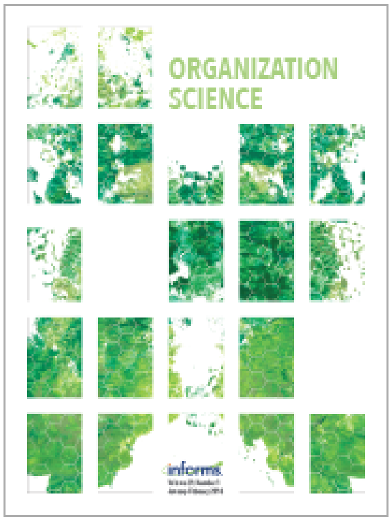

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The Role of Reviewer Characteristics on the Diversity of Successful Applicants

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Abstract. In their efforts to foster diversity and talent, organizations, banks, and venture capitalists utilize the expertise of reviewers to evaluate applications from a broad range of applicants. Reviewers make decisions under different types of cognitive load, such as the necessity to aggregate complex information and workload pressure. To cope with the stress, reviewers might use automatic biases to make decisions faster, which can result in lower organizational diversity. We explore the characteristics of reviewers in a particular setting—patent applications at the U.S. Patent and Trademark Office (USPTO). We leverage quasi-exogenous variation from the random assignment of patent examiners, allowing us to find the causal impact of applicant gender and examiner characteristics on the application success rate. We find evidence that applicants with more female-sounding names have a 3.6-percentage-point lower likelihood of patent approval. We find that a high workload of the examiner leads to a decrease in the likelihood that the patent application of a female inventor would be approved, consistent with theories on coping strategies when experiencing cognitive load. Our results extend to applications filed by teams of inventors. These results suggest that it is essential to manage the stress related to reviewers' workloads to guarantee a variety of successful candidates.

Supplemental Material: The online appendix is available at https://doi.org/10.1287/orsc.2023.17910.

Keywords: diversity • innovation • patents

1. Introduction

Consider the general context of applying for a position, loan, or financing. There are two applicants, Emily and Michelle. Their applications would be assessed by a reviewer, who could be a recruiter, bank loan officer, or venture capitalist. Emily's application is assigned to a male reviewer. He has applications landing on his desk continuously. The reviewer has to keep up with his workload, so he decides to quickly reject the application. Michelle's application is assigned to a female reviewer. The reviewer's experience aids her in assessing the merits of the application at a glance. Although this leads her to be negative from the outset, she takes her time to screen the application thoroughly. Finally, the reviewer decides to invite Michelle for an interview.

In practice, both Emily and Michelle are likely to view this experience as a decision based on the merits of their application, not as the random whim of an overworked reviewer managing their workload. This example shows that when decisions depend on a reviewer, multiple factors on the reviewer's side can impact the diversity of successful applicants, such as their stereotypical beliefs, workload, and experience.[1]

Creating innovation is a key policy of firms and governments around the world. An important aspect of cultivating robust innovation is the equal participation of talent and diversity in the innovation process. However, in 2019 at the U.S. Patent and Trademark Office (USPTO), only 12.8% of inventors were women (Toole et al. 2021). This gender gap is mirrored in other major economies (UKIPO 2019). Although multiple reasons can be behind this inequality snapshot of modern innovation, the "leaky pipeline" in the career of female talent stands out. All talent has to pass the muster of an authority—the committee that promotes scientists, the recruiter who screens applicants, or the venture capitalist who hears out sales pitches. Extensive literature documents gender biases in reviewers' decisions on the promotion of women in science, entrepreneurship, and hiring (e.g., Moss-Racusin et al. 2012, Bagues et al. 2017, Lane et al. 2023, Snellman and Solal 2023), and on the consequences of rejections on women exiting talent pipelines (e.g., Fernandez-Mateo et al. 2023). However, evidence is sparse concerning the characteristics of the reviewers that make these biased decisions, apart from the correlation of genders. There are two challenges to this. First, the data have to be rich enough to allow for the testing of various hypotheses related to factors such as workload pressure. Second, there has to be a source of exogenous variation that would allow us to causally identify the impact of reviewer characteristics on the promotion of women.

We choose the patent application process at the USPTO as a near-laboratory environment to identify the effect of reviewer characteristics on the hiring and promotion of women. The richness of the available data enables us to create measures relating to cognitive load and stress, such as experience and workload. These factors are potentially significant, but typically unobserved in other settings. Additionally, applications are allocated to specific art units during the patenting process. Within a given art unit, the assignment of applications to reviewers is random. This assignment rule allows us to identify the causal effect of the applicant's gender and examiner's characteristics on an application's outcome.

We analyze half a million patent applications from the Patent Examination Research Dataset from the USPTO. To get a clear-cut effect, we focus our main analysis on original single-author applications for utility patents at the USPTO filed between 2001 and 2014. We find that applications from female inventors have a 3.6 percentage points lower probability of obtaining a patent than comparable applications by male inventors, conditional on observable characteristics of the application and the same examiner. Remarkably, this effect is consistent when examining team applications as well. By looking at the characteristics of the examiner, we focus on three paths to reveal the mechanisms that drive different outcomes.

First, we exploit the extensive literature on the identity of reviewers in decision-making committees, which finds that the gender of the examiner interacts with the gender of the applicant. One of the hypotheses in this literature is that gender homophily in the reviewer-applicant pair leads to more favorable outcomes for the applicant due to a self-image bias (Lewicki 1983). We find that the reviewer's identity has a negligible effect on the observed differences in outcomes for male and female inventors. Although female examiners seem to be more strict than male examiners, we find no evidence of a gender interaction effect in the reviewer-applicant pair in this context.

Second, we explore predictions on automatic stereotypes and cognitive load. Once a patent application lands on the desk of the reviewer, the reviewer makes a quick intuitive assessment. In this moment, a variety of automatic stereotypes could be activated, dependent on gender identifiers within the application (e.g., Devine and Sharp 2009). In the case of patent applications, these would be the names of inventors, Emily versus Michael. Beyond this moment of first impression formation, the reviewer begins the process of analytically evaluating the merits of the application.

The amount of attention that an application can receive depends on the cognitive load of the reviewer (e.g., Deck and Jahedi 2015). If the reviewer is simultaneously engaged in many tasks, then it would take them more time (effort) to thoroughly review an application. In the most serious case, the reviewer would have no available cognitive resources to counteract the initial biased impression based on automaticity (Gilbert and Hixon 1991). We explore two factors of cognitive load when making a decision. First, a patent examiner has to provide a decision based on complex inputs, revealing the potential for a situation with the presence of ambiguous signals on the quality of the application. We use the experience of the reviewer as a way to measure the specialization in resolving ambiguous situations, expecting that more experienced examiners would be more likely to resist automatic stereotypes. Second, a patent examiner could be under time pressure to make a decision, as is the case when they have a large workload. In both of these cases, a reviewer could rely on stereotypical beliefs to make a fast decision (Axt and Lai 2019). In addition, we exploit the structure of the patent application process, where an examiner can take a fast decision in a first-action allowance or reject an application and relegate it to a further review. We interpret the latter action as an examiner choosing to invest more cognitive effort in reviewing the application.

We find evidence consistent with the notion of cognitive load significantly affecting the decisions of reviewers, consistent with the presence of an automatic bias. We observe that experience does not help examiners make decisions free from gender biases. In the primary stage of the review process, in first action allowances, experience seems to dictate that the applications of female inventors should not be accepted right away, but be delegated to further review. In addition, we find that when a reviewer has many applications on their desk, this leads to a lower likelihood of approving patent applications by female inventors. We interpret this as evidence that in the presence of workload pressure, reviewers do not have available cognitive resources to counteract an automatic gender stereotype.

Our analysis extends to applications authored by multiple inventors. For teams, there is potentially a complex interplay between the gender of team members and reviewer's characteristics. We capture this by accounting for the team size and gender ratio among the applicants. We observe qualitatively similar results;

teams with a larger proportion of women tend to face penalties in terms of a lower likelihood of grant approval. Furthermore, we find that the examiner's cognitive load, as captured by excess workload, significantly reduces the probability that a patent is granted.

Taken together, our results carry actionable policy consequences for settings where recruiters select candidates, banking officers select loans, or venture capital managers select entrepreneurs. We show that biased decision making emerges in the way an application is scrutinized and that this difference bubbles to the surface with the time crunches of deadlines and workload among managers. At first blush, an organization could strive to improve the gender mix among managers and recruiters in order to promote talent down the pipeline. The idea would be that more women in the ranks of managers could lead to more promotion of female applications. However, our findings reveal that such a policy would improve the outcomes of female candidates not by the inclusion of more *female* reviewers, but by just the inclusion of *more* reviewers. In this way, the average individual workload of reviewers would be decreased, and they would have more time to focus on assessing the merits of applications. Second, there is a scope for reducing the visibility of the gender of the applicant to counteract the use of a gender stereotype belief under pressure. For instance, using the initials of the first name(s) could be a viable method when applications are abundant enough for feasible anonymization. Ultimately, it can be envisioned that such interventions may not only increase the odds of success for Emily and Michelle, but could also serve as a powerful force to stem the tide of leaks in the talent pipeline.

Specifically, in the context of patenting, our findings emphasize that increasing examiner diversity—a goal of recent DEI (Diversity, Equity, and Inclusion) initiatives by the USPTO and other patent offices[2]—would have no effect on the chances of female inventors to get a patent granted. Rather, a policy of reducing workload requirement among examiners might be more successful, potentially through the hiring of more examiners. Following our estimates, we observe that reducing the workload of an examiner from the 75th percentile (321 applications) to the 25th percentile (142 applications) implies a decrease of the gender gap in patenting by around 25%. Regarding the anonymization of applicants, recent evidence indicates that the drafting of patent claims could reveal the gender of the inventor (Levitskaya et al. 2022). This spells limited success for this policy in terms of improving the odds of women in the patenting process.

2. Theory Development

2.1. The Role of Reviewers on Gender Gaps

The term leaky pipeline refers to how fewer and fewer women are allowed or able to proceed to the next level of their career ladder, leading to a disproportionately low number of women in senior positions. At each stage of the pipeline, there is a committee, sometimes composed of several recruiters or just one decision maker, that agrees on whether a woman can proceed. From now on, we refer to this situation as a reviewer-applicant interaction. The existence of a leaky pipeline in professional fields has been well-documented, and it particularly impacts women's progression up the career ladder, contributing significantly to gender gaps in various industries.

There is an extensive literature on the impact of reviewers on the gender gap in the academic setting (e.g., Abrevaya and Hamermesh 2012, Moss-Racusin et al. 2012, Bagues et al. 2017, Witteman et al. 2019, Hengel 2022), as recruiters for jobs (e.g., Bertrand and Duflo 2017, Campero and Fernandez 2019, Campbell and Hahl 2022, Castilla and Rho 2023), in promotions within private-sector jobs (Benson et al. 2024, Huang et al. 2024), as venture capitalists funding entrepreneurs (Kanze et al. 2018, Guzman and Kacperczyk 2019, Snellman and Solal 2023), and as participants in a thought experiment in the laboratory (e.g., Bertrand and Duflo 2017; Mengel 2020, 2021; Lozano et al. 2022). At the other end of the decision, when a woman encounters her "glass ceiling," she is often dissuaded from seeking further progression, contributing to the observed leaky pipeline phenomenon. (Hunt 2016, Madl and Ouellette 2019, Fernandez-Mateo et al. 2023, Aneja et al. 2024).

In the context of innovation, there are several studies that have examined the state of gender diversity in patenting, focusing on the women who made it past the desk of the patent examiner (e.g., Thursby and Thursby 2005, Whittington 2011, Hunt et al. 2013). Ding et al. (2006) investigate a random sample of scientists and find that women patent at about 40% the rate of men over a 30-year period. Almost 20 years ago, Ding et al. (2006) pointed at limited networks with commercial partners and at traditional views about the academic career as reasons underpinning the gender gap, ending, however, on a positive note on how the culture of patenting is more prevalent among younger women. Using more recent data for the period 2001–2014, Jensen et al. (2018) find that women represent 10% of the inventors, denying the hope of the former paper. In addition, Jensen et al. (2018) show that the applications of teams with female inventors are more likely to be rejected than those of men, and those applications were less likely to be appealed by the inventor. However, Jensen et al. (2018) do not look at the characteristics of reviewers or the mechanisms driving the different outcomes.

Focusing on the application process, Aneja et al. (2024) find that female inventors are more likely to abandon a patent following an early stage rejection. Furthermore, Pairolero et al. (2022) conduct a randomized control trial at the USPTO by assigning inventors without legal representation to examiners who provide enhanced guidance and information. They find that following the intervention, female inventors increase their patenting by 11% more than male inventors. These findings point toward the pivotal role played by the patent examiners on the careers of female inventors.

In practice, our null hypothesis is that there is no difference in the outcomes of patent applications by gender. However, we observe that the literature supports the following alternative hypothesis, and this is what we expect to find in the data:

Hypothesis 1. *Patent applications by female inventors have different outcomes than the patent applications of male inventors.*

In our study, we attempt to isolate some of the mechanisms that underlie the different decision outcomes for women.

2.2. Reviewer Decision Making

Numerous authors have suggested that the observed behavior in many applications is the result of two processing forms, either competing with or complementing each other, at the cognitive level (Kahneman 2011, Evans and Stanovich 2013). Most broadly, the first type of process is intuitive and fast, evoking automatic associations in a nonconscious manner. The second type of process is slower, conscious, and controlled. A reviewer examining an application would involve either of these processes to a different degree in the making of the final decision. On the one hand, the automatic name recognition could activate an unconscious gender stereotype (Devine 1989, Wiese et al. 2008). On the other hand, the review of the claims of the application would activate more conscious and controlled thought processes.

The impact of gender stereotypes on the conscious decision-making process is contingent upon several nuanced factors. These include the self-image of the reviewer, the reviewer's ability to control the application of stereotypes, and their levels of stress due to the cognitive effort devoted to processing applications (Keinan 1987, Gilbert and Hixon 1991, Wickens 2002, Narayan 2024).

2.2.1. Identity of the Reviewer. A significant body of research examines the impact of the gender composition of a scientific committee on the decision of the committee. One underlying hypothesis is that female evaluators give higher grades to female candidates, and male evaluators give higher grades to male candidates. This would imply that homophily (positive correlation) in the gender of the reviewer-applicant pair would lead to a positive outcome for the applicant. A potential mechanism could be due to self-image bias and closeness in identity in terms of socio-economic characteristics and shared life experiences. This allows reviewers to make confident decisions by utilizing their own type as a benchmark to evaluate the research of others (Lewicki 1983, McPherson et al. 2001, Siniscalchi and Veronesi 2021). We define the following broad hypothesis:

Hypothesis 2. *Female* (*male*) *reviewers make different decisions on applications by female (male) inventors.*

Previously, this hypothesis has found support in some contexts (e.g., Casadevall and Handelsman 2014, Murray et al. 2019, Liu 2021). In other contexts, there is a partial effect—only one group of evaluators (males or females) would have strong preferences over gender of the applicants (Moss-Racusin et al. 2012, De Paola and Scoppa 2015, Bagues et al. 2017, Hospido and Sanz 2021, Mengel 2021, Arceo-Gomez and Campos-Vazquez 2022). In some settings there is no association between the genders of the reviewer and the applicant (e.g., Abrevaya and Hamermesh 2012). This hypothesis has not been tested previously in the patenting literature, and we remain agnostic to the expected effect.

However, in principle, these disparate findings in the previous literature could be explained by third factors that drive an observed effect. If, for example, scarce female examiners tend to be cognitively busy with various tasks due to gender quotas, then these female examiners would make decisions under different pressures than their male counterparts. In the following discussion, we present potential underlying mechanisms and focus on the literature on decision making under cognitive pressure.

2.2.2. Stereotype Activation. Group-based stereotypes get invoked automatically by the presence of a salient group-identifying characteristic (Bargh 1994, Stanley et al. 2008). The activation of stereotypes when making decisions, including in relation to gender, has been widely studied in laboratory experiments measuring subjects' responses while controlling for social desirability concerns (Devine 1989, Bargh et al. 1996, Fazio and Olson 2003, Devine and Sharp 2009). Further evidence has been found in field and quasi-experimental settings. Leveraging the reviewer-applicant situation, Rooth (2010) finds evidence that automatic processes can have a significant impact on hiring decisions for ethnic groups by recruiters.

The mechanisms of these automatic processes are revealed in several field experiments. In the more narrow context of gender, Budden et al. (2008) explore the introduction of double-blind peer review in a biology journal. As a result of the new policy, the journal saw a significant increase in female first-authored accepted articles. More specifically, Budden et al. (2008) find that reviewers tend to favor submissions from male authors, attributing more credibility and value to their work than to the work of female authors. In this vein, in a CV correspondence study, Bartoš et al. (2016) find that negatively stereotyped minority names result in less effort by the employer to inspect the resumes. This is consistent with a self-serving bias, where a reviewer would give more cognitive processing time to preference-consistent information, rather than to preference-inconsistent information (Ditto and Lopez 1992). Therefore, the consequence of the automatic stereotype activation can be twofold: a more positive view in terms of credibility for the favored category of applicants and less effort for inspecting the nonfavored category of applicants.

The specific industry context of the decision-making situation plays an additional role in the way that automatic processes are triggered. Dasgupta and Asgari (2004) show that automatic gender stereotyping is mediated by the frequency of exposure to the affected group (female leaders in the study). In a setting where female applicants are infrequent, there is a higher likelihood for automatic gender stereotypes against women to continue. The implicit intuition is that higher exposure to the minority group would alleviate the stereotype against the group. In our specific context, the field of patenting boasts close to 90% of the patented inventions being authored by men. This fact on its own implies a strong stereotyping effect in favor of male applicants, where the occasional invention with a female name is rare. In addition, it is well-documented that women are underrepresented in many STEM disciplines, particularly in fields likely to lead to patentable innovations, such as computer science, engineering, and physics (Kahn and Ginther 2018, National Center for Science and Engineering Statistics 2021). In sum, it is likely that there is gender stereotyping in an industry dominated by male inventors.

This gender stereotype is a feature of the first type of automatic cognitive processes (Evans and Stanovich 2013). A reviewer receives an application on her desk, scans the contents, and decides how much of the second type of cognitive processes to employ, which requires more deliberate thinking on the merits of the application. This thinking is subject to cognitive pressure such as stress, desire to control prejudice (Plant and Devine 1998, Monteith et al. 2002), and availability of attentional resources (Gilbert and Hixon 1991, Pratto and Bargh 1991, Ditto and Lopez 1992, Devine and Sharp 2009, Brewer 2014).

2.2.3. Cognitive Load. Cognitive load, defined as the overall mental effort used in working memory, is instrumental in the use of stereotypes during decision-making processes. Research indicates that under high cognitive load, individuals are more likely to perform poorly across a range of tasks that require logic and reasoning (Sprenger et al. 2011, Deck and Jahedi 2015, Paas et al. 2016). When cognitive resources are limited, individuals are pushed toward less effortful cognitive strategies such as stereotyping, leading to potentially biased decisions (e.g., Gilbert and Hixon 1991, Ditto and Lopez 1992, Hilton and Von Hippel 1996, Spencer et al. 1998, Van Knippenberg et al. 1999, Bodenhausen 2000, Wheeler and Petty 2001, Keller 2005, Kahneman 2011, Evans and Stanovich 2013).

In the case of reviewers of patents, there can be several sources of cognitive load (Rogers and Monsell 1995, Maule et al. 2000, Moran 2016, Phillips-Wren and Adya 2020). First, the complexity of a patent application and information overload requires reviewers to aggregate the input from several sources of information into a simple pass/fail decision. In the case of patents, the reviewer makes a judgment based on the claims within the patent and on the claims of previous patents. A prime example of an ambiguous situation is a patent application that is novel or spans several fields, distant from the field of expertise of the examiner. From the angle of institutional gate-keeping, Ferguson and Carnabuci (2017) show that examiners are more likely to reject an application if it combines knowledge from different domains. This suggests that difficulties in assessing ambiguous applications can significantly influence an application's success. Koning et al. (2021) find that female biomedical inventors tend to create inventions targeted at solving gaps in the provision of female health, which could appear as having limited utility to examiners. In addition, applications by female inventors could be written in a perceptibly different way (Levitskaya et al. 2022), making it costly for an examiner to evaluate the claims within. Ultimately, making a decision with multiple inputs can invariably lead to ambiguous situations. In such cases, an evaluator might resort to stereotypes to arrive at a final decision, exhibiting a subtle bias that wouldn't exist in an unambiguous decision context (Sherman et al. 1998, Dovidio and Gaertner 2000, Axt and Lai 2019).

The reaction to cognitive load due to ambiguous situations could be tempered with experience. Arguably, an experienced reviewer has specialized in the process of aggregating information when evaluating efficiently a patent application. Potentially, experienced examiners have more automatic filters that allow them to evaluate the merit of applications. For example, wide knowledge of prior patents could allow a patent examiner to determine the merit of an application by reading the abstract and citations. An experienced examiner would be able to discount different writing styles to get at the core of the claims of the application. Therefore, if women tend to present more ambiguous applications in the absence of an automatic gender bias, this ambiguity would be less problematic for experienced examiners.

Another source of cognitive pressure is related to hitting targets for performance reviews or performing according to expectations. Patent reviewers usually multitask, reviewing several applications at a time, while managing their workload to hit their production requirements (Marco et al. 2017). Time concerns and multitasking are positively correlated with cognitive load and can lead to the activation of implicit biases as a heuristic to make fast decisions (e.g., Rogers and Monsell 1995, Maule et al. 2000, Stepanikova 2012). Hence, we anticipate that examiners burdened with a high workload might spend less time on an application and resort to automatic stereotypes more frequently.

Our hypothesis is the following:

Hypothesis 3. *Reviewers invoke stereotypes when making a decision on the patent application of inventors of different genders.*

Although we cannot directly measure the stereotypes and their relative influence in the decision making of reviewers, we employ a similar strategy to laboratory experiments such as Gilbert and Hixon (1991). We measure the characteristics of a decision under different types of cognitive load. We propose the following hypotheses:

Hypothesis 3(a). *Reviewers with more experience rely less on gender stereotypes while deciding on patent applications.*

Hypothesis 3(b). *Reviewers under high cognitive load rely on gender stereotypes while deciding on patent applications.*

In our application, we measure cognitive load in several ways. First, we capture susceptibility to ambiguous situations through examiner experience. Second, we account for cognitive pressures through the workload on the desk of the examiner. We continue the discussion of these channels in Section 4.

There are a number of papers that show that the experience and workload of the examiners matter for the decision making of patent examiners. Lemley and Sampat (2012) follow a cohort of patent applications and focus on the characteristics of the patent examiners. They find that experienced examiners are more likely to grant patents than less-experienced examiners. Frakes and Wasserman (2017) confirm this finding by exploiting the fact that promotions within the USPTO carry with them more workload. Frakes and Wasserman (2017) find that promotion leads to a decrease in rejections at first. As examiners become more experienced in their new roles, the rejection rates increase. Both of these results point toward experience as an indicator for specialization in resolving complex applications into a simple pass/fail decision and, thus, dealing with ambiguous situations. The promotion results suggest that increasing workload could lead to an increase in granting behavior. However, this effect could obscure a situation where automatic biases are effective, and the winners are male inventors. We contribute to this literature by attempting to replicate previous findings and by exploring whether gender stereotypes aid patent reviewers in reaching faster decisions.

3. Institutional Background and Data

3.1. Decision-Making Process and Organization

U.S. patent law requires new inventions to fulfill three criteria: novelty, nonobviousness, and utility. At the USPTO, reviewing examiners are responsible for ensuring that these requirements are indeed fulfilled. Applications at the USPTO require applicants to specify and describe their invention and to disclose "prior art"—that is, previous publications (including patents and patent publications). An application is assigned to an art unit, a group of examiners responsible for applications in a specific technology field. The application is then randomly assigned to one of the examiners within the art unit (Frakes and Wasserman 2017). The examiners evaluate whether the application fulfills the patentability and disclosure[3] requirements. As such, the reviewers are a one-person scientific committee that has to determine the merit of an application. Usually, a given patent application is one among many on the desk of an examiner. Without any prior contact, the name on the application is the only way for the examiner to deduce the gender of the inventor. An application can be denied for a lack of subject matter, novelty or utility, insufficient disclosure, or obviousness. The required work to assess a patent is significant, and unless examiners can articulate a proper basis for rejection, the examiners are legally expected to grant an application (Frakes and Wasserman 2017).

In our analysis, we exploit two additional characteristics of the patent review process. First, an examiner can grant a first action allowance. A particular fast way to clear an application from the desk of an examiner is a fast grant. After receiving an application, the reviewer evaluates the claims for compliance with the applicable laws. She checks whether the subject matter is patent-eligible, that the invention is sufficiently disclosed, that the claims clearly define the invention and conducts a prior art search to determine novelty and nonobviousness of the invention (see Graham et al. 2018 for an overview on the examination process). The first action of an examiner after this examination is the first action on the merits. The application can be approved, or it can receive a nonfinal rejection. The vast majority receive the latter decision. In our data, 9.5% of the applications, or 15.7% of the granted applications, receive a first-action approval. An application that receives a first-action approval is considered to be disposed (Marco et al. 2017, p. 4). All other applications receive a nonfinal rejection. The applicant can then respond and change their application. We exploit this feature of the decision-making process in our hypothesis testing.

Second, reviewers at the USPTO are promoted to a higher general schedule (GS) pay scale based on a variety of reasons, among which is how the examiner meets their workload expectations. Generally, a higher GS level implies more workload (Lemley and Sampat 2012, Frakes and Wasserman 2017). This induces a positive correlation where more experienced examiners are required to make faster decisions on the many applications on their desks. We account for the GS seniority level in a separate part of our analysis.

3.2. Data

We rely on the Patent Examination Research Dataset from the U.S. Patent and Trademark Office. We focus our analysis on original applications for utility patents at the USPTO filed between 2001 and 2014. We restrict our analysis to single-inventor applications to isolate the effect of the applicant's gender.

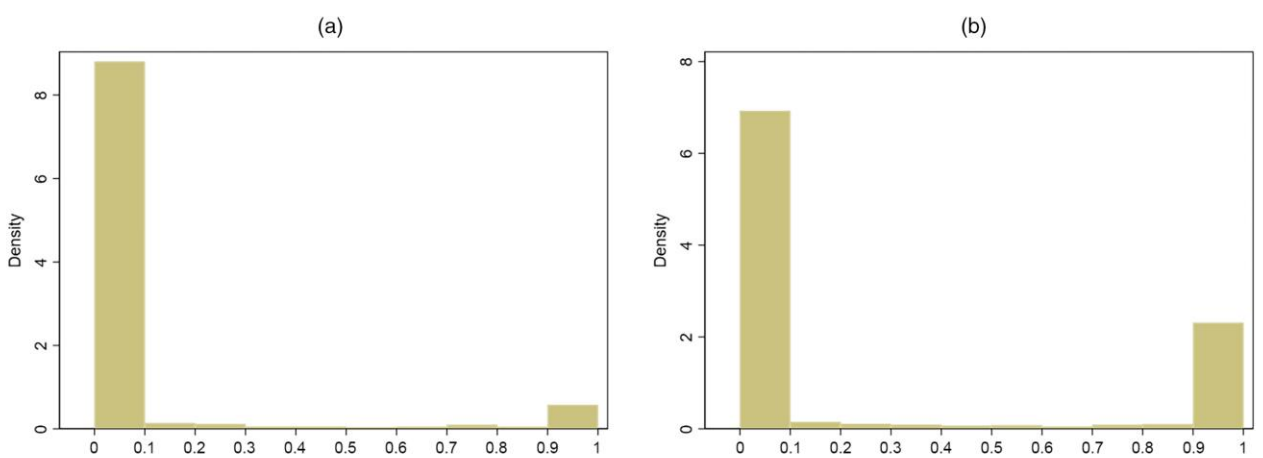
We focus our main analysis on applications with one inventor for two reasons. First, as outlined in the next paragraph, we cannot clearly identify the gender of all applicants because some names are gender ambiguous and can be linked to men and women. Furthermore, some are missing, typically names from international inventors. The larger a team of inventors is, the more likely it is that we cannot determine the gender of all the team members and, consequently, cannot calculate the share for the team. Second, we have a clear hypothesis on the stereotype imposed on a single inventor, whereas in the case of multiple inventors, it is unclear whether and why a given stereotype would be applied. With this caveat, we provide an extension with an analysis of teams in Section 5.4.

We determine the gender of the inventor by using their given name, which is specified in the application. To do that, we rely on data provided by the U.S. Social Security Administration (SSA). The SSA offers lists that contain all first names, differentiated by gender, for each year since 1880. In order to define the gender for a first name, we merge all years from 1880 to 2015 and calculate the *female likelihood*—the probability that a given name belongs to a woman. Figure 1 shows the distribution of the female likelihood in our sample. Every name with a female probability of more than 90% is defined as a female name, whereas every name with a female probability of less than 10% is a male name. All other names are removed from the analysis, as they would potentially introduce a bias in the analysis.

We present summary statistics in Table 1. We observe that, on average, 6.2% of the applications are authored by inventors with female names. Figure 2 shows the development of grant rates over time. On average, the grant rate for males is 61.0%, whereas for females, it is lower, at 47.3%. Thus, in the raw data, we observe a gender gap of 22.7%. It is notable from the figure that the gap between the grant rates of males and females remains constant through almost the entire sample period, despite the year-to-year variation.

In addition, in Table 1, we observe that, on average, 25% of the applications have a female reviewer, implying that there is diversity in the pool of potential examiners. The average experience of reviewers—measured as the filing year of an application minus the year of the first appearance of the reviewer in the database—is about 9.4 years. We measure an examiner's workload by the number of new and ongoing applications (from single inventors and teams) in a given year, divided by 100. In particular, we assign applications to an examiner's workload from the year of the filing to the year of the issue or final abundance (rejection).[4] We assign the workload of the respective examiner during the filing year to an application. We observe an average examiner workload of 237 applications per year.[5] This amount of workload implies that, on average, a reviewer has to make a decision on about one application from their desk every day.

Figure 1. (Color online) Female Likelihood Distribution Across Cases



Notes. The panels plot the histogram of the distribution of female likelihood of the inventors (a) and the examiners (b) across the cases in our example. In our main analysis, we exclude the ambiguous names—that is, those between 0.1 and 0.9.

Table 1. Patent Application and Examiner Characteristics

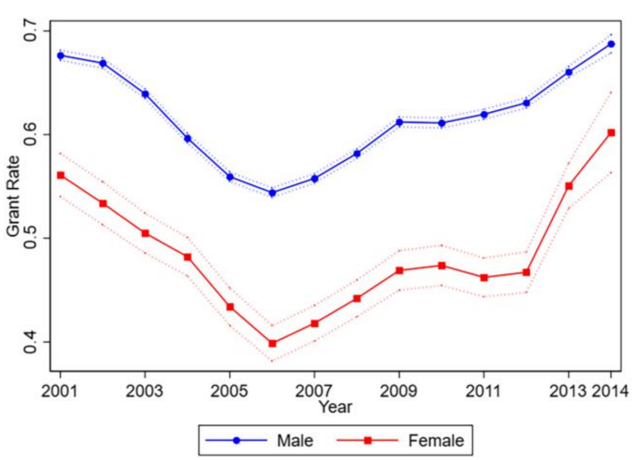
Variable	Mean (SD)
Female Inventor (*FI*)	0.062
	(0.241)
Granted Application	0.601
	(0.490)
Granted Female Apps.	0.029
	(0.169)
Examiner Female	0.251
	(0.433)
Examiner Experience	9.431
	(6.973)
Examiner Workload	2.370
	(1.224)
Observations	568,535

Note. Each observation is a single-authored patent application.

The main control variables in our analysis are sourced from PATSTAT and the USPTO Patent Claims Research Dataset. We restrict our sample to those observations for which all of our control variables are available. Online Appendix Table A.1 shows the definition and sources of all control variables. In Table A.2 in the Online Appendix, we present the pairwise correlation between the variables in our data. Note that there is a correlation of 0.572 between observed reviewer experience and workload, consistent with the organizational structure of the USPTO, as mentioned above. Experienced examiners tend to have a higher workload, as a characteristic of their level of promotion (Frakes and Wasserman 2017, Marco et al. 2017). We deal with this issue in two ways. First, we present results separately with each variable of interest. Second, we account for the pay grade in Section 5.3. Unfortunately, the information of an examiner's grade scale is not generally available in the USPTO examination data set. However, Frakes and Wasserman (2017) share the data from their analysis, and we are able to match the information to a subset of around 350,000 applications. Figure 3 shows the distribution of grade scales in our sample.

Online Appendix Table A.3 presents the summary statistics for the control variables in our analysis for the single-inventor case by gender and granted status. The control variables in our analysis are an indicator for an assignee, small entity applicant indicator, family size of the patent, number of dependent and independent claims, patent scope, and backward citations. In Online Appendix Table A.4, we tabulate the variables from Table 1 by field. Table A.4 reveals that there is large heterogeneity across technology fields, providing rich identifying variation in order to determine which reviewer characteristics are important in explaining the gender gap in acceptance of applications.

Figure 2. (Color online) Patenting Over Time for Applicants with Different Name Types



Notes. Each dot represents the average grant rate for each year. The smaller dots and the dotted lines indicate the 95% confidence interval.

4. Methodology

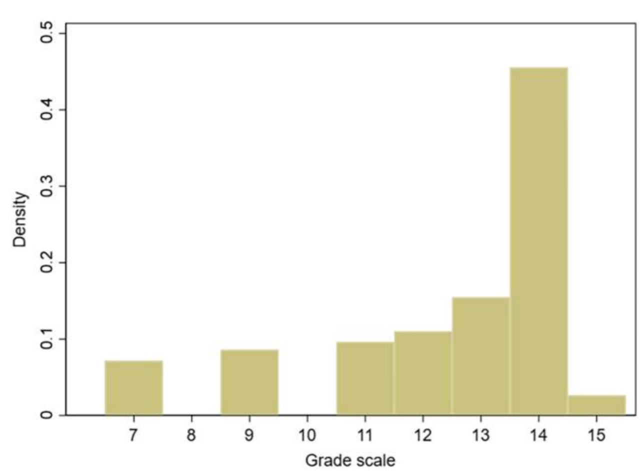
In this section, we provide notes on our methodology. We first focus on the estimating equation and the scope for causal inference. Then, we focus on linking the potential estimates to the hypotheses discussed in Section 2.

In our first hypothesis, we are interested in the impact of the gender of the applicant on the outcome of the application process. We estimate equations of the following type:

$$Grant_{ijst} = \alpha + \beta Female_{ist} + \delta Female_{ist} \times Examiner_{jst} + \gamma X_{ist} + \epsilon_{ijst}, \tag{1}$$

where $Grant_{ijst}$ is a dummy variable that takes value one if applicant i's application in art unit s filed in year t is granted by examiner j. $Female_{ist}$ is a dummy variable identifying the name type of the applicant, Male or Female. $Examiner_{jst}$ are observable examiner characteristics, and X_{ist} are the observable application and applicant

Figure 3. (Color online) Grade Scale Distribution



characteristics. The coefficient β identifies the difference between Female and Male names, and thus the impact of the Female name on the status of the application relative to a Male name. A significant estimate for β would imply a confirmation of Hypothesis 1. More specifically, in view of previous literature, a negative estimate for β would signify that the patent applications of women are less likely to be granted than the patent applications of men.

The coefficient δ identifies the effect of examiner characteristics, together with the gender of the applicant, that impact the potential granting of an application. We use the significance and the sign of δ to determine whether we observe evidence in favor of Hypotheses 2, 3(a), and 3(b). We discuss this in more detail below.

There are two main challenges to giving causal interpretation to β in a simple bivariate model. First, there could be productivity differences between male and female applicants based on factors such as whether the applications originate from a small company. To reduce the influence of such confounds and to refine the comparison, we include a variety of control variables X_{ist} that proxy for the quality of an application and, therefore, likely impact the probability of having a patent granted. These variables are an indicator variable for an assignee in the application, a small entity indicator, family size, number of granted applications, number of independent and dependent claims, patent scope, and backward citations. The variables are defined and presented in Tables A.1 and A.3 in the Online Appendix.

Second, there could be concerns about endogenous sorting of examiners based on the applicant's gender, where, for instance, more experienced examiners might prefer to review applications from males. To alleviate these sorting issues, we leverage the fact that examiners within a given art unit are randomly assigned to applications. To capture this source of variation, we include art unit fixed effects in Equation (1). We interact these fixed effects with the filing year to account for differences within art units over time. Therefore, the identifying variation in Equation (1) comes from differences in granting behavior between examiners within a given art unit within a given year. These steps should allow us to identify a causal effect of applicant gender on the application outcome.

Recently, Righi and Simcoe (2019) cast doubt on the randomization of examiners to applications, pointing toward knowledge specialization required to evaluate the merit of a given application. Righi and Simcoe (2019) find that in some technology classes, examiners specialize, and more specialized examiners tend to be more stringent, on average. Furthermore, Frakes and Wasserman (2020) claim to have conducted interviews to determine that assignment is not random "occasionally" in instances when an examiner has a high backlog of applications or on subspecialization grounds within art units. For the purpose of our application, the identifying assumption is that any such assignment is not related to the gender of the inventor. A violation of this assumption implies gender discrimination per se. In addition, Farre-Mensa et al. (2020) provide evidence that the assignment does not seem to be systematic based on examiner experience and seniority.

In some specifications, we refine Equation (1) by including examiner-year fixed effects. These adjustments allow us to filter out variations related to differences among examiners and to concentrate on the variation within each examiner in a given year. This approach allows us to specifically compare applications submitted in the same year and evaluated by the same examiner in our empirical model, while holding constant experience, workload, and other characteristics. However, in these specifications, we cannot compare whether an examiner makes a different decision under other sets of cognitive loads. As a result, our main focus throughout the explanation will be on the formulation with art unit-time fixed effects, utilizing the adjustments with examiner-year fixed effects to validate effect size.

As mentioned previously, we use the coefficient δ to determine whether we observe evidence in favor of the hypotheses from Section 2. First, we test whether the identity of the reviewer impacts the decision process. For this, we take the gender of the reviewer and interact it with the gender of the inventor. If the coefficient on the interaction δ is significant, this implies that a female examiner treats female inventors differently compared with their male counterparts, and it supports Hypothesis 2.

In addition, we are interested in whether we can observe the activation and application of stereotypes due to cognitive load. First, we take the years of experience of a reviewer as a measure and posit that reviewers with less experience could be more likely to use gender stereotypes in a situation where the inputs to the decision are more ambiguous. Therefore, if the gender gap is driven by such differences in productivity between the two types of inventors, we would expect that the interaction coefficient is positive, in support of Hypothesis 3(a).

Second, we are interested in the role of an examiner's workload. In a framework of high cognitive load, additional workload could lead to examiners employing strategies to move applications fast. Examiners could use the name of the inventor as a signal for quality and go with an automatic stereotype based on the gender of the applicant. In our setting, we would expect that examiners with high workloads are more likely to reject applications by female applicants, and δ would be negative, consistent with Hypothesis 3(b).

Note that in the context of patenting and in other organizations, experience carries with it promotion, which leads to more responsibilities and workload.

Frakes and Wasserman (2017) explore the role of grade-level promotions within the USPTO (GS levels), which bring a shock of increased workload levels to experienced examiners. In this vein, for a subset of our data, we examine the joint effects of workload expectations and experience.

5. Results

5.1. Patent Granting in the Single Inventor Case

We present our estimates in Table 2, where the dependent variable is the granting of a patent over the whole review process. In Panel A, we include art unit-year fixed effects. In Panel B, we absorb the between-year variation at the examiner level. Whereas in Panel A, we compare application outcomes within an art unit in a given application-filing year, in Panel B, we compare decisions taken by the same examiner within the same year. We also include control variables to account for all observable characteristics of the application.[6] In column (1), we compare male and female inventors who are similar in the observable characteristics of their applications. We observe evidence in favor of Hypothesis 1: patent applications by female inventors have different outcomes than the patent applications of male inventors. In Panel B, column (1), we observe that the same examiner is more likely to reject female-authored applications by 3.6 percentage points, on average, relative to male-authored applications ($p < 0.001$). This finding remains consistent throughout Table 2, as we focus on other characteristics of the reviewing process from the side of the examiner.

In the following columns, we add interaction terms to test Hypotheses 2, 3(a), and 3(b). These terms are identified by between-examiner variation and compare the gender gap in granting behavior for, for example, examiners with different levels of experience. First, we focus

Table 2. Patent Granting in the Single Inventor Case

	(1)	(2)	(3)	(4)	(5)	(6)
Variable	Granted patent application					
			Panel A			
Female Inventor (FI)	−0.043***	−0.042***	−0.042***	−0.029***	−0.028***	−0.024***
	(0.003)	(0.003)	(0.005)	(0.006)	(0.006)	(0.006)
Examiner Female		−0.016***			0.000	
		(0.004)			(0.003)	
FI × Examiner Female		−0.001			−0.006	0.005
		(0.007)			(0.006)	(0.005)
Examiner Experience			0.008***		0.004***	−0.286***
			(0.000)		(0.000)	(0.071)
FI × Examiner Experience			−0.000		0.001	−0.000
			(0.000)		(0.001)	(0.000)
Examiner Workload				0.058***	0.046***	0.024***
				(0.001)	(0.002)	(0.002)
FI × Examiner Workload				−0.006**	−0.009***	−0.005**
				(0.002)	(0.003)	(0.002)
Observations	568,535	568,535	568,535	568,535	568,535	568,535
Art unit-year FE	x	x	x	x	x	x
Examiner FE	—	—	—	—	—	x
Control variables	x	x	x	x	x	x
			Panel B			
Female Inventor (FI)	−0.036***	−0.038***	−0.029***	−0.023***	−0.024***	
	(0.003)	(0.003)	(0.004)	(0.005)	(0.006)	
FI × Examiner Female		0.006			0.005	
		(0.006)			(0.006)	
FI × Examiner Experience			−0.001*		−0.000	
			(0.000)		(0.000)	
FI × Examiner Workload				−0.005***	−0.005*	
				(0.002)	(0.002)	
Observations	568,535	568,535	568,535	568,535	568,535	
Art unit-year FE	x	x	x	x	x	
Examiner-year FE	x	x	x	x	x	
Control variables	x	x	x	x	x	

Notes. The dependent variable is the dummy variable whether a patent was granted. Fixed effects (FE) are noted at the bottom. All models include the following control variables: assignee, small entity, family size, number of patent grants obtained previously by the applicant, number of independent claims, number of dependent claims, patent scope, and backward citations. Robust standard errors clustered at the examiner level are reported in parentheses.

* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

on Hypothesis 2 on the identity of the examiner and compare the behavior of male versus female examiners. We add the interaction with the gender of the examiner in the second column. We observe that female examiners are, on average, more strict and less likely to approve any application compared with male examiners. Female examiners have a 1.6-percentage-point lower grant rate ($p < 0.001$). The coefficient on the interaction itself is small and shows a relatively high standard error, implying that likely female examiners do not favor or disfavor, especially female applicants. In Panel B, we observe that the addition of examiner-year fixed effects changes the sign on this interaction. Hence, we find no strong support for Hypothesis 2.

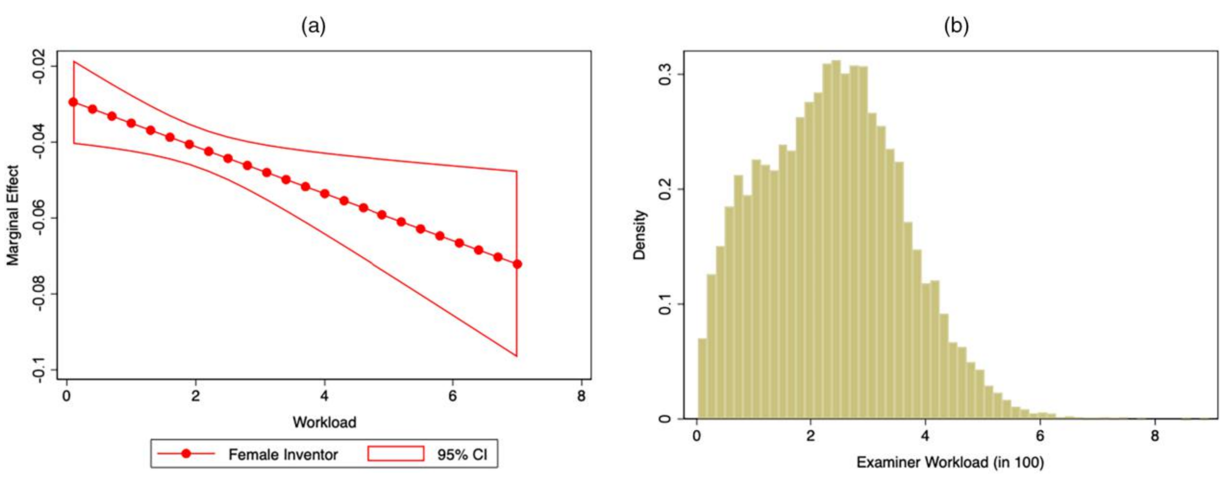
In Table 2, column (3), we focus on Hypothesis 3(a) by accounting for the experience of the examiner. We observe that more experienced examiners are more likely to grant applications, consistent with the literature (Lemley and Sampat 2012, Frakes and Wasserman 2017). However, the interaction term between examiner experience and the gender of the applicant is small and insignificant in all specifications of Panel A, whereas the female inventor effect remains consistently negative. We interpret this as general evidence that the application of an automatic female stereotype does not change with experience. More specifically, younger (in terms of experience) examiners are not more likely to use gender stereotypes than older examiners. We interpret this result as a lack of support for Hypothesis 3(a).

In Table 2, column (4), we focus on the workload of the examiner. Given the intensity of the examination process, examiners may decrease the thoroughness of their assessment and use an automatic gender stereotype when being faced by workload pressure. We observe a positive coefficient on examiner workload, implying that, in line with Frakes and Wasserman (2017), examiners with a high workload are more likely to grant applications. However, we find a negative coefficient for the interaction with the applicant's gender. We consider this as evidence supporting Hypothesis 3(a). Faced with a high cognitive load related to time pressure and multitasking, examiners could have little resources to battle an automatic gender stereotype based on the name on the application. Even though the effect seems to be small compared with the general workload effect, Panel B shows that reducing the workload from the third quartile to the first quartile ($3.21 - 1.42 = 1.79$) decreases the observed gender difference in the grant rates by 0.9 percentage points, or by around 25%. This reduction is also equivalent to 25% of the gender gap observed in column (1). The dynamics of the impact of workload on the grant rate for female applicants are illustrated in Figure 4, which presents the marginal effect of the interaction term.[7]

Table 2, column (5) includes all interactions. We observe qualitatively the same patterns. In column (6), we include examiner fixed effects only, comparing applications handled by the same examiner. The estimates are virtually identical to the estimates in Panel B, column (5)—indicating that differences within examiners across time play a negligible role.[8]

In the Online Appendix, we explore these interactions for different subsets of our sample in Table A.6. This includes restrictions on patent scope, the international orientation of the application, the ownership of the application, the size of the art unit, and the origin of the application. Across subsamples, we find the same consistent pattern with examiner workload having a

Figure 4. (Color online) The Effect of Reviewer Workload on Female Applicants



Notes. Panel (a) plots the marginal effect of workload on the probability that a patent application submitted by a woman would be granted. The marginal effect is computed based on the model in Table 2, column (4). Panel (b) plots the histogram of the distribution of workload of the examiner in the sample.

negative impact on the success rate of applications of female inventors. The full marginal effect of female inventors remains negative in all cases.

Furthermore, we present results by technology fields in Table A.7 in the Online Appendix. In Table A.8 in the Online Appendix, we use the female likelihood based on the data from the SSA instead of the dummy variable indicating a female inventor. Table A.9 in the Online Appendix shows results for different cut-offs in the categorization—that is, deviations from the 90% cut-off used in our main analysis. We present the results from a logistic regression in Table A.10 in the Online Appendix. Finally, we use an alternative workload measure. In our main analysis, we include applications that are on the docket of the examiner and the applications that have been filed, but have not arrived yet on the examiner's desk. We present results with an alternative measure for workload in Table A.11 in the Online Appendix, where we take into account only the application on the desk of the reviewer. We observe qualitatively similar results in all instances.

5.2. First Action Allowance Decisions

In this subsection, we look for evidence of our hypotheses by focusing on a different dependent variable—the first action allowance. As described in Section 3, the first decision point for an examiner occurs after the first evaluation—the first decision on the merits. Allowing an application at this stage is the quickest way to dispose an application, and we expect examiners under more cognitive pressure to be more likely to go this route. The dependent variable is coded as one if the patent application is granted in this first round. Therefore, a rejection at this stage is consistent with deferring a decision for later. It is still possible that a patent is subsequently granted. Therefore, we compare first allowance granted applications to both ultimately successful and unsuccessful applications.

Table 3 reports the results. As a first observation, consistent with Hypothesis 1, we find a significant disadvantage for female inventors in Panels A and B, column (1), similar to what we find in Table 2.[9]

Similar to the previous subsection, we find little support for Hypothesis 2 on the gender identity of the reviewer. Focusing on Hypothesis 3(a), we observe a consistent negative effect for experience—as the experience of examiners increases, the likelihood for an early grant of the application of a female inventor decreases. This evidence speaks in favor of an increased reliance on an automatic stereotype, which is not mitigated but amplified with experience. According to column (5), seven years of additional experience—roughly one standard deviation—decreases the first action allowance rate of female inventors by 0.7 percentage points ($p = 0.043$). However, the coefficient decreases when including examiner-year fixed effects in Panel B, and the coefficients are no longer significantly different from zero.

Regarding our workload measure, we observe a negative interaction effect, consistent with reviewers employing automatic stereotypes to defer female applications for later screening. In other words, if an examiner has a high workload, he is more likely to grant the application of a male inventor than the application of a female inventor at an early stage.

5.3. Seniority

At the USPTO, the concepts of experience, workload, and pay grade position are tightly related (Lemley and Sampat 2012, Frakes and Wasserman 2017, Marco et al. 2017). Generally, examiners with a lot of experience would tend to be at a higher pay grade (GS) position, with increased workload expectation.[10] It is ex ante unclear how this increased efficiency could interact with the application of a gender stereotype under cognitive load, on average. To account for this additional way to characterize examiners, we present results in Table 4.

Note that the sample size in Table 4 is smaller than in Table 2. Therefore, we replicate the main analysis in columns (1) and (2) and find qualitatively similar results. In column (3), we account for the grade of the examiner. Similarly to Frakes and Wasserman (2017), we find that the granting rate increased between GS levels. As examiners get promoted, they become more likely to grant patents. In both columns (3) and (4), we observe no differential impact of the pay grade on female inventors. In columns (5) and (6), we put together all variables—experience, pay grade, and workload. Given that GS grades carry with them the expectation of a higher workload, they could be considered equivalent to fixed effects on workload levels. Thus, we interpret the workload variable as a measure of excess workload beyond the expectation of the pay grade. We observe that the interaction effect between the applicant's gender and the examiner's workload continues to attain significance. In other words, considering two examiners at the same GS level with different workloads, the examiner with the higher workload would be less likely to approve the patent application of a female inventor.

From the interactions with the grade scale, only the highest grade, 15, shows a significantly positive effect in specifications 5 and 6.[11] For context, at grades 14 and 15, an examiner carries the right to sign off on all aspects of an application independently, without secondary review. As both grades 14 and 15 have higher coefficients than the other grades, there may be an interaction between decision autonomy and stereotypes—a potential route for future research.

Furthermore, Table 4 also shows again a negative effect of the examiners' experience on female applications, supporting the observation from the previous section.

Table 3. First Action Allowance Decision

	(1)	(2)	(3)	(4)	(5)
Variable	First action allowance				
Panel A					
Female Inventor (FI)	−0.008***	−0.008***	0.003	0.009***	0.012***
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
Examiner Female		−0.017***			−0.007***
		(0.003)			(0.003)
FI × Examiner Female		0.001			−0.003
		(0.003)			(0.004)
Examiner Experience			0.005***		0.004***
			(0.000)		(0.000)
FI × Examiner Experience			−0.001***		−0.001**
			(0.000)		(0.000)
Examiner Workload				0.026***	0.013***
				(0.001)	(0.001)
FI × Examiner Workload				−0.007***	−0.005***
				(0.001)	(0.002)
Observations	568,535	568,535	568,535	568,535	568,535
Art unit-year FE	x	x	x	x	x
Examiner FE	—	—	—	—	—
Control variables	x	x	x	x	x
Panel B					
Female Inventor (FI)	−0.005***	−0.005***	−0.001	0.001	0.001
	(0.002)	(0.002)	(0.002)	(0.003)	(0.003)
FI × Examiner Female		0.001			0.001
		(0.003)			(0.003)
FI × Examiner Experience			−0.000*		−0.000
			(0.000)		(0.000)
FI × Examiner Workload				−0.002**	−0.002
				(0.001)	(0.001)
Observations	568,535	568,535	568,535	568,535	568,535
Art unit-year FE	x	x	x	x	x
Examiner-year FE	x	x	x	x	x
Control variables	x	x	x	x	x

Notes. The dependent variable is the dummy variable whether a patent was granted by a first action on the merits—that is, it did not receive a nonfinal rejection. Fixed effects (FE) are noted at the bottom. All models include the following control variables: assignee, small entity, family size, number of patent grants obtained previously by the applicant, number of independent claims, number of dependent claims, patent scope, and backward citations. Robust standard errors clustered at the examiner level are reported in parentheses.

$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

5.4. Teams

So far, we have focused the analysis on single-inventor applications. In this section, we turn briefly to teams. Previous literature has found that diverse teams are more likely to produce research and patents that are novel (see, e.g., Hofstra et al. 2020, Yang et al. 2022). Taken together with observed tendencies for gatekeeping (Ferguson and Carnabuci 2017), one empirical prediction is that diverse teams would face high rejection rates. Relative to our main hypotheses, there could be a more complex interplay between the identity of the reviewer and the process of reviewing. First, the distance in observable and socio-economic characteristics between team members and the reviewer practically varies with each team member. Consider the following example. A male reviewer might consider themselves better able to judge the work of a single inventor that is male. When this inventor joins a team with a woman, the variation in gender distance might dilute the quality signal that the reviewer appreciates. Second, if team research is more likely to span several boundaries, then these applications would tend to be more ambiguous. If a reviewer employs automatic biases to resolve ambiguous application signals, then a mixed-gender team confuses the heuristic. Third, it might be that the presence of multiple team members serves as a separate signal for quality from the assumption that team members referee the work of each other. This could lead to granting the application of any team relative to single inventors, holding circumstances constant. These caveats could impact the way that we interpret estimates relative to the relatively clear-cut case of single inventors.

As anticipated in Section 3, we restrict our analysis to teams of up to five inventors to diminish the problems of missing gender information. As teams of size five account for 97.5% of all cases, we exclude only a small

Table 4. Seniority—Including the Examiners' Grade Scales in the Analysis

	(1)	(2)	(3)	(4)	(5)	(6)
Variable	Granted patent application					
Female Inventor (FI)	−0.024**	−0.014	−0.047***	−0.030**	−0.022	−0.009
	(0.011)	(0.010)	(0.012)	(0.012)	(0.014)	(0.015)
Examiner Female	−0.001				−0.005	
	(0.004)				(0.004)	
FI × Examiner Female	−0.004	0.003			−0.004	0.003
	(0.009)	(0.008)			(0.009)	(0.008)
Examiner Experience	0.004***				0.003***	
	(0.000)				(0.000)	
FI × Examiner Experience	0.000	−0.001			−0.001	−0.002**
	(0.001)	(0.001)			(0.001)	(0.001)
Examiner Workload	0.050***				0.039***	
	(0.002)				(0.003)	
FI × Examiner Workload	−0.009**	−0.006*			−0.012***	−0.008**
	(0.004)	(0.003)			(0.004)	(0.004)
GS-9			0.025***		0.007	
			(0.005)		(0.005)	
GS-11			0.048***		0.013**	
			(0.005)		(0.005)	
GS-12			0.072***		0.023***	
			(0.005)		(0.006)	
GS-13			0.108***		0.041***	
			(0.005)		(0.007)	
GS-14			0.154***		0.051***	
			(0.005)		(0.008)	
GS-15			0.056***		−0.024	
			(0.017)		(0.015)	
FI × GS-9			−0.010	−0.015	−0.006	−0.012
			(0.015)	(0.016)	(0.016)	(0.016)
FI × GS-11			0.016	0.009	0.024	0.017
			(0.015)	(0.016)	(0.016)	(0.016)
FI × GS-12			−0.003	−0.010	0.010	0.002
			(0.015)	(0.016)	(0.016)	(0.016)
FI × GS-13			−0.002	−0.006	0.016	0.011
			(0.014)	(0.015)	(0.016)	(0.016)
FI × GS-14			0.001	−0.011	0.031*	0.025
			(0.013)	(0.013)	(0.018)	(0.018)
FI × GS-15			0.027	0.032	0.054*	0.067***
			(0.024)	(0.021)	(0.028)	(0.025)
Observations	350,083	350,083	350,083	350,083	350,083	350,083
Art unit-year FE	x	x	x	x	x	x
Examiner-year FE	—	x	—	x	—	x
Control variables	x	x	x	x	x	x

Notes. The dependent variable is the dummy variable whether a patent was granted. Fixed effects (FE) are noted at the bottom. All models include the following control variables: assignee, small entity, family size, number of patent grants obtained previously by the applicant, number of independent claims, number of dependent claims, patent scope, and backward citations. Robust standard errors clustered at the examiner level are reported in parentheses.

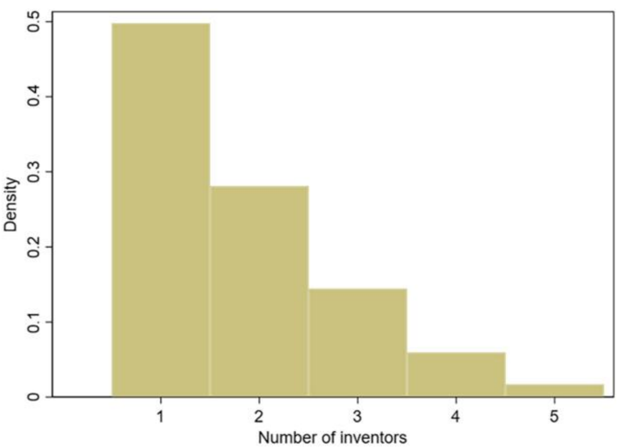
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

fraction of cases. Figure 5 shows the distribution of the team size, and Table A.12 presents the summary statistics.

Instead of an indicator variable for a female inventor, we use the share of females and its interactions with examiner characteristics. To account for differences in team sizes, we add the number of inventors as an additional control variable. Table 5 presents the results. We observe qualitatively similar results, as in the case of the single inventor. We observe significantly negative estimates for the share of female inventors throughout all specifications. We observe that the larger the teams, the higher the likelihood of patent approval, and the success rate of mixed-gender teams is weighted down by the participation of female inventors.

Furthermore, we find some support for Hypothesis 2. Female examiners appear to be stricter with the applications of teams with a high share of female inventors relative to teams with a low share—a team of only women has a 1.2-percentage-point lower grant probability if the examiner is a woman ($p = 0.022$). The examiner's experience shows some alleviating effect ($p = 0.012$), where

Figure 5. (Color online) Distribution of Team Size



more senior examiners are likely to grant the patent for teams with a higher share of female inventors. However, both observations vanish when we include examiner-year fixed effects, and the coefficients decrease in size. The workload effect remains consistent throughout. Finally, Tables A.13 and A.14 in the Online Appendix replicate the results from the previous two sections for the team case.

6. Discussion and Conclusion

The interaction between reviewers and applicants forms an integral conduit through which organizations foster and attract talent. This interaction has a significant gender dimension. In many fields of science and industry, we observe a leaky pipeline of talent, where women drop out before reaching the next level of their careers. Frequently, the foundation of such personal glass ceilings lies in the perspectives of reviewers or committees, who assess the quality of an application. However, such evaluations can frequently be influenced by the intricacies of daily work stressors, such as time constraints and various forms of cognitive load. Consequently, these assessments may reflect both a verdict on the inherent quality of an application and reviewer-specific reactions to pressures.

In this article, we focus on examining the impact of reviewer characteristics on the gender diversity of applicants. We focus on the setting of patent applications at the USPTO. This setting allows us to leverage quasi-exogenous variation from the random assignment of patent examiners within art units and, therefore, determine the causal effect of reviewer characteristics. Consistent with previous literature, we find evidence that the applications of women inventors have a 3.6-percentage-point lower likelihood of patent approval.

We examine whether a theory of self-image bias by the reviewer can fit the observed systematic outcomes for women. We find that the gender gap does not seem to be impacted by the gender of the examiner of the application, contrary to a large literature finding and predicting significant interactions. That result shows that increasing examiner diversity, for example, through DEI initiatives, will not benefit female inventors.

Further on, we focus on theories of the use of automatic gender stereotypes under cognitive load as a way to cope with work pressure. Considering that innovation is male-dominated, we hypothesize that female inventors are too few to challenge the establishment of an automatic stereotype against women. We then examine two main sources of cognitive load: resolving ambiguity in decisions and workload pressure. We exploit the fact that patent examiners likely specialize in making decisions on applications. We predict that inexperienced examiners would be less likely to resist automatic stereotypes when faced with a complex reviewing decision than experienced examiners. We find no support for this hypothesis. If anything, we find that as examiners gain more experience, they are more likely to defer applications of female inventors to further review through a rejection at the first stage of the review process. This still indicates the presence of an automatic bias correlated to experience, but not through the mechanism that we had in mind.

We find strong support for our workload pressure hypothesis. We find that the gap in application outcomes between male and female inventors increases when the workload of the examiner increases. There are several possible mechanisms at play, possibly all together. First, a time-constrained examiner could rely on stereotypes to assess the merits of an application. Second, examiners could put less effort into reviewing applications with a female name as the inventor. The effect is present both in single-authored and team applications. That finding implies that female inventors profit from more examiners and not from the inclusion of more female examiners. This highlights the need for continuous recruitment and retention of the workforce at the patent offices. This need is amplified by the baseline workload effect—as the workload increases, all types of applicants profit, and more low-quality patents will be granted. Any policy to decrease the examiners' workload has to be evaluated against both effects.

There are a number of managerial implications beyond the patent office setting. First, the name of the applicant is salient to reviewers, allowing them to deduce gender. Anonymous applications could be valuable. Other research shows that removing stereotype-identifying information could reduce bias (Axt and Lai 2019). However, the success may be limited by different writing styles—Levitskaya et al. (2022) show differences in writing styles across genders.

Second, improving the diversity of the reviewer pool may not lead to the desired outcome. The workload result suggests that organizations benefit from having a

Table 5. Analysis Including Teams

Variable	(1)	(2)	(3)	(4)	(5)
	Granted patent application				
Panel A					
Female Share (FS)	−0.048***	−0.045***	−0.051***	−0.037***	−0.035***
	(0.003)	(0.003)	(0.004)	(0.005)	(0.005)
Examiner Female		−0.017***			−0.002
		(0.003)			(0.003)
FS × Examiner Female		−0.006			−0.012**
		(0.006)			(0.005)
Examiner Experience			0.008***		0.004***
			(0.000)		(0.000)
FS × Examiner *Experience*			0.000		0.001**
			(0.000)		(0.000)
Examiner Workload				0.056***	0.045***
				(0.001)	(0.001)
FS × Examiner Workload				−0.004**	−0.008***
				(0.002)	(0.003)
Number of inventors	0.009***	0.009***	0.009***	0.008***	0.008***
	(0.001)	(0.001)	(0.000)	(0.000)	(0.000)
Observations	1,141,678	1,141,678	1,141,678	1,141,678	1,141,678
Art unit-year FE	x	x	x	x	x
Control variables	x	x	x	x	x
Panel B					
Female Share (FS)	−0.038***	−0.038***	−0.036***	−0.028***	−0.028***
	(0.002)	(0.003)	(0.004)	(0.004)	(0.005)
FS × Examiner Female		−0.001			−0.001
		(0.004)			(0.004)
FS × Examiner Experience			−0.000		0.000
			(0.000)		(0.000)
FS × Examiner Workload				−0.004**	−0.005***
				(0.002)	(0.002)
Number of inventors	0.007***	0.007***	0.007***	0.007***	0.007***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Observations	1,141,678	1,141,678	1,141,678	1,141,678	1,141,678
Art unit-year FE	x	x	x	x	x
Examiner-year FE	x	x	x	x	x
Control variables	x	x	x	x	x

Notes. The dependent variable is the dummy variable whether a patent was granted. Fixed effects (FE) are noted at the bottom. All models include the following control variables: assignee, small entity, family size, the average number of patent grants obtained previously by the applicant, number of independent claims, number of dependent claims, patent scope, and backward citations. Robust standard errors clustered at the examiner level are reported in parentheses.
*$p < 0.1$; **$p < 0.05$; ***$p < 0.01$.

larger pool of reviewers, who can spread the workload more thinly. Although this does not address the existence of the bias, it does give more time to the examiner to review the merits of an application. In general, as stress and cognitive load invoke the use of stereotypes, it is important to manage the reviewer pool well, so that they have sufficient time to review applications. Additional stress management at certain times or parts of an organization may complement the reviewer recruitment and retention efforts. This could be complemented by additional initiatives: recent evidence shows that two policies together—a diverse reviewer pool and gender diversity awareness training—could significantly influence the diversity in the successful applicant pool (Axt and Lai 2019, Baron et al. 2024).

There are several articles and policy briefs documenting the existence of a gender gap in patenting (e.g., Ding et al. 2006, Frietsch et al. 2009, Sugimoto et al. 2015, Meng 2016, Milli et al. 2016, Jensen et al. 2018, Shaw and Mariano 2021). We contribute by exploiting the random assignment of examiners, identifying the causal effect of gender, and determining the nature of the influence of examiners on the outcome of the application. We find evidence that reviewers could be unable to resist automatic stereotypes when faced with a high workload.

We show that the decision to grant an application might not be fully rooted in the underlying quality of the application, but instead can be subject to the cognitive load of the reviewer. Our findings suggest the existence of a gender bias in the examination of patent applications at the USPTO. However, our results should be interpreted with care, as we do not have a perfect overview of the whole submission process, and we cannot point to a specific instance of bias. There are several possible research questions that could go down that road. For example, one open question remains in examining different versions of a patent application—from submission to final outcome—to determine whether women and men face different types of scrutiny. Another interest lies in examining the communication during the application process. Finally, we do not take into account the role of the attorney who handles the application on behalf of the applicant and serves as a conduit for the previously mentioned correspondence. It could be very well that the bias is alleviated, strengthened, or not influenced at all by the attorneys themselves.

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Endnotes

[1] Throughout the article, we refer to this situation as a reviewer-applicant interaction. As we discuss the application of patents, we use the word examiner as a synonym for reviewer.

[2] See Hosler (2018) from the Office of the Chief Communications Officer at USPTO.

[3] The patent law code 35 U.S.C. 112(a) requires an applicant to include a specification that enables a person skilled in the art to "make and use the same."

[4] Even though an application is assigned to a particular examiner a bit later in the process, examiners are aware of the upcoming number of applications, and we argue that this awareness affects their decision making. In Online Appendix Table A.11, we replicate our main results using the docketing year—that is, the year in which an application is allocated to the examiner—instead of the filing year.

[5] Measuring the workload for all examiner-year observations in our sample rather than applications, we observe a very similar average workload of 242 applications.

[6] The estimates on the control variables and a step-by-step estimation can be found in Table A.5 in the Online Appendix.

[7] We present nonlinear estimates of the marginal effect in Figure A.1 in the Online Appendix.

[8] We observe similar patterns in the other specifications and therefore leave out this in-between step in the following for simplicity.

[9] To see this, it is important to remember that we observe 9.5% of first action allowances, whereas we observe 60.1% of granted applications. Hence, for a rough comparison with the coefficients from Table 2, we can multiply the coefficients by six.

[10] This generates the high positive correlation in Online Appendix Table A.2 between experience and workload.

[11] Note that Frakes and Wasserman (2017) exclude grade 15 in their main results but include them in a robustness check. For simplicity, we report only results that include grade 15. All results are nearly identical when excluding the observations.

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