029	0.013	0.010	-0.011	-0.027
Female Definition	Half Female	All Female	Half Female	All Female	Half Female	All Female

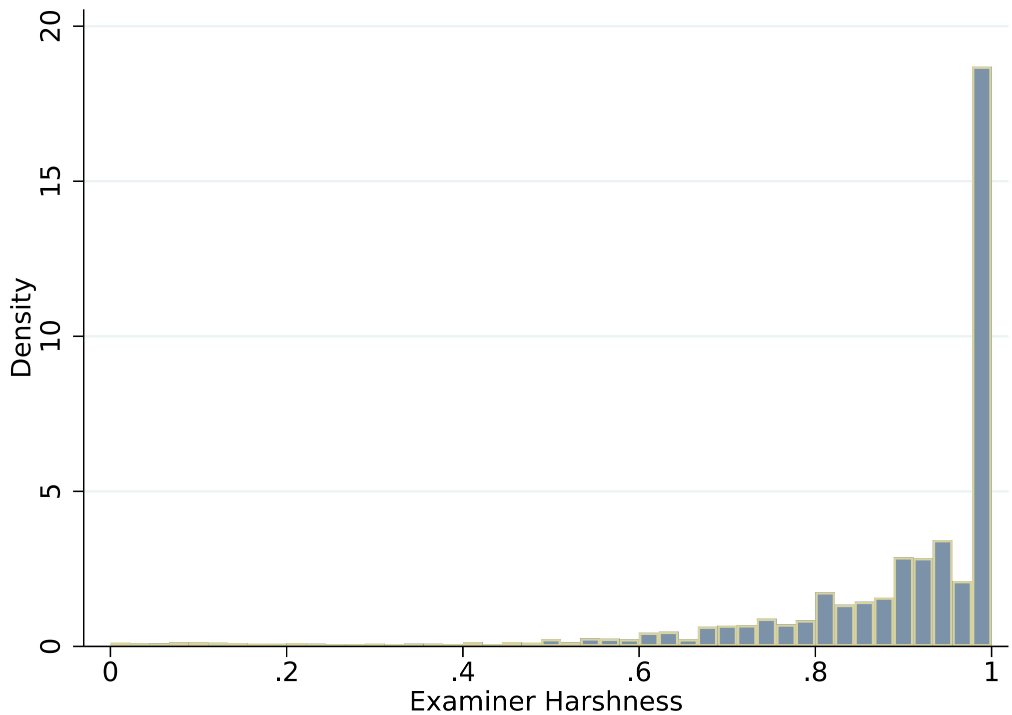
Standard errors in parentheses

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

Specifications 2 and 3 group employers based on the number of patents the firm has received, where 1-75 represents the bottom 75% of firms by number of patents granted and 75+ represents the top 25% of patent-receiving firms. 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

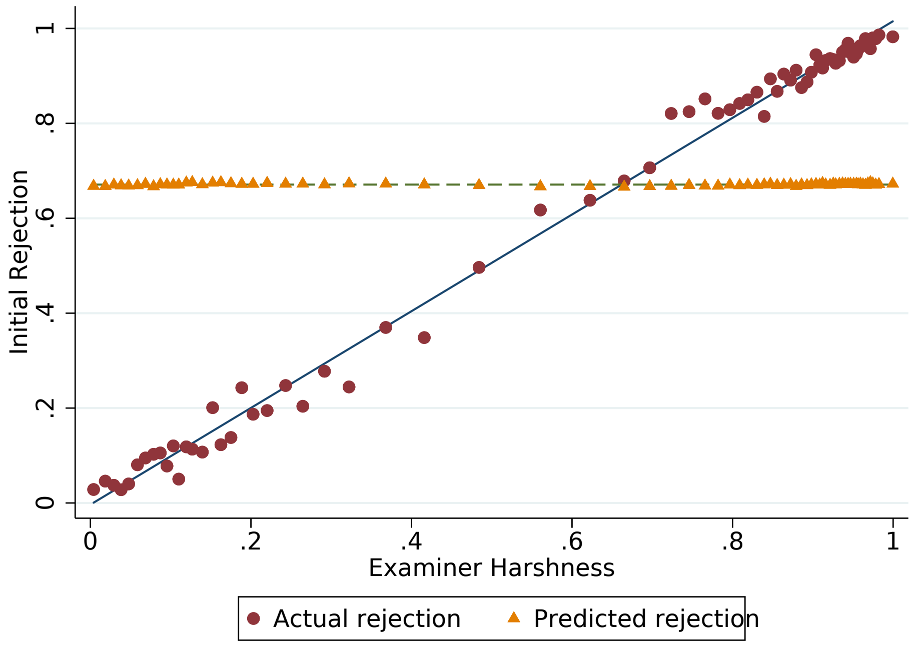
Figure A1: Distribution of Examiner Harshness by Initial Rejection (nonresidualized)



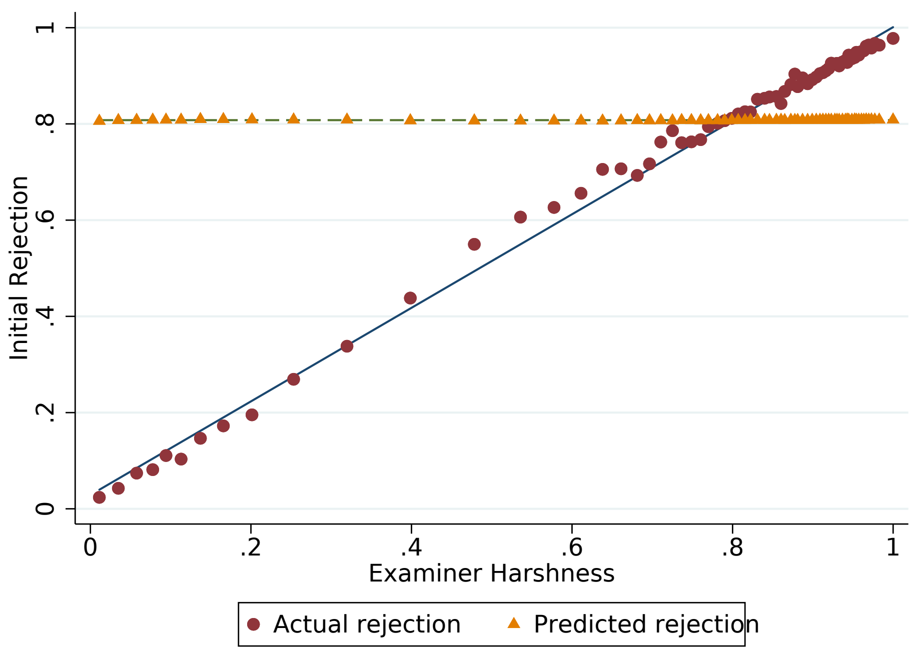
This figure shows the distribution of patent examiners' initial rejection rates.

Figure A2: Probability of Initial Rejection by Examiner Harshness: Figures by gender

All-female inventors



All-male inventors



These figures relate 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. These figures illustrate that examiner harshness is an effective instrument regardless of applicant gender; for both male and female applicants, there is no relationship between examiner harshness and these application characteristics.

Table A1: Effect of Initial Rejection on Patent Application Continuation: Alternate Definition of Harshness IV

	(1)	(2)	(3)	(4)
Panel A: Effect of Initial Rejection on Initial Amendment				
Female X Initial Rejection	-0.055***	-0.046***	-0.095***	-0.058***
	(0.008)	(0.007)	(0.009)	(0.010)
Initial Rejection	0.380***	0.379***	0.381***	0.274***
	(0.015)	(0.015)	(0.015)	(0.021)
Panel B: Effect of Initial Rejection on Patent Granted				
Female X Initial Rejection	-0.116***	-0.086***	-0.109***	-0.099***
	(0.019)	(0.017)	(0.020)	(0.020)
Initial Rejection	-2.892***	-2.894***	-2.895***	-2.830***
	(0.041)	(0.041)	(0.041)	(0.048)
Observations	971547	971547	971547	461147
# of Clusters	36851	36851	36851	36727
Female Definition	Proportion	Half Female	All Female	Solo

Standard errors in parentheses

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

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 A2: Heterogeneity by Examiner Gender (IV)

	Initial Amendment		Patent Received	
	(1)	(2)	(3)	(4)
Female $\times$ Initial Rejection $\times$ Examiner Female	-0.003	0.002	-0.003	0.011
	(0.006)	(0.009)	(0.010)	(0.013)
Initial Rejection $\times$ Examiner Female	-0.002	-0.003	-0.036***	-0.037***
	(0.002)	(0.002)	(0.006)	(0.006)
Female $\times$ Initial Rejection	-0.034***	-0.078***	-0.059***	-0.109***
	(0.004)	(0.006)	(0.007)	(0.009)
Female $\times$ Examiner Female	0.003	-0.001	0.006	-0.001
	(0.003)	(0.004)	(0.007)	(0.009)
Observations	816168	816168	816168	816168
# of Clusters	30300	30300	30300	30300
Female Definition	Half Female	All Female	Half Female	All Female

Standard errors in parentheses

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

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 A3: Effect of Initial Rejection on Patent Application Continuation: Limited Sample (IV)

	(1)	(2)	(3)	(4)
Panel A: Effect of Initial Rejection on Initial Amendment				
Female X Initial Rejection	-0.044**	-0.032**	-0.043**	-0.040**
	(0.017)	(0.016)	(0.018)	(0.019)
Initial Rejection	0.555***	0.555***	0.554***	0.559***
	(0.038)	(0.038)	(0.038)	(0.042)
Panel B: Effect of Initial Rejection on Patent Granted				
Female X Initial Rejection	-0.090***	-0.074***	-0.092***	-0.099***
	(0.024)	(0.022)	(0.025)	(0.026)
Initial Rejection	-1.005***	-1.005***	-1.007***	-0.980***
	(0.044)	(0.044)	(0.045)	(0.048)
Observations	40310	40310	40310	32931
# of Clusters	15305	15305	15305	13320
Female Definition	Proportion	Half Female	All Female	Solo

Standard errors in parentheses

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

This table captures the effect of receiving an initial rejection on continuing in the patent process for the sample of applications that do not use an attorney and are not associated with a firm. This sample represents applications for which we can reasonably assume 1) the inventor is handling communication with the examiner directly, and 2) there is no outside sponsorship of the patent application by an organization. Each column reports coefficients from a separate regression. An observation is a patent application. We instrument for initial rejection using examiners' leave-out mean initial rejection rate for all other applications within art unit-year.

Table A4: Effect of Initial Rejection on Patent Outcomes (Mixed-Gender Teams only)

	Initial Amendment	Patent Granted
Female X Initial Rejection	-0.031***	-0.058***
	(0.004)	(0.006)
Initial Rejection	0.883***	-0.644***
	(0.005)	(0.012)
Observations	510382	510382
# of Clusters	36840	36840
Female Definition	Half Female	Half Female

Standard errors in parentheses

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

In this table, we limit our analyses only to mixed-gender teams and evaluate how teams composed of $\geq 50\%$ of women differ from teams whose members are majority male. Our effect sizes are very similar to what we find when we do not limit the sample only to teams composed of both men and women as in our main analyses.

Table A5: Variation in Persistence by Number of Rejections

	(1)	(2)	(3)	(4)
Female X Rejection	-0.038***	-0.033***	-0.078***	-0.043***
	(0.003)	(0.003)	(0.004)	(0.004)
Female X Rejection X Round 2	0.112***	0.074***	0.093***	0.084**
	(0.032)	(0.024)	(0.035)	(0.038)
Female X Rejection X Round 3	0.073	0.013	0.094	0.060
	(0.063)	(0.045)	(0.082)	(0.090)
Female X Rejection X Round 4	0.244*	0.139	0.226	0.151
	(0.126)	(0.098)	(0.139)	(0.138)
Female X Rejection X Round 5	0.054	-0.043	0.119	0.131
	(0.250)	(0.157)	(0.391)	(0.533)
Observations	1751944	1751944	1751944	785307
# of Clusters	36851	36851	36851	36733
Female Definition	Half Female	Proportion	All Female	Solo

Standard errors in parentheses

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

This table examines variation in persistence across multiple rejections. We instrument for initial rejection using examiners' 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. All regressions include art unit-year fixed effects and are clustered at the examiner-year level.