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Closing the gender gap in patenting: Evidence from a randomized control trial at the USPTO*

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Abstract

Women are underrepresented in patenting and the gap is not closing quickly. One major roadblock to progress is a dearth of causal evidence on the potential effectiveness of policies to reduce the gender gap in patenting. Analyzing a randomized control trial at the United States Patent and Trademark Office that was designed to provide additional help to applicants who do not have legal representation, we find heterogeneous causal impacts across gender and technologies on the probability of obtaining patent rights. While both men and women applicants benefited, the probability of obtaining a patent was about 11 percentage points greater for women, and the effects were largest for U.S. inventors, new U.S. inventors, and in technology areas where women had the worst relative outcomes. Our results suggest that a portion of the gender gap in patenting could be eliminated through additional assistance during patent examination.

Keywords: RCT, patent, gender gap, invention, innovation

JEL Codes: O31, O34, O38, J16

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1 Introduction

Evidence from U.S. patents shows that women are underrepresented as inventors (Toole et al. 2019; Toole et al. 2020). The percentage of women inventors named on patents was about 13 percent in 2019, rising from less than 5 percent in 1976, well below standard benchmarks for gender parity. Recent legislation and policy initiatives by the U.S. Government, including the SUCCESS Act of 2018 and the creation of the National Council for Expanding American Innovation in 2020 (now called the Council for Inclusive Innovation), demonstrate that closing this gap is a major policy objective. Doing so could increase the overall rate of invention (Bell et al. 2019) and direct inventive activity toward technologies that address unmet needs, particularly for women consumers (Koning et al. 2021). Although recent research suggests a role for public policy (Whittington and Smith-Doerr 2005; Ding et al. 2006; Murray and Graham 2007; Colyvas et al. 2012; Hunt et al. 2013; Sugimoto et al. 2015, Meng 2018), evaluating and formulating such policies is hindered by a dearth of causal evidence on the effectiveness of current interventions and potential alternatives.

The gender gap exposed by data on patents issued by the U.S. Patent and Trademark Office (USPTO) has two broad determinants: first, the opportunities, processes, and choices that influence whether women are listed as inventors on patent applications submitted to the USPTO[1]; and second, the success of those applications in the examination process. Our contribution focuses on the second component. Prior research by Jensen et al. (2018) finds that inventor teams with only women are 7 percentage points less likely to receive a patent than teams with only men, and this gap increases to 11 percentage points in the life sciences. Aneja et al. (2021) find that women inventors are 5.9-10.4 percentage points more likely to abandon patent applications during the examination process at the USPTO. They explain their result as reflecting differential access to legal expertise and other resources.

This paper presents causal evidence on the impact of enhanced examination assistance given to inventors on the likelihood of receiving a patent. We analyze the first randomized control trial (RCT) conducted by the USPTO and estimate overall and heterogeneous average treatment effects (ATEs) by gender and technology. In 2014, the USPTO established the Pro Se Pilot Examina-

[1] Previous studies find that women are more likely to patent in academic institutions and in organizations with flat management structures (Whittington and Smith-Doerr 2005, 2008; Sugimoto et al. 2015; Delgado and Murray 2018)

tion Unit (PSPEU) to help inventors without legal representation (pro se inventors) as they went through the patent examination process by providing enhanced guidance and information. After stratifying by technology, pro se patent applications were randomly assigned to the treatment group, the PSPEU, or the control group, the regular examination process. The random assignment of treatment allows us to directly estimate the effects of additional examination assistance without the usual endogeneity concerns (e.g., unobserved patent application and applicant quality).

We find that the PSPEU increased the likelihood of receiving a patent for both men and women inventors, but the causal effect for women was about 11 percentage points greater. Among U.S. inventors, and especially for first-time U.S. inventors, the estimated heterogeneous ATEs for women were again substantially larger than for men at 15.1 and 17.7 percentage points, respectively. The effects were also larger for women in particular technology areas such as software and communications (TC2100 and TC2400) where they had the worst relative outcomes in the control group. Overall, the PSPEU completely eliminated the gender patenting gap between men and women in these technologies and among U.S. first-time inventors filing at the USPTO. Our results demonstrate that enhanced examination assistance is an effective policy to address differential success rates among men and women inventors in the patent examination process.

One mechanism that may explain our overall findings is the use of interviews during examination, initiated by either the examiner or the applicant, to discuss the patentability of an application in real-time. PSPEU examiners were trained to initiate and encourage applicants to request interviews, which was often communicated through Office actions, in order to discuss the reasons for rejection and how the application might become allowable.[2] We find that the use of interviews was 20.6 percent higher in the treatment group relative to the control group, with examiner-initiated interviews being 128 percent higher and applicant-initiated interviews being 18.1 percent higher. Interestingly, in the treatment group, we do not find any difference between men and women in their use of interviews. These findings suggest that the larger causal effect of examination assistance for women does not reflect the number of interviews, but rather how women inventors responded to those interviews. This result is further supported by the robustness checks described below.

By design, the PSPEU examiners were very experienced, having achieved a high level of seniority

[2] An Office action is a written correspondence from the examiner that includes a discussion on the patentability of an application, and must be formally responded to in order to continue patent examination. For more information, see `https://www.uspto.gov/patents/maintain/responding-office-actions`

at the USPTO. Existing literature has shown that more experienced and senior examiners have higher allowance rates (Lemley and Sampat 2011; Frakes and Wasserman 2017; deGrazia et al. 2021), potentially explaining the impact we observe in the PSPEU. We show that this was not the case. The heterogeneous average treatment effect persists after controlling for examiner experience and seniority. We also show that our results are not explained by other examiner characteristics potentially used in hiring PSPEU examiners, including their propensities to issue patents to pro se inventors and their propensities to issue patents to women applicants (relative to men).

Another potential concern is that the PSPEU examiners may have allowed more patent applications at the expense of patent quality. We do not find any evidence of this, showing that there were no differences in the scope granted to applicants or in the propensity of examiners to allow patent applications without modifications during the first round of review. Our results are robust to a number of other considerations, including potential violations of the stable unit treatment value assumption, including direct and indirect spillovers between the treatment and control groups, alternative parametric and semi-parametric estimators, as well as the use of non-parametric statistical tests.

In light of the effectiveness of the Pro Se Pilot Examination Unit for improving patenting outcomes, particularly for women, it would be ideal if the treatment could be applied broadly by the USPTO to all patent applicants. In a formal sense, our results are not directly applicable because the RCT only included pro se applicants who represent a small fraction of all patent applicants. Nevertheless, the insights from this experiment can help inform policies for applicants that are similar. For instance, inventors and legal representatives associated with small and micro entities (for example, small businesses, universities, and non-profit organizations) are potential candidates because these applicants typically have inventors and legal representative with less experience relative to those associated with large, multinational corporations and major law firms (Hall and Lerner 2010). Recent research suggests that attorney quality matters (de Rassenfosse et al. forthcoming) and our data show that the attorneys associated with small and micro entities are less experienced (based on patent applications submitted to the USPTO), have lower allowance rates, and make substantially more changes to their applications during the examination process.

In addition to these observations, our data show that *first-time* women inventors named on patents filed at the USPTO are more likely to file their applications with small or micro entities. Of all women inventors who entered the patent system in 2018, over 50 percent were either independent or affiliated with a small entity, a full 4.2 percentage points higher than men. Additional guidance and information during patent examination could help this group, with greater benefit to women.

Our paper contributes to an influential literature that uses randomized evaluations to improve policy formulation within U.S. federal, state and local government agencies (Lalonde 1986; Friedlander and Robins 1995; Krueger and Whitmore 2001; Hotz et al. 2006; Finkelstein et al. 2012). There is growing interest amongst policy-makers in the use of RCTs to rigorously evaluate programs and initiatives. For example, since 2015, the J-PAL State and Local Innovation Initiative has helped 18 state and local governments implement and analyze evaluations to assist those experiencing poverty.[3] Within the area of science and technology policy, one of the aims of the recently announced J-PAL Science for Progress Initiative is to improve the allocation of funding in scientific research by partnering with the National Science Foundation and others (Niehaus and Williams 2022). As the first-ever RCT at the USPTO, our paper illustrates the value of conducting randomized evaluations within a large U.S. federal agency to improve the functioning of the innovation ecosystem.

Our paper proceeds as follows: In Section 2, we provide a brief description of the patenting process at the USPTO and describe the prior literature on patenting outcomes and gender at the USPTO. In the following section, we introduce the Pro Se Pilot and discuss our corresponding research design and sample construction process. In Sections 4 and 5 , we discuss our empirical methodology and present our main results, respectively. Section 6 extends our analysis by identifying the mechanisms that drive our overall results, describing survey evidence from PSPEU applicants, and discussing the generalizability of our results. In Section 7 we discuss additional considerations and present several robustness checks. Section 8 concludes.

2 Background

A patent application reflects an invention claimed by the set of listed inventors. Once the applicant submits the application to the USPTO and pays the required submission fees, the office will review the application for completeness. The application is then given an initial technology classification

[3]See `https://www.povertyactionlab.org/initiative/state-and-local-initiative-current-partners`

and routed to an examiner within a Technology Center (TC), and more narrowly, a Group Art Unit (GAU) responsible for that technology. The payment of initial application fees generally entitles the applicant to two rounds of examination. During the first round, the examiner must read and understand the application, and conduct a "prior art" search for earlier material related to the claimed invention. In order to grant a patent, the examiner determines if the patent application satisfies all conditions necessary for patentability, including, but not limited to, eligible subject matter (35 U.S.C. 101), novelty (35 U.S.C. 102) and non-obviousness (35 U.S.C. 103) (see `https://www.uspto.gov/web/offices/pac/mpep/s706.html`). The examiner's determination is described in an Office action document mailed to the applicant, detailing the reasons for rejection, or if no reasons for rejection are found, an allowance (see `https://www.uspto.gov/web/offices/pac/mpep/s2262.html`. During the first round of examination, this determination is called the first-action on the merits decision.

After receiving an Office action rejection in the first round of review, an applicant can amend their application for reconsideration by the examiner in the second round. If not allowed in the second round, applicants can extend examination to additional rounds by paying additional fees (i.e., by filing a Request for Continued Examination, or RCE). At any point during examination, an applicant can abandon their application by notifying the Office or by failing to respond which ends the examination process.

The USPTO allots each examiner a prescribed amount of time to conduct the first two rounds of examination, which varies across technology classes, examiner seniority, and other characteristics. For example, during the time period of our analysis, a senior examiner (GS-14) in technology class 14 (i.e., bridges) was expected to complete the first two rounds of examination in 15.46 hours whereas a junior examiner (GS-7) was allotted 27.5 hours to complete the same tasks (Marco et al. 2017).

Most inventors do not prepare their patent applications or interact directly with patent examiners but instead hire patent attorneys, who must satisfy several requirements to practice before the USPTO, including passing a registration examination (see `https://www.uspto.gov/sites/default/files/documents/OED_GRB.pdf`). However, some inventors, called pro se applicants, choose to prepare their own applications and represent themselves during patent examination at the Office.

3 Description of the Intervention

3.1 Introduction to the Pro Se Pilot Examination Unit

Created in October 2014, the Pro Se Pilot Examination Unit contained 15 patent examiners specializing in a diverse set of technologies. The examiners were selected based on their experience, having achieved a high level of seniority for USPTO examiners (called GS-14 primary examiners). They were given 40 initial hours of training that focused on strategies to better assist pro se inventors who may not understand the legal aspects of obtaining patent protection. The initial training materials provided a set of expectations for PSPEU examiners: (1) to educate and conduct interviews with applicants at each stage of the examination process, (2) to draft and propose allowable claims to applicants when patentable subject matter was identified, and (3) to be proactive in providing exceptional customer service.[4] After this initial training, the PSPEU held quality enhancement meetings where the examiners could share learned best practices with their peers.

The examination of application number 14,272,542, examined in the PSPEU, helps clarify some of these objectives. On September 28, 2015, the PSPEU examiner issued a non-final rejection, identifying several issues with the application. At the beginning of the written correspondence, the examiner stated "Please do not hesitate to contact (examiner name omitted) at (phone number omitted) if you have any questions regarding this correspondence or replying." The next statement in the Office action requested that the inventor contact the examiner so that they could explain how to amend a form incorrectly submitted to the office (in this case, the application data sheet). About two weeks later, the applicant initiated an interview, and the examiner discussed the non-final rejection, providing clarification, as well as directed the applicant to a template for submitting an amendment. After another round of review, the examiner issued a final rejection because of remaining issues with the amended application. Shortly after, the applicant initiated another interview where the examiner "noticed some features which appeared different from the prior art," and "spent some time drafting several claims for Applicant's consideration." After one more interview where the applicant asked about a few changes and the examiner agreed, the case was allowed.

This examination history highlights several potentially unique features of examination in the

[4]See MPEP 707.07(j) for more information about the process USPTO patent examiners follow to "state when claims are allowable" to applicants at `https://www.uspto.gov/web/offices/pac/mpep/s707.html#d0e75644`

PSPEU. First, the non-final rejection issued in the first round of examination encouraged the applicant to initiate an interview to discuss submitting a new application data sheet, as well as any questions the applicant had about replying. Second, the examiner and applicant actually spoke several times in interviews, discussing many nuances of the examination process. Finally, the examiner pointed out allowable subject matter in the application and proposed claims for the applicant's consideration, ultimately leading to an allowance. The aim of our study is to understand the impact of these features of examination, best summarized as additional guidance and information provided to the applicant, on patenting outcomes, with an emphasis on differences between men and women inventors.

3.2 Research Design

The USPTO designed the intervention as a randomized control trial, assigning incoming pro se patent applications randomly to either the treatment group, i.e., to the PSPEU, or the control group, the standard patent examination process. Figure 1 presents the stages each application underwent prior to assignment to either the treatment or control group. These stages included submission by the applicant to the USPTO, the assignment of technology classifications by the agency, the identification of pro se applications, and finally assignment to either the treatment or control. Since the USPTO does not collect information directly from applicants on whether they have legal representation, the PSPEU identified potential pro se applications using a search query executed on internal USPTO application data. The approach identified all applications that (1) were not yet assigned to an examiner, (2) did not have a power of attorney communication filed, and (3) were new applications, in the sense that the applications were not continuations, continuations in part, divisionals, reexaminations, requests for continued examination or reissues.[5]

In October 2014, the algorithm was executed and the applications drawn from the query were allocated to the treatment and control groups using stratified randomization within the initial technology centers assigned to each application (with approximately 50 percent going to the treatment and 50 percent to the control). Stratified randomization is generally more informative than a completely randomized experiment as it eliminates severe imbalances in assignment and can lead to

[5]More information on the types of patent applications is available here https://www.uspto.gov/web/offices/pac/mpep/s201.html

Figure 1: Flow of applications from submission to treatment assignment

more precise inference, especially with heterogeneous treatment effects (Imbens and Rubin 2015). At the time of the RCT, however, the administrators' motivation was to ensure appropriate workload balances across PSPEU examiners, i.e., allocating enough applications within each examiner's respective technology to maintain a consistent stream of work. This focus on workload balances within the PSPEU had a second consequence–our sample reflects the technology backgrounds of the examiners in the pilot art unit. For example, since the PSPEU did not have an examiner from TC1600 (Biotechnology and Organic Chemistry), our sample does not contain any applications from this technology area.[6] This implies that our sample should not be thought of as the population of pro se applications, but rather a close approximation.

The RCT had two rounds. RCT Round 1 took place in October 2014 and had a total of 1,430 applications randomly assigned to either the treatment or control groups. RCT Round 2, which used the same assignment mechanism, involved 1,098 in October of 2015. After treatment assignment in both RCT rounds, applications in both the treatment and control groups were manually evaluated to make sure an attorney wasn't present (i.e., that the applications were in fact pro se).

The "treatment" in this setting is the additional guidance and information provided to applicants by PSPEU examiners relative to standard patent examiner practices given to applications in the control. Treatment group examiners sometimes informed applicants in Office actions that their applications were being examined in the Pro Se examination art unit, but nothing else about the pilot. For example, in the beginning of the non-final rejection for application 13,573,824, the examiner wrote, "This case is being examined in Pro Se Examination Unit [...]." Applicants in the control group were not provided any additional information beyond what is provided to them during the standard examination process. The limited information provided to treated applicants about the pilot combined with the fact that patent applicants cannot choose where or by whom

[6]This limitation is not consequential due to the limited number of pro se applications in Biotechnology and Organic Chemistry filed in 2014 and 2015, only about 4 percent. From a staffing perspective, there were simply not enough pro se applications from TC1600 to support a full time PSPEU examiner.

their applications are examined, implies that participation in the program was involuntary and applicants were not able to switch from the control group to the treatment group or vice versa. These design aspects of the PSPEU imply that incomplete compliance with treatment assignment was not an issue.

3.3 Data, Summary Statistics, and Balance

Sample Construction – Our baseline sample includes all treatment and control applications from the RCT, with the treatment/control group assignment obtained from internal USPTO sources. We link these applications to information from PatentsView, the Patent Examination Research Dataset (PatEx), and internal USPTO data sources.[7] PatentsView provides disambiguated inventor data for each pre-grant publication (PGPub) from 2001 to present and granted patent from 1976 to present. The disambiguation algorithm links a given inventor to all of their PGPubs and patents.[8] In addition to extracting the disambiguated inventor identification number for each inventor, we record the number of applications filed by each inventor prior to each application in our sample, which we define as inventor experience. We also use PatentsView to record the number of inventors on each application, or team size, and to identify U.S.-based inventors.

PatentsView also includes an algorithmically-generated inventor gender attribution (Toole et al. 2019). The gender attribution algorithm assigns gender probabilistically based on the inventors name and achieved state of the art performance on a known dataset of examiner names and genders (Toole et al. 2020).[9] Initial linkages show that 92 percent of inventor-level observations in the RCT sample have a gender attributed by PatentsView.[10] For those inventor-application observations with a gender attribution, there were 470 women inventors (15.3 percent) and 2,592 men inventors (84.7 percent). Our sample contains a similar though slightly higher percentage of women inventors than the USPTO's overall women inventor rate in 2019 of about 13 percent (Toole et al. 2020). Since pro se inventors overwhelmingly file as small or micro entities (97 percent of the applications in our sample are associated with small/micro entities), this finding is consistent with Figure 2,

[7] PatentsView data can be found at `www.patentsview.org` and PatEx is located at `https://www.uspto.gov/ip-policy/economic-research/research-datasets/patent-examination-research-dataset-public-pair`.

[8] See `https://patentsview.org/disambiguation` for more information on the disambiguation algorithm.

[9] For all steps in the PatentView gender attribution algorithm, see `http://patentsview.org/gender-attribution`

[10] In general, the PatentsView gender classification algorithm requires that a candidate name reflect a single gender with at least a 97% probability. Candidate names that do not meet this threshold are left unclassified (Toole et al. 2019).

where women inventors were about 4.5 percentage points more likely than men to enter the patent system with these organizations.

Using PatEx, we obtain information on examiner and applicant-initiated interviews using the transaction data.[11] We identify the technology center to which each application was originally assigned using internal USPTO data from the Patent Application Locating and Monitoring (PALM) database.[12] We use an updated version of the Marco et al. (2019) patent claims data internal to the USPTO to identify both patent scope at grant and PGPub, measured by the length of the shortest independent claim (ICL) and the number of independent claims (ICC). For applications that have both a PGPub and were granted, we also extract the difference in ICL and ICC between these two points of examination (Grant minus PGPub), called ΔICL (difference in the shortest independent claim length) and ΔICC (difference in the independent claim count). These differences measure the degree to which patent scope changes over the course of patent examination (Marco et al. 2019).

Finally, for each application in the our sample, we extract three characteristics of the examiner assigned to the application: (1) the experience of the examiner, measured as the number of days between the examiner's start date and the first action date of the application, (2) the examiner's expected output adjustment as determined by seniority (called a position factor) and (3), the examiner's historical grant rate, calculated as the fraction of the examiner's pre-RCT disposed applications that resulted in an allowance. The examiner's start date and position factor were obtained from internal USPTO data, and the historical examiner allowance rate was computed from all of the applications assigned to each examiner in the PatEx dataset (Graham et al. 2018).

Summary Statistics – Summary statistics for all applications where at least one of the inventors has a gender attribution are presented in Table 2. Of the 2,361 applications in the RCT sample with a final disposal (either an abandonment or grant), 52.1 percent of applications were treated, 40.2 percent of applications were granted, 18.1 percent of applications include at least 1 woman inventor, and the average prior inventor experience was 7.5 applications. The RCT sample

[11] Specifically, we record the instance of an examiner-initiated interview if any one of the transaction codes "MEXIE", "MEXET", "MEXEP" appear in the applications transactions history, and an applicant-initiated interview if "MEXIA", "MEXAT" or "MEXAP" appears.

[12] We need the initial technology centers to identify the groups within which the randomization was conducted. Although not an issue for control applications, the PSPEU resided in Technology Center 3600, so the technology center in PatEx (i.e., the most recent technology center) is not necessarily the initial technology center assigned to the applications in the treatment.

grant rate is significantly less than the non-continuation USPTO average of 55.8 percent for all entity types (Carley et al. 2015). The ΔICL and ΔICC variables show that, for granted patents with a PGPub, 86 words on average were added to the shortest independent claim and nearly half an independent claim was removed during examination, demonstrating a significant narrowing of patent scope during examination.

Balance – Patent applications in the RCT sample were assigned to the treatment and control groups using randomization within the initial technology centers of the applications (i.e., stratified randomization). To verify this randomization empirically, we test various pre-treatment assignment characteristics for both mean and distributional differences across the treatment and control groups. The set of application-level variables include filing date, team size, the share of inventors that are from the U.S., independent claim length and count recorded at PGPub, an indicator for at least one woman inventor associated with the application, the proportion of women inventors and average inventor experience. We implement a two-sided two sample t-test and the Kolmogorov–Smirnov test for each of the aforementioned variables and find that, across each tested variable at the ten percent level, that there is neither a statistically significant difference in means nor a statistical difference in distributions between the treatment and control groups. The t-test results are contained in Table 2 and the Kolmogorov–Smirnov tests are available upon request.

4 Empirical Methodology

We estimate the impact of the intervention on the probability of receiving a patent using the following linear probability model that controls for the technology center-by-RCT round stratification groups (i.e., the groups within which the applications were randomly assigned):

$$patent_a = \nu \cdot treatment_a + \delta \cdot Gender_i + \zeta \cdot Gender_i \cdot treatment_a + \beta \cdot X_{ai} + \gamma_k + \epsilon_{ai} \quad (1)$$

where a indexes the application, i indexes the inventor and $patent_a$ is a binary variable for whether application a was granted. The binary variable $treatment_a$ is equal to 1 if application a was treated and zero otherwise, and $Gender_i$ is the gender of inventor i, equal to one if the inventor is a woman and zero if the inventor is a man. The vector of application and inventor level characteristics X_{ai}

includes inventor experience and team size, depending on the precise specification being estimated, and γ_k represents technology center-by-RCT round fixed effects.[13] The coefficient of interest, ζ, measures the heterogeneous average treatment effect for women. We cluster standard errors at the application level since inventor-application observations were assigned to the treatment at the level of the application (Abadie et al. 2017).

In addition to the overall patent application grant decision (either abandonment or grant), we investigate how the treatment affects the scope of granted patents. We estimate the following model using ordinary least squares:

$$Scope_{ai} = \phi \cdot treatment_a + \rho \cdot Gender_i + \pi \cdot Gender_i \cdot treatment_a + \alpha \cdot X_{ai} + \gamma_k + \epsilon_{ai} \qquad (2)$$

where all the covariates are the same as Equation 1 above, but the set of dependent variables $Scope_{ai}$ include the scope at grant (ICL and ICC). In this specification, we include initial patent scope in X_{ai} so that the treatment identifies the degree of change in final patent scope, conditional on incoming patent scope. Broader patents, all else equal, are more valuable (Lerner 1994), implying that differing degrees of scope narrowing during patent examination would result in patents that are substantively different on average between the two groups. If the estimated values of $\hat{\phi}$ or $\hat{\pi}$ are statistically significant, then treatment affects patenting outcomes through additional channels other than just the probability of grant.

5 Results

Table 4 presents our results from estimating Equation (1) with ordinary least squares. We focus on the estimated coefficient on $Gender_i \cdot treatment_a$, $\hat{\zeta}$, which captures the effect of treatment on patenting outcomes for women inventors relative to men. Our baseline estimate of ζ in Column (1) shows that the PSPEU increased the probability of receiving a patent by 11.1 percentage points for women inventors relative to men. In Column (2), we add technology-by-RCT round fixed effects, which are included in all the remaining columns, and, in Column (3), we also include additional application- and inventor-level controls. Our estimate for ζ across these models is very

[13] Additional pre-treatment assignment characteristics are included to potentially increase the precision of the ATEs (Imbens and Rubin 2015).

stable, ranging from 10.7 to 11.3 percentage points. Relative to the unconditional mean grant rate of 37 percent in the control and using the estimate from Column (2), the intervention increased the probability of receiving a patent by 28.9 percent for women inventors relative to men in the treatment. To demonstrate the entire ATE for women, using the estimates from column (2), women in the treatment group were 16.8 percentage points more likely to receive a patent than women inventors in the control. Relative to the unconditional mean in the control, this is a 45.4 percent increase in the patent grant rate. These results demonstrate that the increase in the grant rate for women pro se inventors, relative to men, was not only statistically significant but also large in magnitude.

Column (4) restricts the sample to U.S. inventors, and Column (5) limits to *first-time* U.S. inventors (i.e., inventors located in the U.S. where the application is their first). The estimated heterogeneous gender ATEs are substantially larger than the estimates from the overall sample, at 15.1 percentage points for women U.S. inventors relative to men, and 17.7 percentage points for new women U.S. inventors. Interestingly, as the gender gap in the control group gets larger, the heterogeneous ATE for women relative to men also gets larger and increases in statistical significance. In the U.S. inventor sample (Column 4), women U.S. inventors in the control were 6.13 percent less likely to receive a patent than men inventors in the control (significant at the 10 percent level) and the heterogeneous ATE is larger than the overall sample, at 15.1 percent. Foreign filers of patent applications in the U.S. may have more valuable inventions, as evidenced by their ability to file patent applications abroad (Putnam 1996; Lanjouw et al. 1998), potentially explaining this result. Additionally, the gender attribution algorithm is more accurate for U.S. inventors (Toole et al. 2019), potentially revealing differences between men and women that are less identifiable when also considering foreign applicants. A third explanation is that the difference in the gender gap we observe between U.S. and foreign inventors could reflect underlying differences in institutions, labor markets, industrial structure or other factors across countries (Frietsch et al. 2009).

Beyond U.S. inventors, the largest heterogeneous ATE is in the *new* U.S. inventor sample (at 17.7 percentage points), where the difference between men and women in the control is also the largest, at 13.3 percentage points (significant at the 1 percent level).

In the remaining columns, we assess the consistency of our results with two application level measures of women's participation on inventor teams: the proportion of women listed on the patent application and a binary indicator equal to one if there is at least one woman inventor listed on the application (Columns 6 and 7 of Table 4, respectively). The application-level analysis is consistent with the inventor level analysis in Columns (1) - (5). Consistent with our earlier findings, increasing the share of women on the inventor team (from an all-man team to an all-woman team) increases the impact of the PSPEU by 10.1 percentage points, and inventor teams with at least one woman inventor were 9.24 percentage points more likely to receive a patent than all-man teams in the treatment. Overall, the results in Table 4 demonstrate that the intervention increased the grant rate for women relative to men, with larger effects in areas where women had the worst relative outcomes (U.S. inventors and new U.S. inventors).

Next, we explore the possibility of differences in heterogeneous gender ATEs across technologies. In Table 5, we re-estimate Equation 1 separately for each USPTO technology center (definitions of the technology centers are available in Table 1). Although the data becomes somewhat sparse for certain TCs (ranging from 173 observations for TC 2100 to 1,016 observations for TC 3700), we find that the relative patenting rate for women versus men inventors in the control group varies significantly across technology centers. The largest gender gap exists in TCs 2100 (Computer Architecture Software and Information Security) and 2600 (Communications), where women in the control group are 31 and 20 percentage points less likely to receive a patent than men inventors in the control group, respectively. On the other hand, women are 24 percentage points *more* likely to receive a patent in TC 1700 (Chemical and Materials Engineering) than men in the control group.[14]

Similar to our earlier findings that the largest heterogeneous ATEs were in areas where women had the worst relative outcomes in the control (specifically, for U.S. inventors and new U.S. inventors), the impact of the intervention for women relative to men was generally larger in TCs with the largest gender gap in the control group. We find a heterogeneous ATE of 33 percentage points in TC 2100 (with a 30.8 percentage point gender gap in the control) and 39.8 in TC 2400 (with a

[14] Although this is an interesting finding, we interpret the TC 1700 results with caution since the control group for TC 1700 appears to be substantially different from the other TC control groups. Most significantly, the grant rate for the TC 1700 control was 74 percent, which is likely due to sampling error. We note that this grant rate is not only far higher than the other TC control groups in our sample, but also larger than the broader TC 1700 allowance rate that includes non-pro se applications (e.g., the allowance rates for the other pro se control groups, by TC, are far less than their broader allowance rates). This discrepancy likely explains the negative and statistically significant overall ATE in TC 1700, although this result is not robust. For example, removing one USPC (USPC 428, with 19 observations) that was randomly imbalanced between the treatment and control makes the overall ATE statistically insignificant (p-value of 14 percent).

20.4 percentage point gender gap). With the exception of TC 1700, the other TC gender gaps in the control were indistinguishable from zero, although we do find a positive heterogeneous ATE in TC 3600, at 29.1 percentage points. Finally, it's notable that almost all the heterogeneous average treatment effects are positive, just not always statistically significant.

Table 6 shows our estimates for the impact of the intervention on patent scope. These regressions only include granted patents and explore whether the treatment resulted in patents that were fundamentally different than the control patents. Columns (1) and (2) examine the independent claim count (ICC) and the length of the shortest independent claim (ICL), respectively. Importantly, we do not find that the patents granted to men and women in the treatment group were broader on average, relative to the control group. These results imply that the PSPEU increased the probability of receiving a patent without lowering one dimension of patent quality.

6 Extensions

6.1 Identifying the treatment mechanism

Given the design of the PSPEU, there are at least two channels through which the intervention could have affected patent application outcomes: (1) the training provided to PSPEU examiners that focused on the use of clear and effective communication during patent examination, and (2), the characteristics of the examiners hired for the pilot. From the perspective of (2), an important feature of the program was that the PSPEU examiners were more experienced than the average examiner in the control group. For this reason, it's plausible that their overall ability and production incentives (which vary by seniority) could drive at least a portion of the impact we observe from the intervention.

Previous research on the relationship between patent examination and patent quality has argued that more experienced and senior examiners conduct lower quality patent examination, for example, because of misaligned patent examination incentives, including "binding time constraints" (Lemley and Sampat 2012; Frakes and Wasserman 2017). However, more recent research has cast doubt on this theory, arguing that existing literature fails to account for institutional procedures and statistical issues, leading to inaccurate conclusions about the relationship between examiner experience, seniority, and patent quality (deGrazia et al. 2021). deGrazia et al. (2021) argues that higher allowance rates by more senior and more experienced examiners reflects more efficient, not lower quality, examination.

Regardless of this argument, it is possible that the higher allowance rates observed in the PSPEU treatment could reflect the assignment of examiners to the PSPEU rather than the training that emphasized better examination assistance. To explore this further, we add three controls to X_{ai} in Equation 1: (1) the experience of the patent examiner, measured as the number of days between the first action of the application and the examiner's start date, (2) the examiner's expected output adjustment as determined by seniority (called a position factor), and (3), the historical examiner allowance rate, computed as the fraction of the examiner's pre-RCT disposed applications that resulted in an allowance.[15]

The results are contained in Table 7. In Column (1), examiner experience enters Equation 1 linearly. The heterogeneous treatment effect for women relative to men is 11.6 percentage points (statistically significant at the 5 percent level), which is very similar to our main results. The estimate for examiner experience is positive (statistically significant at the 5 percent level), consistent with prior literature. When controlling for the examiner's position factor in Column (2), the heterogeneous treatment effect does not change. In Column (3), the examiner's historical grant rate is added linearly to the model. The gender treatment effect decreases slightly to 9.9 percentage points, but is still statistically significant at the 5 percent level. The estimate for the examiner's grant rate is also positive and statistically significant. Columns (4) and (5) discretize examiner experience and the grant rate by year and decile, respectively. The estimates for the heterogeneous ATEs are similar to the estimates in Columns (1) - (3). These results suggest that the differential impact on grant rates for women applicants relative to men in the PSPEU were not driven by a greater propensity to issue patent applications by the specific examiners assigned to the treatment, or greater experience and seniority of the PSPEU examiners.

After excluding the possibility of examiner characteristic effects, it is clear that our results are driven primarily by the examiner behaviors encouraged by the training given to PSPEU examiners. One potentially important factor is the use of interviews, which allow the examiner to meet in

[15] Position factors determine how much output the examiner is expected to produce, and increase with seniority (the examiner's position on the GS scale). We use the position factor rather than grade because all examiners in the PSPEU were awarded GS-15 upon entering the art unit, although their expected production did not change (remaining at the GS-14 level).

real-time with the applicant (either in person, over the phone or virtually) to explain legal aspects of the patent examination process or provide more insight into the issues identified in the patent application. Column (6) in Table 7 explores the treatment effect on the probability of an interview during patent examination. The overall treatment effect is about 5 percentage points, and does not differ between men and women inventors. Relative to the unconditional mean in the control of 23.5 percent, inventors in the treatment group were 20.6 percent more likely to have an interview with the examiner. Column (7) explores the impact on examiner-initiated interviews, and Column (8) on applicant-initiated interviews. Both coefficients are positive and statistically significant, representing increases of 2.3 and 4.1 percentage points for examiner- and applicant-initiated interviews, respectively. Since examiner-initiated interviews are relatively rare in the control (at only 1.8 percent of the control observations), an increase of 2.31 percentage points in the treatment is a 128 percent increase. An increase of 4.1 percentage points for applicant-initiated interviews in the treatment represents a 18.1 percent increase in applicant interviews relative to the control.

Although less direct than the increase in examiner interviews in the treatment, applicant-initiated interviews could have increased in response to encouragement by the examiner through better written (e.g, Office actions) or oral communication (e.g., previous examiner interviews). In fact, as noted earlier, many of the non-final rejections in the PSPEU encouraged applicants at the beginning of the correspondence to contact the examiner directly with questions before formally submitting their amendment. For example, the non-final rejection for application 14,309,812 states at the beginning of the Office action "The USPTO recognizes that applicant is representing himself before the USPTO as a "Pro Se Inventor." Applicant is encouraged to speak directly to the examiner whose contact information will be given at the end of this Office action for any help or assistance needed during examination of the application." The data supports this view. Only 13 applications in our sample (0.51 percent) had applicant-initiated interviews before the first action, while 608 applications (24 percent) had them after, implying that applicants request interviews almost entirely after receiving initial feedback from the examiner on the first Office action. Online Appendix table A27 shows our estimates for applicant interviews initiated before and after the first Office action, separately, and shows that almost all of the average treatment effect is driven by interviews initiated after the first official correspondence between the applicant and examiner (i.e., the first Office action).[16] In addition, we proxy for an examiner's encouragement (e.g., by encouraging applicants to request interviews, submit certain forms, or amend certain aspects of the application) by identifying the use of the word "encourage" in first Office actions (as seen in "applicant is encouraged to speak directly to the examiner" from our example). The inclusion of such language is both highly correlated with the use of applicant interviews and is significantly more likely to be used in first Office actions in the treatment group. Office actions that contained the word "encourage" were 4.78 percentage points more likely to have an applicant-initiated interview (statistically significant at the 5 percent level), and Office actions from treated applications were 22.2 percentage points more likely to use the word "encourage" (statistically significant at the 1 percent level) (results contained in Online Appendix Table A28).

Our results show that clear and effective communication, as emphasized in the training provided to PSPEU examiners, was an important channel through which applicants benefited from the intervention. Importantly, the heterogeneous treatment effect is not driven by women applicants disproportionately using interviews at the USPTO, rather women responding more favorably to their use.[17]

6.2 USPTO survey of applicants

A survey of applicants in the treatment and control groups conducted by the USPTO in April 2016 supports our finding that the PSPEU improved the examination experiences of pro se applicants. The 262 respondents in the treatment group and 283 from the control represent a 17.5 and 18.9 percent response rate, respectively. After conditioning on applicant experience level, treatment applicants were more satisfied with the patent application process than the control (56 percent of respondents in the treatment said they were "very satisfied" or "satisfied" vs. 49.3 percent in the control; statistically significant at the 10 percent level). The difference in satisfaction between the treatment and control groups was almost entirely driven by first-time applicants (55.1 percent vs. 41 percent; statistically significant at the 5 percent level), consistent with our finding of larger average treatment effects for first-time U.S. inventors in Table 4. Although not statistically significant

[16]The Online Appendix is available upon request

[17]Other aspects of clear and effective communication that could explain the remainder of the treatment effect include the *quality* of interviews and Office actions. However, the quality of examiner communication is much more challenging to measure than the number of interviews and we are therefore unable to address it directly.

at the 10 percent level, respondents in the treatment group were more likely to understand all of the requirements of the examination process with assistance from their examiner (57.6 percent in the treatment vs. 52.5 percent in the control). While this survey evidence is susceptible to selection bias (differential response rates between the treatment and control on unobserved characteristics), overall, the responses are consistent with our empirical results showing the PSPEU benefited applicants, with some evidence that clear and effective communication was important during patent examination.

6.3 Generalizability to inventors associated with small and micro entities

The heterogeneous ATEs estimated using the PSPEU pertain directly to inventors that file patent applications without patent attorneys. However, additional examination assistance may also benefit the broader set of inventors associated with small and micro entities. Small entities are generally individuals, non-profit organizations, universities, or small businesses and micro entities are a subset of small entities that have stricter income requirements.[18] Inventors associated with these organizations, compared to those associated with large companies, may be less likely to have the complementary resources (both knowledge and financial) to successfully navigate the patent system, including high quality legal assistance.

Figure 2 shows that the share of first-time inventors that are associated with small and micro entities is large, generally increasing over time, and larger for women than men.[19] In 2018, the share for first-time women inventors was just over 50 percent, about 4.2 percentage points higher than new men inventors. There are several reasons why women may be disproportionately entering the patent system through small or micro entities. Previous literature has shown that the representation of women is higher in universities than the corporate sector (Toole et al. 2019; Delgado and Murray 2021), and university researchers likely file as small or micro entities (either as individuals or with universities). Additionally, the gender gap may be especially wide in the hierarchical settings of large firms, causing women to embrace academics or the entrepreneurial settings of small firms (Whittington and Smith-Doerr 2008).

According to survey evidence, legal fees associated with filing and prosecuting, amending, and

[18] See `https://www.uspto.gov/web/offices/pac/mpep/s509.html`

[19] A description of the data construction for this figure is provided in the appendix.

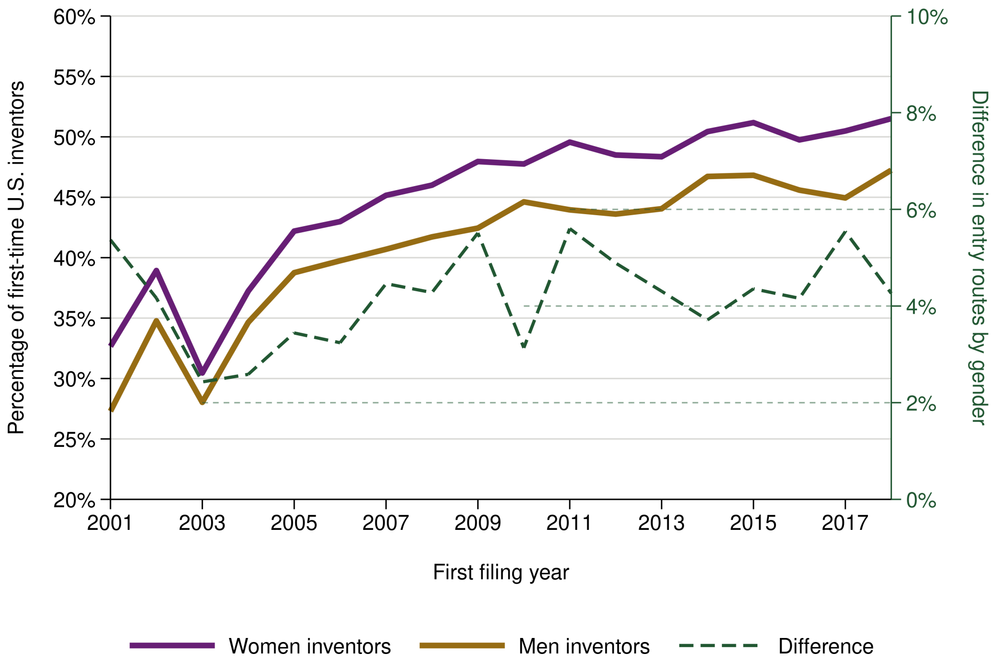

Figure 2: Percentage of first-time U.S. inventors entering the patent system with small or micro entities

appealing a patent application can cost up to $12,000, $4000, and $10,000, respectively (AIPLA 2017). Summary statistics Tables A21 and A22 in our Online Appendix demonstrate that resource constraints could force small and micro entities to hire attorneys who are less experienced. These attorneys have lower grant rates and are likely to draft patent applications that require more changes during patent examination (for example, by narrowing the scope of the claimed invention) than attorneys used by large entities. Our results suggest that additional examination assistance helps close the gender gap in patenting for the most resource constrained inventors (i.e., pro se inventors), but to what degree does this finding generalize to applicants associated with small and micro entities?

To explore this issue, we leverage a sample of nearly two million utility and non-continuation patent application-inventor pairs associated with small and micro entities published between 2005 to 2020.[20] Using this sample, we estimate the gender patenting gap using the following linear

[20]The sample construction was similar to the process described earlier for the RCT sample. More information, including summary statistics are provided in the Online Appendix.

probability model:

$$patent_{ai} = \psi \cdot Gender_i + \tau \cdot X_{ai} + \gamma_t + \gamma_k + \epsilon_{at} \tag{3}$$

where $Gender_i$ is equal to 1 if inventor i is a woman and 0 if inventor i is a man. The vector X_{ai} is a set of application and inventor level covariates, including team size and inventor experience, and γ_t and γ_k represent first-action year and technology center fixed effects, respectively. The coefficient of interest is ψ, which captures the correlation between being a woman inventor and successfully obtaining a patent. If $\hat{\psi}$ is negative and significant, then women inventors are less likely to receive a patent than men inventors when associated with small and micro entities.

Our results are available in Columns (1)-(3) in Table 8 (Column 1 contains the baseline without additional fixed effects and covariates, Column 2 adds technology center and first action year fixed effects, and Column 3 adds inventor experience and team size) and show that for inventors associated with small and micro entities, women inventors are between 3.2 and 3.5 percentage points less likely to receive a patent than men inventors. Similar to the PSPEU estimates in Table 4, Columns (4) and (5) show that the gender gap increases for U.S. inventors, and further still for new U.S. inventors at 4.1 and 5.1 percentage points, respectively.

We found that additional examination assistance can help close the gender patenting gap for inventors with resource constraints, especially in areas where women had the worst relative outcomes (U.S. inventors, new U.S. inventors, and in certain technologies). Although not all inventors associated with small and micro entities file patent applications without attorneys, the quality of legal assistance for these firms, on average, is not as high as that available at larger firms. Better examination assistance could still help these applicants, especially women, but to a lesser extent than pro se applicants. We therefore take a conservative view on the generalizability of our RCT results to the broader sample of inventors associated with small and micro entities. The PSPEU heterogeneous ATEs across gender likely represent an upper bound for this broader group.

In addition, extending better examination assistance to all applications associated with small and micro entities could have a secondary effect on the gender patenting gap. Since women are especially likely to enter the patent system with these entities, providing additional examination assistance to the entire group could reduce the gender gap by helping first time women inventors stay in the patent system.

7 Additional considerations and robustness checks

7.1 Pro se Assistance Program

In addition to creating the Pro Se Pilot Examination Unit, the USPTO responded to the 2014 Presidential Executive Action Number Seven by creating the Pro Se Assistance Program (PSAP) within the USPTO's Office of Innovation Development (OID).[21] The PSAP provides assistance prior to application submission to *any* interested pro se applicants. OID recorded the number of inquires to the PSAP via calls, e-mails, and walk-ins, but unfortunately the office does not record any identifying information or link inquiries to specific pro se applications. This makes it challenging to identify the impact of the PSAP.

Importantly however, participation in PSAP was not considered in assignment to the treatment and control groups, but the program may have changed the incoming quality of the patent applications in the RCT. Earlier in Section 3.3, we tested for differences in application characteristics known at filing between the treatment and control groups, finding no significant differences. This test empirically verifies that participation in the PSAP, which may have increased pre-submission application quality, did not ultimately lead to any compositional differences in the treatment and control groups nor did it affect treatment assignment. Due to the absence of linkages between PSAP participation and application identifiers, we cannot determine what effect, if any, the PSAP had on our estimates. If the PSAP did not affect the quality of incoming applications, our ATE estimates are likely unaffected. If the PSAP did affect the quality of incoming applications, our estimated treatment effects (overall and across gender) would likely represent a *lower* bound for the effects of additional examination assistance on the probability of obtaining a patent, since some of the application issues known at filing would be remedied by the PSAP before reaching the PSPEU treatment or control groups. Regardless, as of the time of writing, the PSAP was still in operation, so any future intervention like the PSPEU could still be expected to produce similar results as those found in our analysis.

[21]See `https://www.uspto.gov/patents/basics/using-legal-services/pro-se-assistance-program?MURL=prosepatents`

7.2 Robustness checks

We assess the robustness of our results in several ways: by (1) exploring potential violations of the stable unit treatment value assumption (SUTVA), including direct and indirect spillovers between inventors in the treatment and control groups (Imbens and Rubin 2015; Glennerster and Takavarasha 2013), (2) assessing the quality of patent examination in the treatment relative to the control using first action decisions (deGrazia et al. 2021), (3) accounting for other examiner characteristics, beyond experience and seniority, and (4) using other parametric and non-parametric estimators and tests to assess the robustness of our estimated treatment effects. The robustness check tables are available in the Online Appendix.[22]

In the first robustness check, we explore potential violations of SUTVA, which states that the potential outcomes of each unit are not affected by the treatment assigned to the other units (Imbens and Rubin 2015). In our context, this could be violated if information flows (or, spillovers occur) between inventors on different applications in a way that relates to treatment assignment and potential outcomes. One way this could occur is if there are pro se inventors that are associated with applications in both the treatment and control groups. For these inventors, having a treated application may affect how they proceed with the control application. We may observe inventors with applications in the treatment and the control for at least two reasons: (1) the inventor actually had applications in both groups, or (2), the inventor disambiguation algorithm incorrectly grouped inventors together when they should have been distinct inventors (for example, disambiguation algorithms have difficulty grouping names of Asian-origin (Li et al. 2014; Yin et al. 2020). Examining the 6.9 percent of RCT inventor-by-application observations that have inventors in both groups reveals that both reasons are potentially relevant for our sample. Regardless, analyzing the sample of inventors that are in either the treatment or control, not both, provides information on the relevance of spillovers from treated applications to control applications through the same inventors, even though some of these inventors are incorrectly excluded because of disambiguation errors.

Tables A9-A12 re-estimate our models on the sample of inventors that are either in the treat-

[22] In addition to the robustness checks described here, Online Appendix Tables A1-A8 and A16 also show that our results are consistent when using both probit and logit models. Tables A1-A8 give the estimated coefficients and Table A17 compares the non-linear average partial effects to the linear model estimates.

ment or control, not both. The estimates are generally similar in sign, statistical significance and economic magnitude to our main results. The one exception is that the gender gap in the control group is generally more negative and statistically significant in the spillover sample that excludes inventors with applications in both the treatment and control, although this is consistent with the fact that some of the inventors were removed because of disambiguation errors in foreign names, and we find that the gender gap is larger for U.S. based inventors.

A second way spillovers might occur is through peer effects. Even though we have already excluded inventors with applications in both the treatment and control, there is still the potential for spillovers through peers on the same inventor teams. For example, an inventor with only a single application in the treatment group (and no applications in the control) may have a co-inventor with applications in both the treatment and control, or be indirectly associated with an inventor that has applications in both the treatment and control through their inventor network. To assess the impact of peer effects, we re-estimate our models on the sample of inventors from applications where each inventor has only a single application in the RCT sample (either in the treatment or control). This restriction ensures that co-inventors, and co-inventors of co-inventors etc., do not have applications in both the treatment and control groups. The results are in Online Appendix Tables A13-A16 and are consistent with our main results, providing further evidence that spillovers do not play a large role in our experiment.

Next, we assess the quality of patent examination using first action decisions. Researchers have used examiner allowance rates as a proxy for examiner quality (Lemley and Sampat 2012; Frakes and Wasserman 2017; deGrazia et al. 2021) under the assumption that if applications are randomly assigned, an examiner with a higher allowance rate could be issuing lower quality patents than an examiner with a lower allowance rate. deGrazia et al. (2021) show that for a variety of institutional and statistical reasons, only the first-action allowance rate without examiner's amendments that occur before the first action (called the "modified first action allowance rate" in Online Appendix table A18) is an appropriate proxy for examination quality.[23] Our results, in Table A18, do not indicate that PSPEU examiners were more likely to issue first action allowance decisions without

[23]Examiner's amendments are a way for the patent examiner to suggest changes to the application without the use of a formal Office action rejection. Applications allowed on the first action without an examiner's amendment are very likely to not have any examiner induced changes. Under random assignment, allowing more applications on the first action without examiner's amendments is more likely to indicate lower quality examination than looking at the final application outcome. See deGrazia et al. (2021) for more information.

examiner's amendments (including heterogeneous treatment effects), indicating that the quality of granted patents in the PSPEU was not lower than the control. In fact, we find some evidence, albeit marginal, that examination quality may have been higher in the PSPEU relative to the control (see Columns (2) and (3) in Table A18 for application-level results, although statistical significance is only at the 10 percent level).

An additional concern is that other examiner specific allowance tendencies, like examiner-applicant homophily, may be driving our results (Murray et al. 2021). As a third robustness check, we account for each examiner's pre-RCT tendency to issue patents to all men teams relative to teams with at least one woman.[24] Although the PSPEU examiners were not selected for their propensity to better assist inventors of one gender over the other, we control for the difference in each examiner's pre-RCT tendency to grant patents to all men teams relative to teams with at least one woman to ensure that this does not drive the heterogeneous treatment effects observed in the PSPEU (specifically, the historical grant rate for all men teams less the grant rate for teams with at least one woman). In Table A19, we find no difference in the heterogeneous treatment effect across gender when controlling for the grant rate difference between men and women alone (Column 1), and including a gender interaction effect (Column 2), as well as when also including the overall pre-RCT examiner grant rate (Column 3).

In addition to experience, PSPEU examiners could have been hired for their demonstrated ability to clearly and effectively communicate with pro se applicants during patent examination. This implies that the average treatment effects could be explained by this characteristic of the examiners themselves, rather than the training provided by the program. To address this concern, we explore whether the examiner's pre-RCT grant rate for *pro se* applications explains the heterogeneous treatment effects. The regression results, displayed in Table A20, show that the heterogeneous gender ATE remains large, and statistically significant when controlling for examiner pre-RCT pro se allowance rates. Overall, this result, combined with our analysis of potential homophily between examiners and applicants, strengthens our conclusion that the heterogeneous treatment effects observed in the PSPEU were driven by clear and effective communication, rather than the selection of examiners into the PSPEU.

[24] The examiner's pre-RCT allowance rate by inventor gender captures both homophily effects and any other gender-based allowance tendencies.

In the final set of analyses, we explore the robustness of our estimated ATEs to other parametric and semi-parametric estimators and non-parametric statistical tests. First, under stratified randomization, linear regression models with strata fixed effects for ATEs (like our Equation 1, except without the gender specific treatment effect) produce consistent estimates of population ATEs if (1), the probability of treatment is 50 percent within each strata, or (2), ATEs are homogeneous across strata (Imbens and Rubin 2015). If neither of these conditions are true, a consistent estimate of the ATE can be obtained by including weighted treatment interactions for each strata, as in the following:

$$Y_{ai} = \nu \cdot W_i \cdot \frac{B_i(J)}{N(J)/N} + \sum_{j=1}^{J} \beta_j B_i(j) + \sum_{j=1}^{J-1} \gamma(j) \cdot W_i \left(B_i(j) - B_i(J) \cdot \frac{N(j)}{N(J)} \right) + \epsilon_{at} \tag{4}$$

where a is for application, i is for inventor, $B_i(j)$ is an indicator for whether inventor-application observation i is in strata j, W_i represents the treatment indicator, $N(j)$ represents the number of inventor-application observations in strata j, N is the number of inventor-application observations across treatment and control groups, and Y is a binary indicator equal to one if the patent application is granted, zero otherwise. Similar to Equation 1 above, we define strata as Technology Center-by-RCT round.

In our sample, applications were divided between the treatment and control within each TC by RCT round with approximately 50 percent probability. However, the final distribution between the treatment and control is not precisely balanced at 50 percent within each TC-round for a few reasons, including (1) that after treatment assignment, applications were manually evaluated to make sure the applications were in fact pro se, (2) our primary analysis was at the inventor level, so random variation in team size could result in treatment imbalance, and (3), we drop inventor observations with an unknown gender attribution. Since treatment assignment within strata may deviate slightly from perfect 50 percent balance, we expect that estimates from a modified Equation 1 (without the $Gender_i \cdot treatment_a$ term) and Equation 4 should produce very similar but perhaps not identical ATE estimates. Table A23 in the Online Appendix provides the estimates from both regression specifications on three samples: (1) all inventor-application observations, (2) women inventor-application observations and (3), men inventor-application observations. Overall, the estimated coefficients are indistinguishable, indicating either minimal heterogeneity or more likely, treatment probabilities that are close enough to 50 percent within each TC by RCT round strata.

Next, we assess the robustness of our ATE estimates by using the inverse probability weight (IPW) semi-parametric estimator (Wooldridge 2010). The IPW estimator is consistent for the population ATE under unconfoundedness and overlap provided that the functional form for the treatment probabilities is properly specified. Since our sample was created using stratified randomization, either probit or logit will produce the correct treatment probabilities within strata, ensuring that the IPW estimator is consistent. Table A24 in the Online Appendix provides the IPW estimates on three samples: (1) all inventor-application observations, (2) women inventor-application observations and (3), men inventor-application observations. Overall, the results are generally consistent with the estimates we obtained using equation 1, where the IPW estimate for men inventors is 5.81 percentage points (relative to 6 percentage points from our main estimates), and 16.1 percentage points for women inventors (relative to 16.77 percentage points from our main estimates).

Finally, we assess the robustness of the statistical significance of our ATE estimates using non-parametric methods. Specifically, we implement Fisher's Exact P-value method (Fisher 1935) for stratified random experiments to test the sharp null that, for each observation, the treatment effect is zero (i.e., $H_0 : \tau_i = 0 \; \forall i$ and $H_1 : \tau_i \neq 0$ for at least one i). We use the following test statistic (Imbens and Rubin 2015):

$$T = \left| \sum_{s} \frac{N(j)}{N} \left(\bar{Y}_t(s) - \bar{Y}_c(s) \right) \right| \tag{5}$$

where j is for strata, N is the number of application observations in the sample, $N(j)$ is the number of applications in strata j, $\bar{Y}_t(j)$ is the mean in the treatment across application observations within strata j, and $\bar{Y}_c(j)$ is the mean in the control across applications within strata j. This test statistic is the absolute value of the weighted average strata differences in mean treatment and mean control outcomes (weighted by strata shares). We randomly simulate 1000 statistics under the null hypothesis. The results are contained in Table A25 in the Online Appendix, and for each sample (all applications, applications with at least one woman, and applications with all men inventors) we are able to confidently reject the null hypothesis that all treatment effects are zero (with p-values ranging from a low of .001 to a high of .004).

8 Conclusion

The gender patenting gap is closing over time, but is not closing quickly. Narrowing the gap could not only raise the rate of invention but also redirect inventive resources toward technologies that might be especially beneficial to women. The difficult aspect for policy is that very little causal evidence is available on the impact of current interventions, or potential alternatives.

In response to the America Invents Act of 2011 and Presidential Executive Action Number Seven, the USPTO established the Pro Se Pilot Examination Unit to better assist patent applicants that pursue patent protection without legal representation. The PSPEU was designed as a randomized control trial, allowing for the causal identification of the impact of increased examination assistance on patent application outcomes. Although the program wasn't specifically designed to help women, we find that the PSPEU increased the patent grant rate for women by 11 percentage points relative to men. Further, the benefit of the treatment for women was greatest in areas where they had the worst relative outcomes, including for U.S. inventors, new U.S. inventors and in certain technologies.

The success of the PSPEU in helping close the gender patenting gap is highly encouraging, especially since women are increasingly likely to file patent applications without the institutional support of large companies. These inventors are less likely to have the quality legal assistance that is crucial for navigating the complexities of the patent system, and better assistance at the USPTO could significantly improve their outcomes. Future research should explore the impact of additional guidance and information for this larger group of inventors (i.e., small and micro entity applicants), using quasi-experimental, and experimental evidence if available.

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9 Tables

Technology Center	Definition
TC 1700	Chemical and Materials Engineering
TC 2100	Computer Architecture, Software and Information Security
TC 2400	Computer Networks, Multiplex, Cable and Cryptography/Security
TC 2600	Communications
TC 2800	Semiconductors, Electrical and Optical Systems and Components
TC 3600	Transportation, Electronic Commerce, Construction and Agriculture
TC 3700	Mechanical Engineering, Manufacturing and Products

Table 1: Technology center definitions

VARIABLES	(1) N	(2) mean	(3) sd	(4) min	(5) max
Treated	2,361	0.521	0.500	0	1
Patent grant	2,361	0.402	0.490	0	1
Ind. Claim Count (ICC - Grant)	948	1.938	1.342	1	20
Ind. Claim Length (ICL - Grant)	948	225.6	162.1	8	1,500
Ind. Claim Count (ICC - PGPub)	2,187	2.392	2.738	0	53
Ind. Claim Length (ICL - PGPub)	2,178	121.1	139.1	4	2,180
ΔICC ($ICC_{GRANT} - ICC_{PGPUB}$)	774	-0.463	2.175	-23	17
ΔICL ($ICL_{GRANT} - ICL_{PGPUB}$)	771	85.96	133.7	-1,047	1,001
Team size	2,361	1.339	0.736	1	7
At least one woman	2,361	0.181	0.385	0	1
Proportion of women	2,361	0.147	0.333	0	1
Inventor experience (prior applications)	2,361	7.499	18.11	0	239
U.S. inventor	2,361	0.759	0.424	0	1

Table 2: RCT sample - Summary statistics

	Treatment			Control			Difference	
	count	mean	sd	count	mean	sd	b	t
Filing date	1131	19763.31	249.77	1230	19761.14	250.39	2.16	(0.21)
Team size	1131	1.32	0.72	1230	1.36	0.75	-0.03	(-1.14)
US inventor	1131	0.75	0.43	1230	0.77	0.42	-0.02	(-1.27)
Inc. scope (ICC)	1051	2.39	2.79	1136	2.40	2.69	-0.01	(-0.06)
Inc. scope (ICL)	1047	122.98	152.55	1131	119.37	125.34	3.60	(0.60)
At least one woman	1131	0.18	0.38	1230	0.19	0.39	-0.01	(-0.70)
Proportion of women	1131	0.14	0.33	1230	0.15	0.34	-0.01	(-0.73)
Inventor exp.	1131	7.33	16.52	1230	7.65	19.47	-0.32	(-0.44)

Table 3: Pro Se Pilot - Summary Statistics By Group

VARIABLES	(1) Baseline	(2) TC/ROUND FE	(3) Addl. Covar.	(4) US Inventor	(5) New US Inventor	(6) Prop. WI	(7) At Least 1 WI
Treated	0.0619***	0.0607***	0.0594**	0.0463*	0.0575	0.0632***	0.0614***
	(0.0240)	(0.0235)	(0.0234)	(0.0269)	(0.0403)	(0.0218)	(0.0220)
Woman inv.	-0.0218	-0.0277	-0.0374	-0.0633*	-0.133***		
	(0.0361)	(0.0339)	(0.0339)	(0.0374)	(0.0460)		
Treated x Woman inv.	0.111**	0.107**	0.113**	0.151***	0.177**		
	(0.0504)	(0.0486)	(0.0482)	(0.0550)	(0.0731)		
Inventor exp.			0.00151***				
			(0.000445)				
Team size			0.0223				
			(0.0143)				
Proportion of women						-0.0238	
						(0.0416)	
Treated x Proportion of women						0.101*	
						(0.0594)	
At least one woman							-0.00597
							(0.0361)
Treated x At least one woman							0.0924*
							(0.0512)
Mean of dep. var. in control	0.37	0.37	0.37	0.374	0.276	0.36	0.36
Observations	3,062	3,062	3,062	2,308	955	2,361	2,361
TC/ROUND FE	NO	YES	YES	YES	YES	YES	YES
Obs.-Level	Inventor	Inventor	Inventor	Inventor	Inventor	Application	Application

Significant at *** p<0.01, ** p<0.05, * p<0.10. Standard errors for the inventor observation regressions (Columns (1)-(5)) are clustered at the application number level and are heteroskedasticity robust for the application observation regressions (Columns (6) and (7)). TC is for technology center, with definitions provided in Table 1 and ROUND is for RCT round. Inventor experience is the number of previously filed patent applications for the focal inventor and team size is the number of inventors on the patent application team. The proportion of women is the share of women on the patenting team and at least one woman is a binary variable that is equal to one if there is at least one woman on the patent application team. New U.S. inventors are inventors in the U.S. where the focal application is their first patent application.

Table 4: Pro Se Pilot - Probability of Patent Grant

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
VARIABLES	TC 1700	TC 2100	TC 2400	TC 2600	TC 2800	TC 3600	TC 3700
Treated	-0.200**	0.229**	0.274***	-0.00110	0.0127	0.00757	0.106***
	(0.0993)	(0.0908)	(0.0885)	(0.0827)	(0.0594)	(0.0456)	(0.0407)
Woman inv.	0.241***	-0.308***	0.0222	-0.204*	0.0123	-0.0531	-0.0782
	(0.0837)	(0.0747)	(0.169)	(0.115)	(0.0940)	(0.0669)	(0.0552)
Treated x Woman inv.	-0.118	0.330*	0.0729	0.398**	0.143	0.291***	0.0301
	(0.131)	(0.172)	(0.214)	(0.164)	(0.128)	(0.106)	(0.0805)
Mean of dep. var. in control	0.735	0.22	0.269	0.427	0.518	0.284	0.304
Observations	233	173	231	257	512	640	1,016
ROUND FE	YES	YES	YES	YES	YES	YES	YES
TC/ROUND FE	NO	NO	NO	NO	NO	NO	NO

Significant at *** p<0.01, ** p<0.05, * p<0.10. Clustered standard errors at the application number level are provided in parentheses. TC is for technology center, with definitions provided in Table 1 and ROUND is for RCT round. Each regression is at the inventor-application observation level. The models include RCT round fixed effects to control for the groups within which the randomization was conducted.

Table 5: Pro Se Pilot - Probability of Patent Grant By Technology Center.

VARIABLES	(1) Grant ICC	(2) Grant ICL
Treated	-0.165*	-6.078
	(0.0989)	(11.28)
Woman inv.	0.354	1.029
	(0.297)	(15.35)
Treated x Woman inv.	-0.276	3.107
	(0.310)	(22.07)
PGPub Ind. claim count (ICC)	0.168***	5.275***
	(0.0390)	(1.919)
PGPub Ind. claim length (ICL)	-0.000108	0.739***
	(0.000264)	(0.0732)
Mean of dep. var. in control	2.016	223.9
Observations	1,057	1,057
TC/ROUND	YES	YES
Obs.-Level	Inventor	Inventor

Significant at *** p<0.01, ** p<0.05, * p<0.10. Clustered standard errors at the application number level are provided in parentheses. TC is for technology center and ROUND is for RCT round. PGPub is pre-grant publication. Each regression is at the inventor-application observation level.

Table 6: Pro Se Pilot - Scope Changes.

VARIABLES	(1) Exper.	(2) Position factor	(3) Grant rate	(4) Exper. FE	(5) Grant rate FE	(6) All interviews	(7) Examiner interviews	(8) Applicant interviews
Treated	0.0224	-0.00862	0.00827	0.0135	0.0101	0.0484**	0.0231***	0.0408**
	(0.0252)	(0.0291)	(0.0245)	(0.0311)	(0.0251)	(0.0209)	(0.00880)	(0.0204)
Woman inv.	-0.0321	-0.0325	-0.0226	-0.0357	-0.0223	0.0264	0.0124	0.0228
	(0.0335)	(0.0334)	(0.0344)	(0.0337)	(0.0344)	(0.0328)	(0.0119)	(0.0324)
Treated x Woman inv.	0.116**	0.112**	0.0992**	0.106**	0.0942*	-0.0356	-0.00349	-0.0346
	(0.0484)	(0.0483)	(0.0487)	(0.0480)	(0.0486)	(0.0450)	(0.0189)	(0.0441)
Examiner exp.	1.81e-05***							
	(5.11e-06)							
Historic ex. grant rate			0.462***					
			(0.0631)					
Mean of dep. var. in control	0.373	0.370	0.384	0.374	0.384	0.235	0.018	0.225
Observations	3,042	3,060	2,967	3,042	2,967	3,060	3,060	3,060
TC/ROUND	YES	YES	YES	YES	YES	YES	YES	YES
Ex. Exp FE	NO	NO	NO	YES	NO	NO	NO	NO
PF FE	NO	YES	NO	NO	NO	NO	NO	NO
Ex. Grant Rate FE	NO	NO	NO	NO	YES	NO	NO	NO
Obs.-Level	Inventor	Inventor	Inventor	Inventor	Inventor	Inventor	Inventor	Inventor

Significant at *** p<0.01, ** p<0.05, * p<0.10. Clustered standard errors at the application number level are provided in parentheses. TC is for technology center. ROUND is for RCT round and PF is for position factor. Examiner experience is the number of days between the examiner's start date and the first action date of the application. The historic examiner grant rate is the examiner's proportion of pre-RCT disposed applications that were allowed. Position factors are the adjustments applied to examiner expected outputs, and vary by seniority (along the GS scale). The examiner experience FE are at the year level and the historic grant rate FEs include 10 evenly spaced levels (i.e., deciles). Each regression is at the inventor-application observation level.

Table 7: Pro Se Pilot - Explaining the treatment.

VARIABLES	(1) Baseline	(2) TC/FAOM YR FE	(3) Addl. Covar.	(4) US Inv.	(5) New US Inv.	(6) Prop. WI	(7) At Least 1 WI
Woman inv.	-0.0341***	-0.0320***	-0.0352***	-0.0409***	-0.0514***		
	(0.00105)	(0.00103)	(0.00103)	(0.00148)	(0.00202)		
Inventor exp.			-6.14e-05***				
			(3.79e-06)				
Team size			0.0107***				
			(0.000166)				
Proportion of women						-0.0584***	
						(0.00173)	
At least one woman							-0.0222***
							(0.00123)
Mean of dep. var.	0.578	0.578	0.578	0.582	0.561	0.563	0.563
Observations	1,749,688	1,742,166	1,742,166	1,001,153	417,782	907,212	907,212
TC FE	NO	YES	YES	YES	YES	YES	YES
FAOM YR FE	NO	YES	YES	YES	YES	YES	YES
Obs.-Level	Inventor	Inventor	Inventor	Inventor	Inventor	Application	Application

Significant at *** p<0.01, ** p<0.05, * p<0.10. Heteroskedasticity robust standard errors are provided in parentheses. TC is technology center and FAOM YR is first action on the merits year. New U.S. inventors are inventors in the U.S. where the focal application is their first patent application. Inventor experience is the number of previously filed patent applications for the focal inventor and team size is the number of inventors on the patent application team. The proportion of women is the share of women on the patenting team and at least one woman is a binary variable that is equal to one if there is at least one woman on the patent application team.

Table 8: Small/Micro Entities - Probability of Patent Grant