Pre-analysis Plan for "Closing the Innovator-Inventor Gap: Evidence from Proactive (Opt-Out) Outreach"*

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ABSTRACT

Our proposed field experiment will investigate the influence that proactive outreach has on STEM professionals' engagement with the invention process at a collaborating high-tech firm. By randomly assigning those who have never submitted an inventive idea for patenting to treatment and control groups, we plan to examine how different framing (opt-in/opt-out) and highlighted factors (extrinsic rewards/intrinsic motives) influence engagement with the inventive process, which we will measure through participation rates in early stages of the process (e.g., attending a brainstorming event) and submitted inventive ideas. Then, we will evaluate whether opt-out framing reduces the innovator-inventor gap, the lower rate of participation in the invention process by innovators from underrepresented groups, as well as STEM professionals' self-identity as inventors and their perceptions of the firm's innovation culture. Overall, this study will provide experimental evidence on the effectiveness of such interventions in closing gaps within firms and will augment quasi-experimental evidence from natural experiments at four other collaborating firms, which provide evidence consistent with opt-out framing attenuating the innovator-inventor gap.

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Patentable inventions are a key driver of long-run economic growth and firm value (Aghion and Howitt, 1992; Farre-Mensa et al., 2019). In today's knowledge-based economies, firms need to rely even more on the creative ideas and breakthrough inventions of their employees to stay competitive (Jaravel, 2019; Kogan et al., 2020; Lerner and Seru, 2022) and to direct technological change (Koning et al., 2021; Koffi and Marx, 2023). However, research has shown that there are significant disparities in innovation participation and patenting rates across different demographic groups, particularly among engineers from underrepresented backgrounds (Bell et al., 2019; Kline et al., 2019; Aneja et al., 2024). In fact, while 96% of engineers identify as problem-solvers, only 46% see themselves as inventors, despite the similarities between these roles in identifying and solving issues innovatively (Chien and Grennan, 2024b). This discrepancy is consistent with a substantial "innovator-inventor" gap among STEM professionals, where relatively fewer engineers from underrepresented groups ("URGs[1]") transition to being named inventors on patents (Chien, 2024). Addressing these disparities is not only a matter of equity and fairness but also a critical imperative for firms seeking to maximize the productivity and efficiency of their diverse talent pool.

In this study, we aim to investigate the influence of proactive outreach to innovators on their participation in the invention process, focusing on understanding how changes in solicitation framing may shape who participates in the invention process. While previous research has demonstrated the power of default settings in shaping behavior in various settings, the potential for opt-out interventions like proactive outreach to have an equalizing effect across demographic groups has been understudied. The impact of framing on participation has broad relevance, given the myriad opportunities, such as prizes, jobs, college admissions promotions, awards, grants, and scholarships, that require individuals to opt into a competitive process. Thus, the study of proactive outreach – a relatively low-cost mechanism for "getting people off the bench" – in the invention context can potentially offer valuable insights for advancing economic inclusion and diversity more generally.

The empirical evidence on how framing effects play out in the context of innovation and patenting within firms is also limited and ambiguous. On the one hand, opt-out framing may nudge

[1] In the context of inventors, we use the term "URGs" to refer to individuals from historically, underrepresented groups. This includes individuals with an ethnicity that is not white or Asian and individuals who do not identify with the male gender.

engineers towards greater engagement in patenting activities by overcoming informational and psychological barriers to participation (Chien and Grennan, 2024b) and communicating an equal expectation of participation across the firm. On the other hand, engineers may be less susceptible to proactive outreach due to their analytical mindset, potentially rendering opt-out framing less effective. Resolving this empirical ambiguity is important for scholars and practitioners seeking evidence-based strategies to promote inclusive innovation and support the career advancement of underrepresented engineers.

To address this research question, we employ a multi-pronged empirical strategy. First, we analyze data from a set of natural experiments where some firms have plausibly exogenous variation in framing patenting activities as opt-in or opt-out. For instance, at one collaborating firm, the patent attorney used a proactive approach in which she reached out to all potential technical staff and tried to get them to submit ideas for the patenting process. Part of this process involved deliberately hanging out in breakrooms and trying to work with and encourage all potential inventors to submit their ideas. However, things changed considerably when the 2020 COVID pandemic hit. Workers were not in the office anymore, and the traditional opt-out strategy described above was no longer viable, forcing the firm to switch to an opt-in strategy.

Then, at three other collaborating firms we worked with, the patent attorneys used a hybrid model, soliciting some inventions through brainstorming sessions on which patent team members attended and allowing innovators to use the traditional opt-in methods. These natural experiments are beneficial because they provide quasi-experimental evidence on the link between opt-out framing and actual inventive outcomes at real firms rather than in the laboratories, thereby providing realistic evidence of how changes to framing may play out in the future. Yet the non-random assignment of firms to different framing conditions and the potential for confounding factors like changes in work-life balance for female innovators limit the causal interpretation of these findings.

To augment the natural experiments and provide a more rigorous test of the mechanism potentially underlying practice outreach, we propose a field experiment within a high-tech firm in Silicon Valley (List, 2007). In this field experiment, engineers are randomly assigned to either an opt-out or opt-in treatment, and then we will observe their subsequent participation in inventive activities and survey them to assess their self-identity as inventors and perceptions of the firm's innovation culture. By employing random assignment and controlling for potential confounders, our inferences from the coefficient estimates for proactive outreach on engineers' participation in inventive activities and changing perceptions of inventiveness can be interpreted causally.

The field experiment also incorporates additional manipulations to test the mechanisms underlying the potential influence of proactive outreach. Specifically, we vary the proactive outreach messaging to remind innovators of extrinsic incentives (e.g., monetary rewards) vs. intrinsic and pro-social motivations (e.g., outreach emphasizing the societal impact of inventing). The underlying incentive structure within the firm remains constant throughout the sample period. We also plan to manipulate the degree of personalization in the messaging, with some engineers receiving personalized encouragement to make them feel more included while others receive generic messaging. These experimental manipulations enable us to explore the relative importance of different motivational levers and communication strategies in shaping engineers' engagement with the invention process.

We anticipate that our study will provide novel, causal evidence on the role of proactive outreach in shaping engineers' inventive activities and patenting behavior, particularly among STEM professionals and across demographic groups, addressing gaps in the literature on the behavioral drivers of early-stage innovation within firms (Ahuja et al., 2008). We expect that our study will extend previous research on the impact of default options in various domains, including 401(k) plans (Madrian and Shea, 2001; Thaler and Sunstein, 2008; Carroll et al., 2009; Bubb and Pildes, 2014), organ donation, mobile shopping, and household recycling (Davidai et al., 2012; Bayer, 2024) by demonstrating their relevance for innovation outcomes, and contribute to recent literature on proactive outreach in preventative medical services (Joseph and Fu, 2015; Junghans et al., 2023). We believe such insights are likely to have far-reaching consequences as digital technologies are making data more available and targeting more cost-effective, suggesting such proactive outreach strategies, even in competitive processes, are likely to become more ubiquitous.

Second, we identify specific motivational levers and communication strategies that firms can use to enhance the effectiveness of opt-out framing and promote greater engagement in the invention process, building on insights from the literature on the role of incentives, motivation, and governance for innovation (Hong and Page, 2004; Sauermann and Cohen, 2010; Manso, 2011; Azoulay et al., 2011; Bloom and Reenen, 2011; Ederer and Manso, 2013; Jaravel et al., 2018; Ganguli et al., 2021; Acemoglu et al., 2022; Celik, 2023). Third, our study can highlight the importance of considering the interplay between framing, motivation, and personalization in designing information flows to support inclusive innovation extending prior experimental work on the behavioral foundations of innovation (Graff Zivin and Lyons, 2019; Sandvik et al., 2020; Bol et al., 2022; Carpio and Guadalupe, 2022; Pairolero et al., 2022) and how workers may derive utility or a warm glow from contributing to inventions with a social value (Bergstrom et al., 1986; Andreoni, 1990; Bénabou and Tirole, 2003).

In addition, our study should advance the literature on equity in innovation by demonstrating the potential for opt-out framing to narrow participation gaps and support the career advancement of underrepresented engineers. While previous research has documented disparities in innovation outcomes across demographic groups (Cook, 2018; Bell et al., 2019; Kline et al., 2019; Ross et al., 2022; Hochberg et al., 2023; Aneja et al., 2024; Chien and Grennan, 2024b), our study may provide evidence on a specific intervention that can help mitigate these gaps. By offering evidence-based strategies for firms to enhance inclusion by changing the invention process from a competitive, opt-in one to a personalized, opt-out one, our research contributes to the growing body of work on diversity and inclusion in STEM and the broader innovation economy (Kim and Marschke, 2005; Ding et al., 2006; Lach and Schankerman, 2008; Buser et al., 2014; Kamas and Preston, 2018; Jensen et al., 2018; Uzzi et al., 2013; Hunt et al., 2013; Hannon, 2020; Hofstra et al., 2020; Lu et al., 2020; Dossi et al., 2021; Goolsbee and Jones, 2021; Koning et al., 2021; Mezzanotti, 2021; Fairlie et al., 2022; Ganguli et al., 2022; Delgado and Murray, 2023; Miller, 2023; Reuben et al., 2024).

Finally, our study can contribute to the literature on corporate investment in human capital by highlighting the role of behavioral interventions in unlocking the full potential of firms' diverse talent pool. Previous research has emphasized the importance of human capital investments for innovation and firm performance (Jones, 2010; Toivanen and Väänänen, 2012; Bloom et al., 2019; Nishesh et al., 2024). Our findings may suggest that opt-out framing, pro-social motivation, and personalization can serve as effective tools for encouraging greater engagement in patenting activities and supporting the development and retention of innovative talent. By examining the behavioral drivers of human capital investment in the context of innovation, our study complements research on how management practices shape human capital (Bloom and Reenen, 2007; Bloom et al., 2012; Aghion et al., 2022; Sandvik et al., 2023) and how to cultivate a culture consistent with inclusive innovation (Guiso et al., 2015; Nollenberger et al., 2016; Li et al., 2020; Graham et al., 2022a,b; Gorton et al., 2022; Grennan and Li, 2023; Chien and Grennan, 2024b).

The remainder of this pre-analysis plan for "Closing the Innovator-Inventor Gap: Evidence from Proactive (Opt-Out) Outreach" is organized as follows. Section 1 provides an overview and describes our hypotheses. Section 2 presents the results of our natural experiments. Section 3 discusses the field experiement, the values that will be measured from the experiment, and lays out the plan for the empirical analysis. The field experiment will start to run on May 7, 2025. Please note that none of the team members have had access to post-treatment experimental data before this submission. The surveys and field experiments described in this document were approved by the IRB at the University of California, Berkeley.

1 Hypotheses Development

Innovators from URGs face multiple challenges to becoming an inventor. Selection into employment in high-tech firms is impacted by early life experiences and exposure to invention (Cook, 2018; Bell et al., 2019). But even conditional on gaining employment within high-tech firms, female engineers and those from underrepresented ethnicities are less likely to participate in every stage of the invention process (Chien and Grennan, 2024b). Then, conditional on submitting an inventive idea, women and men again have different levels of success in converting the idea to a patent application and an eventual patent grant (Chien and Grennan, 2024a; Aneja et al., 2024).

One idea for achieving a more equitable submission of inventive ideas in high-tech firms is to make it the default rule rather than the exception. Prior studies have found that opt-out framing (when the default expectation is of participation) rather than opt-in framing (when individuals must proactively select into an activity) can reduce gender disparities in competitive settings, like patenting. In both leadership and task contexts, researchers have documented smaller gender gaps when women were expected to participate in a competition rather than given the option to participate or not. In a series of experiments, He et al. (2021) compared the rates of competition for men and women under an opt-in vs. opt-out framing. Under opt-in framing, women were significantly less likely to compete than men, 53% vs. 72%. However, under opt-in framing, the gender gap was reduced considerably, and women participated at a rate of 66% as compared to a male participation rate of 71%. Erkal et al. (2022) reach a similar conclusion when experimenting with opt-out vs. opt-in framing in another competitive context, leadership selection. These findings suggest that gender gaps can be reduced by using opt-out framing.

One way of changing the default from opt-out to opt-in is through proactive outreach. Proactive outreach creates a presumption of participation by actively reaching out to individuals and inviting them to participate, effectively changing the default from opt-in to opt-out. Evidence suggests proactive outreach strategies are particularly effective in changing enrollment behaviors of eligible individuals into taking actions that are beneficial in the long term, such as through preventative healthcare measures like smoking cessation programs, cancer screenings, and health checks (Junghans et al., 2023). Moreover, health-based experiments in the UK suggest "personalized" proactive outreach, offering personalized messages tailored to individuals' specific needs and circumstances, is more effective than one-size-fits-all messaging.

How might insights about opt-in vs. opt-out framing and proactive outreach be applied to the invention process? In many high-tech companies, the submission process is voluntary, involving providing one's idea to an invention disclosure portal, for example, by answering a set of questions. Akin to raising one's hand in a classroom when a teacher asks a question, an innovator volunteers their potentially patentable ideas in response to an open call. But another way to get patentable ideas for submission is for patent professionals or others is to actively collect them from all potential inventors, similar to using a panel or "on-call" system in a classroom setting. Rather than relying on innovators to volunteer their ideas by raising their hands, the patent professional could initiate contact and ask the engineer what problems they are solving. As such, first learning the so-called "hidden curriculum" that engineers need to acquire to become named inventors or factors like the time, knowledge, or confidence level needed to start the idea submission process may be less important.

Nevertheless, there are also several reasons why opt-out vs. opt-in framing might not increase inventive engagement among high-tech engineers and innovators as it has in other populations. First, engineers are typically trained to think analytically and make decisions based on logic and reason. Thus, they may be less susceptible to psychological framing effects and more likely to carefully consider the costs and benefits of participating in the inventive process, regardless of the default option presented. Second, engineers working in high-tech firms may already be familiar with the invention and patenting process and have well-formed opinions about the costs and benefits of engaging in such activities. As a result, the innovators that "stay on the bench" may be doing so because of their prior knowledge and experiences and so, be less influenced by framing effects. Finally, engineers in high-tech firms often face significant time pressures and competing demands on their attention, so they may be less responsive to proactive outreach if they perceive the patenting process as not congruent with their personal desires and core work responsibilities. While the above factors suggest that opt-out vs. opt-in framing may be less effective for engineers compared to other populations, it is still worthwhile to empirically test if such low-cost interventions could help achieve more equitable innovation.

Our primary research question is: How does proactive outreach, a type of opt-out framing, influence the inventive activities and idea submission behavior of engineers and technical workers in a high-tech firm? Our secondary research question explores the underlying mechanisms to answer how proactive outreach may work. Specifically, how do highlighted factors (motivating intrinsically/personalizing) in proactive outreach messaging influence self-identity as inventors and perceptions of the firm's innovation culture among these same engineers and technical workers in a high-tech firm? We hypothesize that opt-out framing will lead to higher participation rates in patenting activities than opt-in framing, especially for engineers from URGs. We use a multi-pronged empirical strategy to answer these research questions involving natural experiments, where one firm switches from opt-out to opt-in framing and three firms have parallel opt-in and opt-out submission processes, and our proposed field experiment at one firm.

While the natural experiments depend on how the collaborating firms implement their opt-out framing, the field experiment allows us to consider potential moderating factors in more detail, such as the specific wording of the messages. As such, an arm of our treatment will consider different motivational factors (highlighting extrinsic rewards vs. intrinsic/pro-social motives) and personalizing (generic vs. addressing the engineer by name and mentioning specific projects and relevant tasks to do to become an inventor). By carefully designing the study and examining potential moderators, we seek a more nuanced understanding of the mechanisms through which proactive outreach is linked to diversity and inclusion in innovation. Our hypotheses regarding these additional arms of the RCT are as follows:

1. Extrinsic rewards (e.g., monetary bonuses, gift cards) will have less effect on early-stage inventive activity and idea submission behavior than intrinsic/pro-social motives.
2. Personalizing (e.g., your skill set is valuable for invention, and we can provide feedback on your early ideas) will have a stronger positive effect on idea submission behavior than a generic message.
3. The combination of opt-out framing, intrinsic rewards, and personalizing will lead to the highest levels of early inventive activity for a never-submitter.

Determining how best to incentivize scientists and engineers to be creative is a complex problem that economists have long debated. Holmstrom (1989) posits that innovation projects are inherently risky, unpredictable, long-term, labor-intensive, and idiosyncratic, making performance measures noisy and contracting particularly challenging. In such settings, low-powered incentives may be more effective, as they are less likely to distort an agent's attention away from less easily measurable tasks that are crucial for creativity.

Alternatively, Manso (2011) proposes tolerance for early failure and rewards for long-term success. Manso's key insight is that short-term pay-for-performance might encourage engineers to repeat what has worked in the past at the expense of exploring untested approaches. To model this idea, Manso (2011) proposes a multi-armed bandit model of the invention process, in which agents may explore new ideas in the early stages of the contractual relationship without fear of negative consequences while still being incentivized by rewards for long-term performance. Another insight from Manso is the importance of timely feedback; allowing agents to explore more efficiently and reduce experimentation costs is critical.

Most empirical evidence is consistent with Manso (2011). Specifically, Lerner and Wulf (2007) study the impact of R&D manager compensation on firm-level innovation outcomes, finding that long-term incentives, such as stock options and restricted stock, are positively associated with patent citations and firm innovation, while short-term incentives have no significant effect. Azoulay et al. (2011) study how a combination of incentives closely mimicking those proposed by Manso influences scientists' productivity and creativity. Specifically, they compare the Howard Hughes Medical Institute (HHMI) investigator program, which provides long-term funding and tolerance for early failure, with the National Institutes of Health (NIH), shorter-term and more outcome-focused grants. The HHMI program is associated with higher scientific productivity, creativity, and novel research than NIH grants. Ederer and Manso (2013) conducted a laboratory experiment and found that pay-for-performance schemes that tolerate early failure and reward long-term success lead to more innovation than fixed-wage and standard pay-for-performance schemes. Finally, studies examining CEOs also find that CEOs with pay packages structured for tolerance of failure but long-term incentives lead to firms with greater innovative output (Gonzalez-Uribe and Groen-Xu, 2017).

Despite the empirical relevance of Manso's model, one limitation is that it does not explicitly consider intrinsic motivation, which may be an important part of motivating employee effort, especially historically excluded innovators. From a theoretical perspective, Bénabou and Tirole (2003) define intrinsic motivation as the drive to engage in an activity for inherent satisfaction, in contrast to extrinsic motivation, which involves performing an activity to attain external rewards or avoid punishments (Deci et al., 1999). In the context of innovative activity, intrinsically motivated individuals may pursue invention out of curiosity, passion, or a desire to contribute to knowledge, while extrinsically motivated individuals may be driven by rewards such as prizes or recognition.

Prosocial motivation, a specific form of intrinsic motivation, refers to the desire to expend effort to benefit others (Grant, 2008). Pro-socially motivated researchers may be driven by the desire to solve societal problems, advance human welfare, or contribute to the greater good, beyond personal satisfaction. Bénabou and Tirole (2003) posit that extrinsic rewards can sometimes crowd out intrinsic motivation, leading to less creativity and innovation. Thus, our field experiment allows us to explore whether framing existing incentive structures to align with and reinforce engineers' intrinsic motivation can foster greater creativity and risk-taking. This is important because survey evidence from industrial scientists and high-tech engineers finds that intrinsic motivation, particularly the desire for intellectual challenge, is positively linked to innovative output and a desire to submit new ideas (Sauermann and Cohen, 2010; Chien and Grennan, 2024b).

While prosocial motivation shares many similarities with the empirically supported Manso model, it differs in the predictions it creates related to the resilience it fosters in the face of challenges and the sense of collaboration. Specifically, prosocial motivation provides an additional layer of purpose and meaning that can sustain individuals' commitment to their research even when faced with setbacks or failures. It can also inspire a collaborative and long-term approach to scientific endeavors. Messaging that reminds engineers, who have not previously participated in the invention process, of their pro-social motivations may spur greater collaboration and encourage these engineers to get more involved by working together towards a common inventive goal.

Our proposed field experiment will differ from the existing empirical literature in two novel ways. First, given that most of the existing empirical studies on incentives and creativity have focused on successful individuals, such as R&D managers, national science winners, and CEOs, an important gap in the literature is determining whether there are heterogeneous treatment effects from incentives on innovation and whether alternative incentive schemes would work better for engineers from URGs. Second, to our knowledge, no study examines the feedback aspect of Manso's model. Yet, it is often the case that diverse engineers do not have networks to rely on for feedback. Thus, we believe that by highlighting through personalized messaging in our field experiment that the patent professionals can help and provide feedback during one-on-one meetings, we will learn if this difference in messaging about the costs of obtaining feedback seems to matter more for certain sets of never-submitters.

Our hypotheses regarding these additional insights from the literature are as follows:

1. Intrinsic/pro-social motivation will have a larger effect on engineers from URGs.
2. Intrinsic/pro-social motivation will spur collaboration, leading to larger team formation and more participation in brainstorming events.
3. Intrinsic/pro-social motivation will make engineers more likely to cite their firm as one that creates a culture that aspires to collaborate and has cultural norms that support it.
4. The motivation arm (intrinsic/pro-social vs. extrinsic) will have heterogeneous impacts on diverse and non-diverse engineers.
5. Personalizing will have a larger effect on engineers from URGs.

In conclusion, by exploring the unique challenges and motivations that never-submitters face, we hope to find better ways to target interventions that foster creativity and drive inclusive innovation in the real world. We believe the combination of natural experiments and the proposed field experiment offers complementary approaches because they offer different types of evidence and have different strengths and limitations. By considering both natural experiments and field experiments, we can focus on findings supported across multiple settings and have greater confidence in the results. If the field experiment findings are consistent with the suggestive evidence from the natural experiments, it strengthens the case for practitioners to try opt-out framing at their firms. By combining these approaches, we hope to gain a more comprehensive understanding of the role of opt-out framing in shaping engineers' patenting behavior and its potential to promote inclusive innovation.

2 Evidence from Natural Experiments

2.1 Data and Methods

To test our hypotheses, we worked with four collaborating high-tech firms to take advantage of quasi-random variation in their collection of inventive ideas. For the first firm, a mid-sized artificial intelligence (AI) firm that went public in the 2020s, the natural experiment was brought about by the Covid-19 pandemic in 2020. At this firm, in the years leading up to the pandemic, the patent attorney used an active idea collection process, in which the attorney made a point of reaching out to all potential technical staff and trying to get them to submit ideas for the patenting process. Part of the attorney's process involved deliberately hanging out in breakrooms, having conversations with engineers and technical workers, and guiding them to participate in inventive activities.

However, things changed considerably when the COVID pandemic hit. Workers were not in the office anymore, and the traditional opt-out strategies described above were no longer viable. Thus, the pandemic was an exogenous event that was not influenced by the diversity of inventors submitting ideas at one high-tech firm but which did change the way new ideas were gathered. As the patent attorney explained, a larger share of the ideas submitted comprised voluntary submissions provided without prompting. The firm shifted from primarily opt-out to an opt-in process for inventive idea collection.

While the COVID pandemic was an unexpected shock, this is not the only assumption required for statistical inferences to be unbiased. We also explore the assumption of parallel trends and consider other confounding factors through a variety of robustness checks. In particular, there may be concern that there are spillover effects between the treatment and control groups. Historically excluded engineers, like female engineers, may have been burdened with extra responsibilities at home relative to their male counterparts. This contamination, however, is much less likely to be true for first-time submitters who tend to be younger engineers without family responsibilities. Therefore, using the firm's database of inventive ideas submitted and HR data on gender and ethnicity, we calculate the rate at which ideas submitted had a female named inventor and/or a first-time named inventor for the years pre and post-pandemic.

Using data from the firm experiencing the switch from opt-out to opt-in, we test whether invention participation is less pronounced for females and first-time inventors after the change. An example regression specification is as follows:

$$Female_{ibt} = \alpha + \beta Post_{ibt} + \mu X_{ibt} + \gamma_b + \varepsilon_{it} \quad (1)$$

where $Female_{ibt}$ indicates whether a female inventor is named on the idea submitted. This is one example of a measure of submitter characteristics; other characteristics we explore are first-time inventors. The observation unit is idea i submitted by an inventor in business unit b in year t. X_{ibt} is a vector of idea controls, including the total number of inventors and an indicator for whether the idea is submitted as a patent application, which serves as a proxy for quality. γ_b is a business unit fixed effect and ε_{it} is the residual.

For the second, third, and fourth firms, we also examine whether the number of ideas submitted by female inventors and/or first-time inventors differ under an opt-out vs. opt-in framing. Each of these firms has multiple ways to submit inventive ideas for patenting; some processes are opt-in, while others are opt-out. Specifically, at each firm, the patent professionals attend brainstorming sessions. Therefore, the patent attorney knows what is being talked about and can help with the submission of inventive ideas. Engineers do not select into these sessions voluntarily. Rather, engineers are invited to the sessions at the discretion of their manager and invites typically go out to whole project teams rather than individual engineers for their expertise. We explore whether ideas collected from the opt-out brainstorming sessions have more diverse engineers than the patents collected via traditional opt-in submission processes. One nice feature of brainstorming sessions is that the patent attorneys assured us that the criteria in terms of quality and how ideas are evaluated, selected, and recorded between the opt-in vs. opt-out sessions are similar.

Nevertheless, the assumptions required for causal interpretations may not hold. For instance, if managers, contrary to the anecdotes received, pick engineers to attend sessions because of diversity, we would not have a plausibly exogenous assignment of opt-in vs. opt-out. Similarly, if engineers self-select into sessions based on their motivation to participate, they may also be exactly the type more willing to submit an idea in the first place. Finally, if the number of brainstorming sessions increases over time and the number of females attending sessions increases over time, it could lead to a higher number of ideas submitted through the opt-out framing, potentially confounding coefficient estimates for opt-out framing. Thus, we will carefully account for any $firm \times year$ trends in our analyses.

Using data from each of the three firms, which have multiple ways to submit ideas, with some being opt-out and others being opt-in, we test whether invention submission participation is less pronounced for females and first-time inventors under the opt-in regime using the following regression specification:

$$Female_{ift} = \alpha + \beta Opt\_out_{ift} + \mu X_{ift} + \gamma_{f\times t} + \varepsilon_i \tag{2}$$

where $Female_{ift}$ indicates whether a female inventor is named on the idea submitted. This is one example of a measure of submitter characteristics; other characteristics we explore are first-time inventors.

$$Opt\_out_{ift}$$

is an indicator for the inventive idea being submitted through the opt-out process. The observation unit is idea i submitted by an inventor in firm f in year t. X_{ift} is a vector of idea controls, including the total number of inventors and an indicator for whether the idea is submitted as a patent application, which serves as a proxy for idea quality. $\gamma_{f\times t}$ is a firm-by-time fixed effect and ε_i is the residual.

2.2 Results

In this section, we describe our findings from the natural experiments. We begin by examining the visual evidence to support the identification strategy. An important assumption to assess in determining the validity of the identification strategy is the visual evidence from the parallel trends figure between females and males before the pandemic. The key assumption underlying the use of the pandemic as a natural experiment is that, in the absence of the switch to opt-in framing, the percentage of ideas submitted by female and male inventors would have continued to follow similar trends. Figure 1 shows that before the pandemic (quarters -8 to 0), the percentage of ideas submitted by both female and male inventors exhibits parallel trends, with no discernible differences in the pre-existing trajectories. This finding supports the credibility of the natural experiment, as it suggests that any observed changes in the gender composition of idea submissions after the pandemic can be attributed to the switch to opt-in framing rather than pre-existing differences in trends.

Figure 2 shows the raw percent of inventive ideas submitted by a female engineer under the opt-in and opt-out regime at Firm 1. Here, we observe almost a 16 percentage point decrease in female submission rates under the opt-in framing. Specifically, around 34% of ideas submitted pre-pandemic had a female inventor, yet only 18% of ideas submitted post-pandemic (under the opt-in regime) had a female inventor. This visual evidence suggests an economically meaningful change, representing almost twice as many submissions with a named female inventor under the proactive regime.

Table 1 presents regression estimates for the relation between opt-in framing induced by the pandemic and inventor diversity, as measured by the likelihood of an idea submission having a female inventor. The coefficients are reported for different model specifications, with each column introducing additional control variables and fixed effects. Column 1 shows the baseline estimate, indicating that the switch to opt-in framing due to the pandemic resulted in a 16.8 percentage point decrease in the probability of an idea having a female inventor. The model is refined by adding inventor controls and business unit fixed effects in column 2 and an indicator for whether the idea is submitted as a patent application (a proxy for idea quality) in column 4. In columns 3 through 5, the sample is limited to the three-year window around the switch. Finally, in Column 5, the data is limited to the engineers still active in the firm, which serves as a quality check. Because HR could not provide demographic data on departed employees, the patent attorney gave us the details for the missing observations from memory. Regardless of the specification, we see that the magnitude of the effect remains consistent, ranging from a 9.8 to 16.7 percentage point reduction in female inventor submissions under the competitive opt-in regime.

The robustness of the estimates across different specifications suggests that the negative impact of opt-in framing on female inventor participation is not driven by confounding factors such as inventor characteristics, business unit priorities, or data quality issues. The coefficients' consistent statistical significance suggests that the finding for this firm is reliable. Moreover, the adjusted R-squared values, which increase from 0.027 for the baseline coefficient in column 1 to 0.175 in column 5, demonstrate that the explanatory power of the model improves as more controls and fixed effects are included. Overall, the table provides suggestive evidence that the shift to opt-in framing induced by the pandemic relates negatively to the inclusion of female inventors in idea submissions.

Table 2 presents regression estimates for the relation between opt-in framing induced by the pandemic and inventor diversity, as measured by the likelihood of an idea submission having a first-time inventor. presents regression estimates for the effect of opt-in framing on the participation of first-time inventors in idea submissions. The results show a consistent negative link between switching to opt-in framing and first-time inventors. The probability of an idea having a first-time inventor decreases by 20.6 to 38.3 percentage points across different model specifications. The estimates remain statistically significant at the 1% level across all specifications. The findings from this first natural experiment suggest that the pandemic-induced shift to opt-in framing not only adversely correlates with the participation of female inventors but also has a detrimental influence on the inclusion of first-time inventors in idea submissions.

As described earlier, data limitations mean we cannot rule out other reasons not accounted for that could contribute to the observed differences. Important questions remain, such as whether the quality of the submissions and the number of inventors and submissions provided under the two conditions are comparable. Although this "natural experiment" has limitations, particularly because it coincided with many changes in the workforce that impacted men and women differently, it shows how variations in the conditions of inventing can have implications for who participates and be useful for gaining insights into inclusive innovation, even when not the intent.

Next, we examine the differences stemming from heterogeneous idea submission paths. Figure 3 shows the percent of ideas submitted out of the total number of ideas submitted via the opt-out, brainstorming sessions. While we see variation over time, we do not see any specific trend over time in the aggregate, but we see some trends in the percentage of ideas submitted within each firm over time. For instance, two firms see fewer ideas submitted over time, while one firm experiences a larger uptick. Another thing of note, however, is that, at least at these firms, there do not seem to be any big spikes or declines around the COVID pandemic.

Therefore, in Figure 4, we plot the coefficient estimates along with confidence intervals for opt-out framing annually for each of the three firms that offer both opt-in and opt-out framing. This figure illustrates several important phenomena. First, on average, the coefficient estimate is positive and significant. Second, the figure shows considerable heterogeneity, even within firms, across the years. For this reason, in our regression analyses, we are careful to include $firm \times year$ fixed effects.

Table 3 presents regression estimates using the combined data from the three firms. The coefficient shows the relation between opt-out framing and inventor diversity from 2017 to 2023. The dependent variable is whether an idea submission has a female inventor. The results show that opt-out framing has a positive and statistically significant impact on the likelihood of an idea having a female inventor, with the estimated magnitude ranging from 1.4 to 5.6 percentage points across different model specifications. The estimates remain significant at the 1% level, as firm-by-year fixed effects, idea quality controls, and total inventors controls are progressively included in columns 2 through 4. These findings suggest that opt-out framing, such as that employed in brainstorming sessions, can effectively increase the participation of female inventors in idea submissions. The positive impact of opt-out framing on inventor diversity is consistent across the three firms studied, highlighting the potential of this approach to foster greater inclusion of URGs in the invention process.

Table 4 presents regression estimates for the relationships between opt-out framing and the participation of first-time inventors in the idea submission process across three firms from 2017 to 2023. Column 1 shows the influence of opt-out framing on the likelihood of a submitted idea having a first-time inventor, which is a positive, significant 3.8 percentage point and is similar to the small, positive estimate we observed for female inventors. Once we control for fixed effects, idea quality, and total number of inventors, the estimate becomes insignificant and even switch signs.

The estimates' inconsistency and the models' relatively low explanatory power suggest that unobservable factors may be confounding the relationship between opt-out framing and the participation of first-time inventors. These unobservables could include individual-level characteristics, such as motivation or exposure to support networks for feedback, which may influence an inventor's decision to participate in the invention process. In our proposed field experiment, these are features we hope to explore in more detail.

In conclusion, the natural experiments suggest that opt-out framing is linked to more inclusive innovation outcomes for women and, to a lesser extent, for first-time inventors, providing suggestive evidence for the potential of opt-out framing to promote diversity in the invention process. In the next section, we describe our proposed field experiment, which aims to build upon this suggestive evidence by providing a more rigorous test of the causal effects of proactive outreach on engineers' participation in the inventive process. By combining insights from both the natural and field experiments, we seek to develop a more comprehensive understanding of the factors that shape inventor diversity and to inform the design of scalable and effective interventions to foster inclusion in innovation at firms.

3 Evidence from a Field Experiment

3.1 Data

The field experiment will be implemented among engineers and technical staff actively employed at a collaborating Silicon Valley high-tech firm that is publicly traded. Our data come from both surveys of the employees and administrative data sources at the company. On March 14, 2024, we received anonymized administrative data from the company, allowing us to divide the population of engineers and technical staff into those engineers who have submitted an idea to the patent team and those who have never submitted an idea to the patent team. In shorthand, we refer to these people as "never submitters." This pre-field experiment data from the company's HR department indicates that submitters and never-submitters are statistically distinct along a number of dimensions.

As shown in Columns 1 and 2 of Table 5, 80% of submitters work in the U.S., while only 61% of never submitters are U.S. based. Unsurprisingly, engineers are more likely to have submitted a patent than managers or other non-eneginering employees with 86% of submitters being engineers relative to only 27% of non-submitters. Another difference to note among submitters is that they been at the company longer. On average, submitters have been at the company 6 years, and non-submitters have been there 3 years. Finally, submitters are less likely to be from under-represented groups. Specifically, only 11% of submitters are female, while 25% of the never-submitters are female.

In March 2024, the patent team at the firm sent an email to obtain consent from engineers to be studied in accordance with our IRB. Then, in April 2024, we distributed a short survey with five questions to all the non-submitters. The survey asks participants (1) to indicate in which ways they have previously participated in the early stages of the invention process, including meeting with IP personnel, learning about the patent submission process, participating in a brainstorming session, attending an IP training, seeking advice about IP, working on projects likely to yield patentable inventions, and/or having an idea that the participant thought might be patentable; (2) how strongly they identify as an inventor; (3) how interested they are in working on tasks leading to being a named inventor, and (4) asks why participants have not submitted an idea before in an open text box. Participants are debriefed about the goal of the survey, and told that only members of the research team will have access to the responses, and are asked for permission. To take the survey, participants are authorized by their email address. This then allowed the patent team to match to HR records and provide us with an anonymized version of the survey responses that included demographic data.

Table 6 provides descriptive statistics from the baseline survey. On average, non-submitters do not identify as inventors. On a scale of 1 to 7 with 7 being strongly self-identifying as an inventor and 4 being neutral, the mean is 3.1, and the standard deviation is 1.6 for non-submitters. Females are significantly less likely to self-identify as inventors than their male counterparts: the average female score is 2.8, and the average male score is 3.3. On the same scale, these non-submitters are much more interested in working on tasks, leading to being named inventors. The mean score is 4.6, and the standard deviation is 1.9. This suggests almost a full standard deviation gap between identity and desire. But again, females indicate statistically lower interest in working on tasks leading to being a named inventor (4.2 vs. 4.8 for males).

Regarding participation in the early steps of the invention process, about 1/3 of respondents have participated in at least one early step in the invention process, but this is lower for females. Only 23% have participated, whereas 39% of males report having participated. The most common early step that participants have taken is to learn about the patent submission process with 19% of respondents saying that they have done so. Similarly, 15% report attending a formal IP training. Interestingly, 5% report having had an idea that they thought might be patentable and 10% have met with a patent professional. In contrast, only 5% have worked on projects likely to yield patentable inventions; only 3% have attended a brainstorming session, and only 3% have sought advice about patenting their idea.

The survey also had an open-ended question asking for the reasons for not submitting an idea. We hand-classified the responses for the open-ended question into categories. The most common reason for why they had not submitted was that they had not had an idea that they thought was patentable (30%). The next most common response was that they needed to understand the patent process (24%) better. Some respondents were simply unaware of the patent office (15%). Some report not being assigned to projects likely to yield patents (6%) or working in a job that does not lend itself to patenting (e.g., sales or finance). The remaining reasons were more idiosyncratic to the individual such as being too busy (9%) or those associated with self-identity (14%) like being too much of a perfectionist, too unsure, or not seeing themselves as an inventor.

This baseline survey helps determine the sample size for our randomization scheme and will be compared with surveys that we plan to administer later in the study. As a point of clarification, it is worth noting that all engineers and technical staff are eligible to receive formal IP training.

3.2 Treatments and Randomization

We will be studying the innovation engagement of technical and engineering staff at a Silicon Valley high-tech firm, some of whom will receive targeted emails encouraging them to participate in innovation and suggest specific steps they can take to be involved in the early stages of the invention process. The firm will provide us with anonymized data on their active employees, who are both submitters and non-submitters. Then, using a computer, we will randomize the non-submitters into control and treatment groups. To ensure experimental integrity, the randomization process will be conducted using a secure random number generator, and the assignment will be concealed from participants before the intervention.

The patent team at the firm will then send three or more targeted emails to this randomly selected subset of never-submitters, inviting them to participate in the invention process. Subsequently, the firm will follow business as usual, noting who participates in innovation according to their normal processes.

The population will be divided into control and 4 treatment arms. A description of the emails the groups will receive is included below.

1. **Control:** A group of never-submitters who will not get additional emails through this experiment. They will, however, periodically receive neutral messages without any specific framing or motivational factors from the patent team that are part of the routine course of business.
2. **Arm 1 (personalization + intrinsic motivation)**:
3. **Arm 2 (personalization + extrinsic motivation)**:
4. **Arm 3 (generic + intrinsic motivation)**:
5. **Arm 4 (generic + extrinsic motivation)**:

When writing emails that appeal to intrinsic motivation, we plan to emphasize the potential to contribute to the greater good through the broader impact and societal benefits that patenting has. These are example phrases that we plan to include (1) "By contributing to patenting, you are helping to advance scientific knowledge and understanding in your field. Your ideas and innovations can inspire and enable future discoveries that benefit society as a whole."; (2) "By engaging in patenting activities, you are fostering a culture of innovation and progress within our company and beyond. Your ideas can stimulate further advancements, encourage collaboration, and inspire others to think creatively for the betterment of society."; (3) "Your inventive ideas have the potential to leave a lasting impact on society. By working with the patent team to pursue novel patents, you are creating a legacy of innovation that can benefit future generations and shape the world for years to come."; (4) "Your inventive ideas have the potential to solve real-world problems and improve people's lives. By submitting your ideas and contributing to patenting, you can empower others by providing them with new tools, technologies, or solutions that enhance their lives, work, or communities. How awesome is it that you can enable others to achieve their goals and make a positive difference in the world!"

When writing emails that appeal to extrinsic motivation, we plan to emphasize the potential prizes and monetary awards associated with idea submission and successful patent applications. When crafting these email messages, we are working with the internal patent team at the firm to clearly communicate the specific rewards available to employees for their idea submission and patenting efforts at the time of the email, which may be subject to change and have certain eligibility requirements. At present, to incentivize idea submission, the company offers a small reward for submitting, which is typically paid out as an Amazon gift card or an equivalent value prize. As such, an example extrinsic motivation treatment would be: "By contributing to patenting, you not only help drive innovation within our company but also have the chance to earn exciting rewards. For each patentable idea you submit, you'll receive a $100 Amazon gift card as a token of appreciation for your valuable contributions." The company also rewards employees with bonuses for each patent application that is successfully submitted. An example of an extrinsic motivation phrasing associated with that is, "We value your innovative ideas and want to reward your efforts in patenting. For each patent application successfully submitted, you'll receive a bonus of $1,000. The more patentable ideas you contribute, the higher your potential earnings."

When writing emails with personalization, we plan to address the engineer by name, mention specific projects or tasks they may be working on that could be patentable, and remind them that they can get feedback on these early ideas. We will also emphasize the availability of support and guidance throughout the invention process, encouraging engineers to seek feedback from their managers, mentors, or the intellectual property team to refine their ideas and navigate the patenting journey. These are examples of the type of phrases that we plan to include: (1) "Dear [Name], I've been impressed by your innovative ideas and problem-solving skills since you joined our team."; (2) "Your manager, [Boss's Name], has spoken highly of your creative thinking and technical expertise."; (3) "I believe that your unique background and experiences, [Name], could lead to valuable inventions that drive our company's success."; (4) "[Name], your dedication to continuous learning and professional development is evident in your work."; (5) "Engaging in the patenting process, [Name], can help you refine your critical thinking and communication skills, which are essential for your long-term career growth."

In the Appendix, we provide an email template for each treatment arm to provide more concrete examples. Because we repeat the emails, we will use variations in the exact phrasing along the lines above. The templates are for the first batch of emails.

To ensure that our randomization process works, we perform balance tests. Specifically, as shown in columns 3 through 8 of Table 5, we display the mean demographics for the control and treatment arms of the study. The control group (column 3) represents engineers who were not part of any treatment arm, while columns 5 through 8 represent the four different treatment arms of the study. Looking at the demographic characteristics across the control and treatment arms, we can assess the balance of the proposed treatment design. Regarding work location, the percentage of engineers based in the USA is relatively consistent across all arms, ranging from 60% to 66%. The percentage of engineers with U.S. citizenship is also similar across the control and treatment arms, ranging from 46% to 51%. The job titles of the engineers (Manager, Other) and their years of experience at the company are well-balanced across the control and treatment arms. The gender composition is also relatively balanced, with the percentage of female engineers ranging from 24% to 27% across all arms.

In terms of ethnicity, the percentage of Asian engineers is slightly higher in the treatment arms (ranging from 37% to 41%) compared to the control group (39%), but the difference is not statistically significant as indicated by the joint F-stat reported in column 9. Similarly, the percentage of White engineers is also relatively balanced, ranging from 54% to 59% across all arms. The percentage of workers from any underrepresented group (URG) is also balanced, ranging from 26% to 29% across all arms.

Overall, the demographic characteristics of the engineers appear to be well-balanced across the control and treatment arms, suggesting that the proposed treatment design is adequately randomized. This balance helps ensure that any observed outcomes between the control and treatment arms can be attributed to the interventions rather than pre-existing differences in demographic characteristics. The balance also indicates that the experiment's internal validity is guaranteed by design.

3.3 Measurement of Outcomes and Power Calculations

Our primary endpoints are divided into four categories: initial reaction (e.g., email opened), participation in early-stage innovative activities (e.g., learning about the patent submission process through website, attending an IP training, attending a brainstorming session, requesting a meeting with a patent team member, reaching out on Slack, meeting with a patent ambassador (limited to offices with patent ambassadors), sought advice on an inventive idea (only survey), worked on projects likely to yield patentable inventions (only survey)), involvement in later-stage invention activities (e.g., submission of an inventive idea, that idea being filed as a patent application, that idea being abandoned, that idea receiving other IP protection, and the size of the team submitting the idea), and perceptions of self and workplace (e.g., identifying as an inventor, desire to work on tasks leading to being a named inventor, the extent to which teamwork and collaboration are part of the culture and norms are developed around it).

We will calculate the average treatment effect by comparing the mean patenting activity between the treatment and control groups to estimate treatment effects. We will report coefficient estimates and standard errors. Given that we will be testing multiple hypotheses, we plan to use the Bonferroni correction method and follow other robustness suggestions outlined in (Harvey et al., 2015).

To calculate the minimum detectable effect size (MDES) for our main outcomes, we will consider several factors, including sample size, level of statistical significance, and desired power. Our study does not present clustering, so we will not account for the intracluster correlation coefficient. While we have considered the potential for spillover effects and the use of clustering in the randomization design, the logistics of implementing the study with the collaborating firm prevent this. Nevertheless, we do not believe this is a concern because we do not believe that it is common to forward a proactive outreach message personalized to you to your other co-workers. Nevertheless, we can monitor such email actions in our data and check if this is a concern later.

For the initial reaction category, we do not have an exact baseline to compare to calculate the standard deviation for the outcome. The patent team promised to send us statistics on previous open rates, but we did not receive them in time to analyze them as part of the pre-analysis plan. We will use standard email services (e.g., Mailchimp) to track click rates once the proactive messages are sent.

For the early-stage involvement in inventive activities, we have data for the precise population under study from our baseline survey. To collect future outcomes, we will have a research assistant record requests for contact based on the patent professionals' emails and correspondences on Slack. The same research assistant will also keep track of participation in brainstorming events and IP training. Since the probability of being assigned to each treatment is equal across observations, our power calculation follows a common format across all treatment-control comparisons. In particular, there is a control group with 988 engineers and a combined treatment group with 3933 engineers. That treatment group is further split into four arms. Arm 1 has 1002, arm 2 has 945, arm 3 has 1000, and arm 4 has 986 observations.

Our baseline survey shows that 33% of never-submitters have done at least one step in the invention process, and the standard deviation is 47%. Further, we know that the total number of early steps completed is 0.6, and the standard deviation is 1.08. We assume a statistical significance level of 0.05 and a desired power of 0.80. The MDES, based on a two-sided test using our assumed $\alpha = 0.05$ and $\beta = 0.80$, is 6.58 percentage points for the proportion of never-submitters who will complete at least one step in the invention process.

By comparison, the MDES for the proportion of never-submitters who will complete at least one step in the invention process for only the extrinsic treatment group (i.e., Arm 2 + Arm 4 = 945 + 986 = 1931) relative to the control group is 8.58 percentage points. The higher MDES is attributable to fewer never-submitters receiving the extrinsic treatment rather than the proactive outreach treatment.

When we perform similar calculations for the total number of early steps completed, we see that the MDES for the total number of early steps completed is 0.151 steps for the proactive outreach messaging and 0.196 for the extrinsic arms for the proactive outreach. This means that we can detect a statistically significant average treatment effect for the extrinsic treatment group for the total number of early steps completed when it differs from the control group by 0.196 steps or more.

For the inventive outcomes, Table 7 provides baseline statistics for submitters. We see that the months to first submission from hiring is 34 months, on average, with a standard deviation of 28. It appears that ideas of higher quality take more time. The months to first patent application from hiring is 36 months with a standard deviation of 28 months. Interestingly, the months to the second submission are much shorter. This is consistent with a "hidden curriculum" that must be learned inside the firm, and once the process is figured out, inventive activity increases. The months to second submission from first submission is 10, on average, but it is 13 if the first submission is rejected.

To help visualize these inventive outcomes, Figure 5 shows kernel density estimations of the time to the first inventive idea submitted for female and male inventors. The distributions show separate densities plotted for each gender. In the second figure, we repeat this exercise for the distributions based on job title (engineer vs. technical staff). While the densities suggest that the time for females to learn the hidden curriculum is more elongated (about 12 months longer), there does not appear to be a difference in timing between engineers and technical staff. Given that the average never-submitter across all of our treatment groups has been at the firm for 3.4 years, we do not believe the baseline data from submitters is an appropriate population to estimate an MDES.

Instead, we will rely on our randomization process to obtain estimates of an effect on inventive ideas submitted and ideas being applied for as patent applications. We also plan to explore hazard rates to quantify the likelihood of a submission occurring at a specific time, given that the event has not occurred up to that point. In the context of our study, the hazard rate to first submission would represent the instantaneous probability of an engineer making their first submission at a particular time, given that they have not submitted until that time. A typical model in the literature is the Cox proportional hazards model, which assumes that the hazard ratios are constant over time. We can estimate a model with our demographic covariates and our treatment groups. Based on repeated model simulations, we could then compare estimates across study participants to see if there is a change for our treated group.

Finally, our last set of outcomes includes employees' perceptions of themselves as inventors and their firm's culture of collaboration. The baseline survey shows that the mean for non-submitters is 3.1 and the standard deviation is 1.6. For the full treatment vs. control, our calculations show the MDES for self-identification as an inventor would need to be 0.16 points larger on the 1-7 scale to detect a difference. This calculation uses the same size, significance level, and power assumptions as before. Performing the same calculations for the extrinsic treatment arms, we see that the difference must be 0.21 points to detect a significant difference.

Is it possible to detect a bigger change for females than males, given that females are already statistically less likely to self-identify as inventors? To answer this question, we ask what is the minimum sample size needed to detect a difference of 0.5 points on the 1-7 scale for females. Performing this calculation, we learned that we would need a sample size of 164 females in both the treated and control groups. The proposed randomization has 237 females in the control group and many more in the treated group. Therefore, it is plausible that we could detect a more significant treatment effect among women.

Finally, a prior survey was conducted on engineers' perceptions of the culture at their firm (Chien and Grennan, 2024b), which showed that fostering cultural norms associated with collaboration and integrity may make innovation more inclusive. As we explained in the hypotheses development section, proactive outreach is one way to make innovation more inclusive, and therefore, we seek to understand if treated engineers, especially those in the personalized and intrinsic motivation arms, perceive the culture as more collaborative. We plan to ask via our follow-up survey about norms associated with information sharing among employees and if the engineers feel important details are explained. To avoid ambiguity, we plan to use the same questions asked in the previous study, which itself replicated previous questions on studies of culture (Graham et al., 2022a). Given this setup, we will rely on randomization to detect significant treatment effects.

3.4 Implementation and Integrity

We will register this pre-analysis plan (PAP) in the AEA registry and include it with our submission to any registered report. The timeline for our research project is as follows:

- Fall 2024: Obtain IRB approval and work with the firm to ensure they can gather baseline data
- March-May 3, 2024: Conduct baseline survey, finalize study design, and register PAP.
- May 7, 2024: Send first intervention email
- May-July 2024: Send follow-up intervention emails
- September 2024: Collect and analyze intermediate survey data
- November 2024: Collect and analyze idea submission data
- April 2025: Collect and analyze final survey data
- May 2025: Collect and analyze final idea submission data

We will adhere to ethical principles and guidelines for human subjects research throughout this study. We have already obtained informed consent from all participants, ensuring they understand the study's purpose, procedures, risks, and benefits. Participants will have the right to withdraw from the study at any time without consequence. Moreover, data governance and management will follow strict protocols to protect participants' privacy and confidentiality. All data will be anonymized and stored securely, with access restricted to authorized research team members. We will comply with relevant data protection regulations, such as the General Data Protection Regulation (GDPR). Finally, we will note that the study design and interventions have been carefully considered to minimize potential risks and maximize participant benefits. We will treat all participants with respect and ensure their autonomy in decision-making. The random assignment of participants to treatment and control groups ensures a fair distribution of potential benefits and burdens.

4 Conclusion

In this study, we have leveraged a unique set of natural experiments to investigate the impact of proactive outreach and opt-out framing on the diversity and inclusivity of the innovation process. Our findings from these experiments suggest that opt-out framing, the switch away from which was induced by the pandemic and implemented through proactive outreach in brainstorming sessions, can significantly increase the participation of women and underrepresented groups in the invention process. These results suggest that the way we structure default options and engage with innovators at the firm who may be potential inventors could potentially influence who ultimately participates in generating new ideas.

However, while the natural experiments offer valuable insights, they also have limitations. The sudden onset of the pandemic and the potentially non-random assignment of inventors to different framing conditions raise concerns about potential confounding factors. We propose a carefully designed field experiment to address these limitations and provide a more rigorous test of the relationship between opt-out framing and participation in the invention process. By randomly assigning inventors to different framing conditions and controlling for observable characteristics, our field experiment aims to build upon the analyses reported earlier and help determine whether and how proactive outreach may reduce the innovator-inventor gap.

Importantly, our proposed field experiment goes beyond the simple opt-out vs. opt-in dichotomy and explores the role of personalization and motivation (extrinsic vs. intrinsic/pro-social) in shaping engineers' engagement with the inventive process and the inventive ideas that they submit. By varying the content and framing of the outreach messages, we can better understand the psychological mechanisms that drive innovators' decisions to engage in the invention process. This understanding is crucial for designing effective policies and interventions that foster a more diverse and inclusive innovation ecosystem.

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Figure 1.

Parallel trends: Ideas submitted by gender

This figure illustrates the parallel trends in the percentage of ideas submitted by gender before and after the switch to opt-in framing due to the pandemic. The vertical line at quarter 0 represents the onset of the pandemic and the switch to opt-in framing. The percentage of ideas submitted by female and male inventors is plotted separately, with confidence intervals shown as the shaded region.

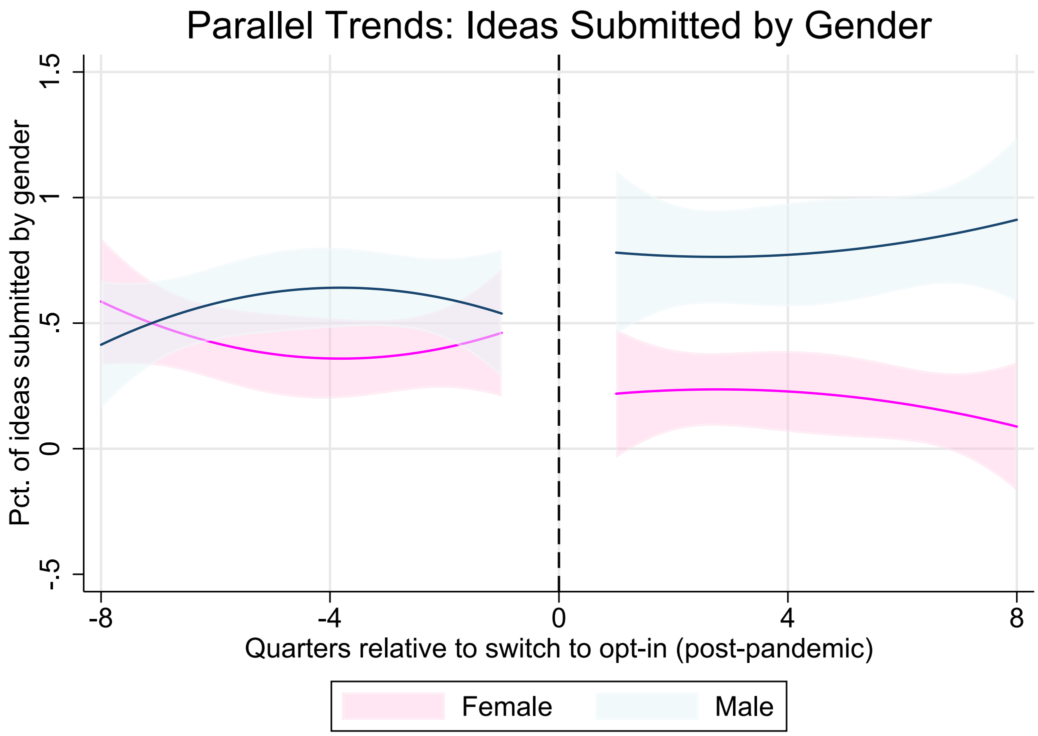


Figure 2.
Submission with female inventors pre and post-proactive outreach
This figure illustrates the share of ideas submitted with a female inventor before and after the pandemic-induced switch from proactive outreach to opt-in idea collection.

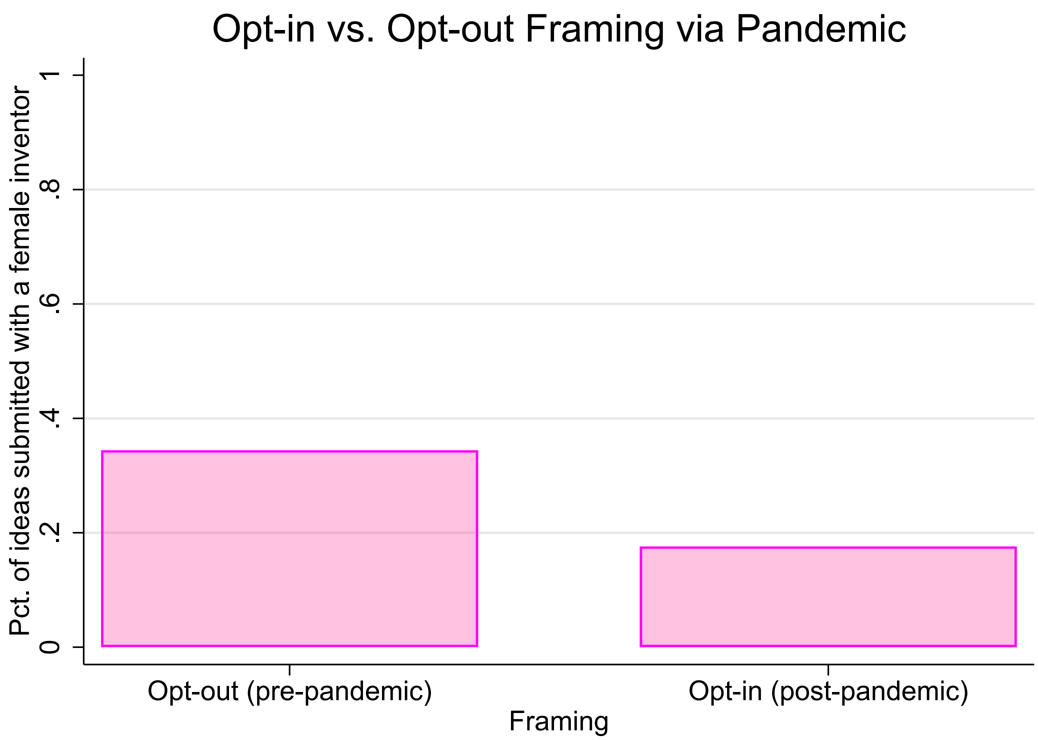


Figure 3.

Percentage of ideas submitted via opt-out brainstorming sessions over time

This figure illustrates the percentage of ideas submitted through opt-out brainstorming sessions for three collaborating firms from 2017 to 2023. The graph shows trends within firms over time in the extent to which inventive ideas are collected via brainstorming sessions. No firm follows the same trends, suggesting that these paths are idiosyncratic in terms of the firm's initiatives and strategies.

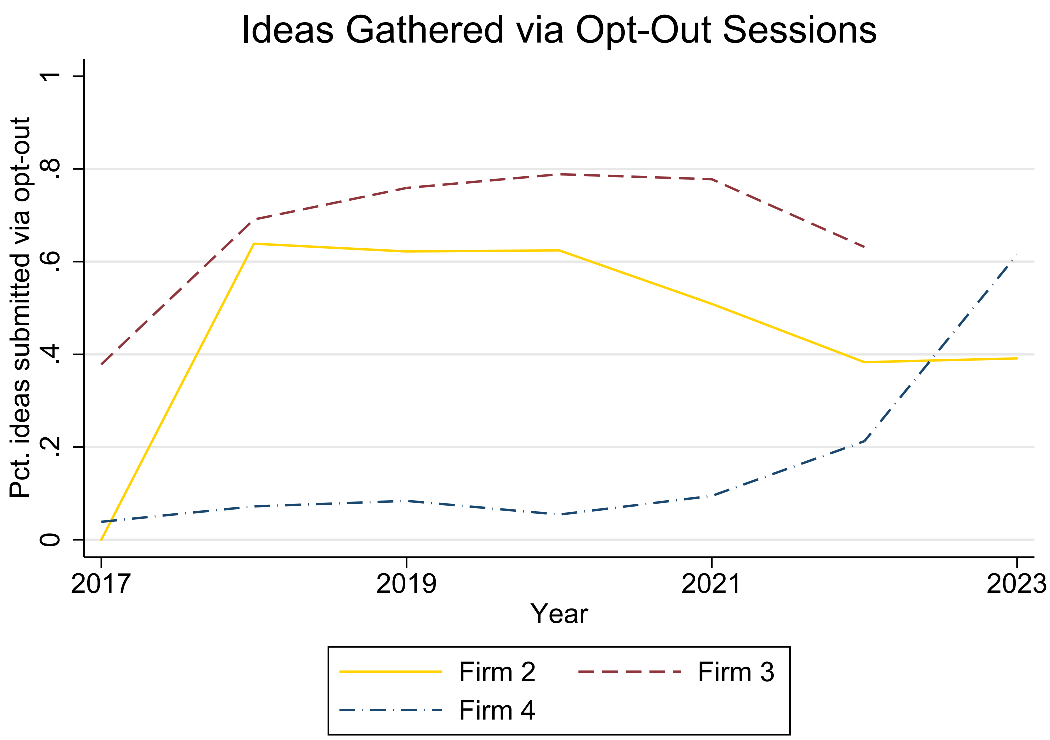


Figure 4.

The influence of opt-out framing on female inventor submissions across firms

This figure presents the coefficient estimates and confidence intervals for the relationship between opt-out framing and inventor diversity across three firms from 2017 to 2023. The black line at 0.024 (std. error = 0.008) represents the overall estimate when all firms are combined and firm-by-year fixed effects and idea quality are accounted for. This significant coefficient estimate suggests small yet positive gains in diverse submissions under the opt-out framing, despite the underlying heterogeneity at individual firms.

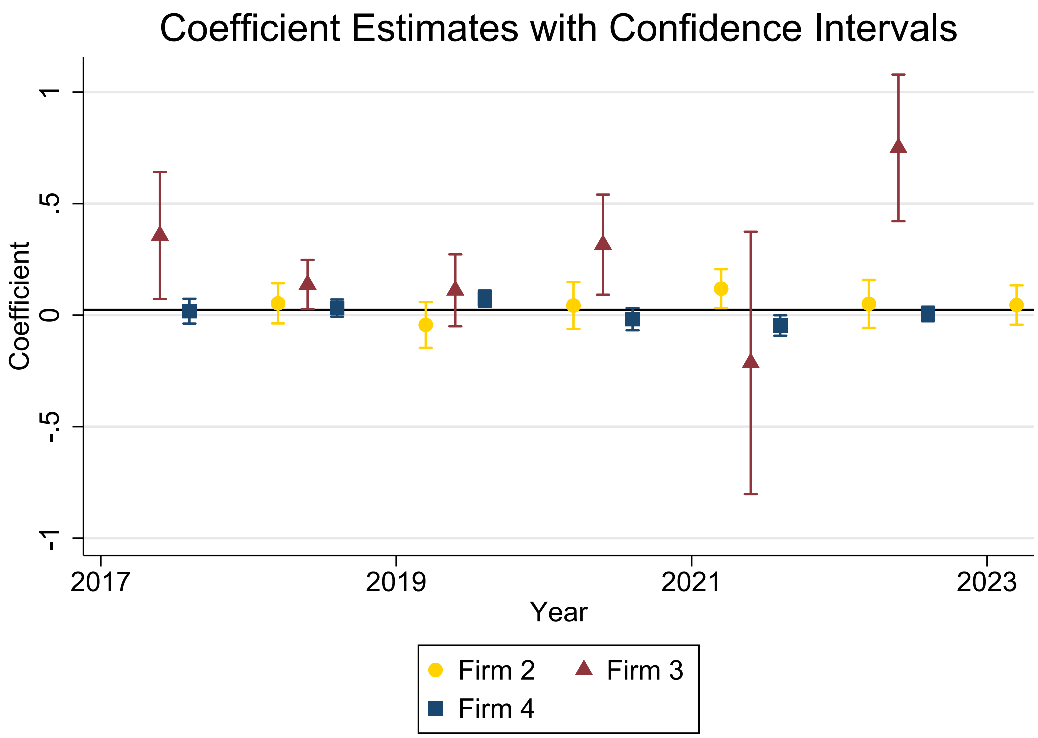
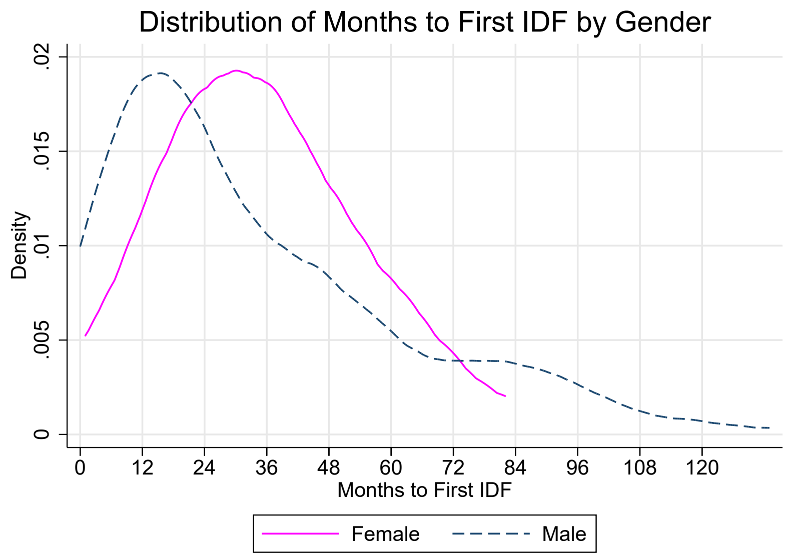


Figure 5.

Months to first submission

These figures illustrate kernel density estimations of the months elapsed until an employee provides their first invention disclosure form (IDF) submission. The first figure depicts female (pink solid line) and male inventors (navy dashed line), with separate densities plotted for each gender. The second figure depicts engineers (blue solid line) and non-engineers (orange dashed line), with separate densities plotted for each job title.



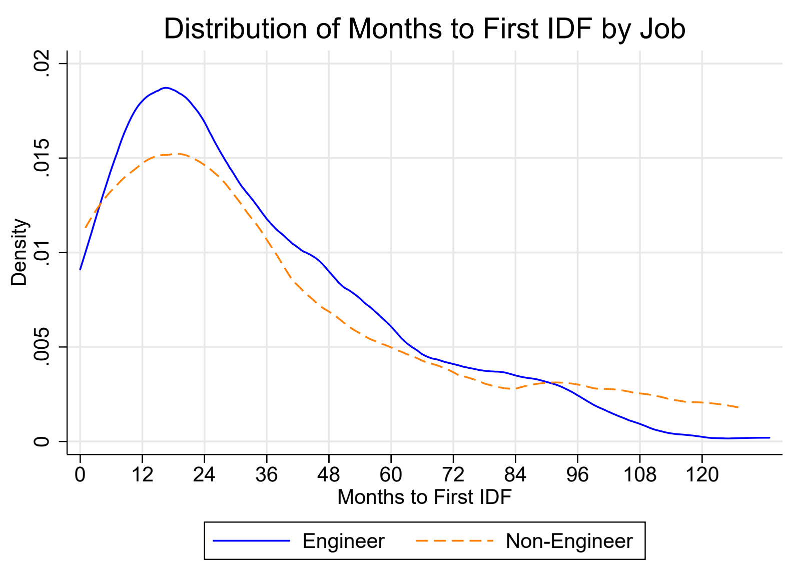


Table 1.
Pandemic-induced opt-in framing and female inventor submissions
This table provides regression estimates linking opt-in framing induced by the pandemic to inventor diversity at one high-tech firm. The unit of observation is an idea submitted for patenting, and the dependent variable is whether the idea submitted has a female inventor on it. Robust standard errors are in parentheses below the coefficient estimates. ***, **, and * indicate p-values under the assumption of a single test of 1%, 5%, and 10%, respectively. For a detailed description of each variable, see Appendix A.

	Dep var. = Has a female inventor				
	(1)	(2)	(3)	(4)	(5)
Switch to Opt-in	-0.168**	-0.144**	-0.098	-0.153*	-0.167*
	(0.068)	(0.064)	(0.076)	(0.082)	(0.087)
Observations	237	237	173	173	157
Adjusted R^2	0.027	0.117	0.189	0.200	0.175
Total inventors control	No	Yes	Yes	Yes	Yes
Business unit fixed effects	No	Yes	Yes	Yes	Yes
Only data in three-year window	No	No	Yes	Yes	Yes
Idea quality control	No	No	No	Yes	Yes
Data quality check	No	No	No	No	Yes

Table 2.
Pandemic-induced opt-in framing and first-time inventor submissions
This table provides regression estimates linking opt-in framing induced by the pandemic to inventor diversity at one high-tech firm. The unit of observation is an idea submitted for patenting, and the dependent variable is whether the idea submitted has a first-time inventor on it. Robust standard errors are in parentheses below the coefficient estimates. ***, **, and * indicate p-values under the assumption of a single test of 1%, 5%, and 10%, respectively. For a detailed description of each variable, see Appendix A.

	Dep var. = Has first-time inventor				
	(1)	(2)	(3)	(4)	(5)
Switch to Opt-in	-0.206***	-0.256***	-0.288***	-0.330***	-0.383***
	(0.073)	(0.074)	(0.086)	(0.097)	(0.096)
Observations	237	237	173	173	157
Adjusted R^2	0.031	0.114	0.163	0.166	0.234
Total inventors control	No	Yes	Yes	Yes	Yes
Business unit fixed effects	No	Yes	Yes	Yes	Yes
Only data in three-year window	No	No	Yes	Yes	Yes
Idea quality control	No	No	No	Yes	Yes
Data quality check	No	No	No	No	Yes

Table 3.
The influence of opt-out framing on female inventor submissions
This table provides regression estimates for the effect of opt-out framing on inventor diversity across three firms from 2017 to 2023. Robust standard errors are in parentheses below the coefficient estimates.***, **, and * indicate p-values under the assumption of a single test of 1%, 5%, and 10%, respectively. For a detailed description of each variable, see Appendix A.

	Dep. var. = Has a female inventor			
	(1)	(2)	(3)	(4)
Opt-out	0.056***	0.015**	0.024***	0.014*
	(0.006)	(0.008)	(0.008)	(0.008)
Firm $\times$ year fixed effects	N	Y	Y	Y
Idea quality control	N	N	Y	Y
Total inventors control	N	N	N	Y
Observations	19,629	19,628	19,628	19,628
Adjusted R^2	0.004	0.018	0.019	0.033

Table 4.

The influence of opt-out framing on female inventor submissions

This table provides regression estimates for the effect of opt-out framing on inventor diversity across three firms from 2017 to 2023. Robust standard errors are in parentheses below the coefficient estimates.***, **, and * indicate p-values under the assumption of a single test of 1%, 5%, and 10%, respectively. For a detailed description of each variable, see Appendix A.

	Dep. var. = Has a first-time inventor			
	(1)	(2)	(3)	(4)
Opt-out	0.038***	-0.018**	-0.007	-0.019**
	(0.008)	(0.009)	(0.009)	(0.009)
Observations	19629	19628	19628	19628
Adjusted R^2	0.001	0.035	0.037	0.051

Table 5.

Demographic summary statistics for submitters and non-submitters

This table provides descriptive demographic statistics from the collaborating firm's HR department on engineers and technical staff. Columns 1 and 2 display the mean demographics for never-submitters and submitters. Columns 3 and 4 display the mean demographics for the control and treatment groups of never-submitters. Columns 5 through 8 display the mean demographics for the treatment arms. Column 9 displays the F-statistic from the joint hypothesis test that the treatment arm coefficients are equivalent. ***, **, and * indicate p-values under the assumption of a single test of 1%, 5%, and 10%, respectively. For a detailed description of each variable, see Appendix A.

					Treatment Groups				
	Never submitters	Submitters	Control	Treat	Arm 1	Arm 2	Arm 3	Arm 4	Joint F-stat
Panel A. Demographic characteristics	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Work location									
USA	61%	80%***	62%	61%	60%	61%	60%	63%	0.71
Citizenship									
USA	48%	43%	49%	49%	49%	50%	46%	51%	1.19
USA resident (e.g., greencard)	8%	19%***	7%	7%	7%	7%	8%	7%	0.50
Job Title									
Engineer	27%	86%***	25%	24%	23%	24%	22%	26%	1.29
Manager	33%	29%	36%	34%	35%	33%	34%	34%	0.37
Other	44%	7%***	44%	46%	46%	47%	48%	44%	1.26
Experience									
Time at [Company] (years)	3.4	6.3***	3.5	3.3	3.3	3.3	3.5	3.3	1.32
Gender									
Female	25%	11%***	24%	26%	27%	25%	26%	24%	0.47
Ethnicity									
Asian	41%	63%***	41%	39%	41%	38%	41%	37%	0.50
Black	2%	2%	1%	2%	2%	3%	2%	2%	0.80
Latinx	4%	2%	3%	5%*	5%	3%	6%	5%	1.62
White	55%	36%***	57%	56%	55%	59%	54%	58%	0.57
Historical exclusions									
Any underrepresented group (URG)	26%	12%***	26%	27%	29%	27%	28%	26%	0.73
Observations	5226	253	988	3933	1002	945	1000	986	3933

Table 6.
Baseline survey of non-submitters

This table provides descriptive from a baseline five-question survey that we sent to non-submitters. ***, **, and * indicate p-values under the assumption of a single test of 1%, 5%, and 10%, respectively. For a detailed description of each variable, see Appendix A.

	All		Male	Female
	Mean	Std. Dev.	Mean	Mean
Panel A. Pre-RCT survey of never submitters	(1)	(2)	(3)	(4)
Self-identity and motivation				
How strongly do you identify as an inventor? (Scale 1-7)	3.1	1.6	3.3	2.8***
How interested are you in working on tasks leading to being a named inventor? (Scale 1-7)	4.6	1.9	4.8	4.2***
Participation in early steps of the invention process				
Attended a brainstorming session	3%	17%	3%	4%
Attended an IP training	15%	36%	19%	9%***
Had an idea that I thought might be patentable	5%	22%	6%	3%
Learned about the patent submission process	19%	39%	22%	13%**
Met with a patent professional	10%	30%	10%	10%
Sought advice about patenting	3%	16%	3%	3%
Worked on projects like to yield patentable inventions	5%	21%	6%	2%*
Any early step in the invention process	**33%**	**47%**	**39%**	**23%*****
Total number of early steps in the invention process	**60%**	**108%**	**69%**	**45%****
Reasons for not submitting ideas				
Have not had an idea that I thought was patentable	30%	46%	31%	28%
My job doesn't lend itself to patenting (e.g., finance)	12%	32%	10%	16%
Need to better understand the patent process	24%	43%	25%	19%
Self-identity (too much of a perfectionist, too unsure, don't see myself as an inventor, etc.)	14%	35%	14%	13%
The projects I'm assigned are unlikely to yield patents	6%	23%	6%	6%
Too busy to work on innovative ideas	9%	29%	9%	9%
Unaware of the patent office	15%	36%	13%	18%
Observations	477	477	307	162

Table 7.
Statistics on initial idea submissions

This table provides descriptive statistics on data collected from the firm for all ideas submitted by STEM professionals, who are still actively employed by the firm. Column 1 displays the number of observations, where the observation unit is an inventor. Columns 2 and 3 display the mean and standard deviation of months to submission for all inventors. Columns 4 and 5 display the mean months to submission for male and female inventors. ***, **, and * indicate *p*-values under the assumption of a single test of 1%, 5%, and 10%, respectively. In this case, the lack of stars indicates that male and female idea submitters are statistically indistinguishable. For a detailed description of each variable, see Appendix A.

Panel A. Baseline data on idea submitters	Obs. (1)	All Mean (2)	All Std. Dev. (3)	Male Mean (4)	Female Mean (5)
First idea submissions					
Months to first submission from hiring	247	34	28	34	35
Months to second submission from hiring	136	40	30	40	42
Second idea submissions					
Months to second submission from first submission	137	10	14	10	12
…conditional on first submission not being rejected	116	10	14	10	9
…conditional on first submission being rejected	35	13	12	13	17
First patent applications					
Months to first patent application from hiring	211	36	28	35	40
Months to second patent application from hiring	119	42	32	42	43

Appendix

Consent Email

Cheers from the ACME Patent Team!

As you may have heard at last week's XYZ, the ACME Patent Office is dedicated to nurturing a truly inclusive innovation program. We are excited to announce our continued partnership with the Diversity Pilots Initiative, who highlighted our inventors in their inaugural Diversity Pilots Diary in 2023.

The DPI researchers are conducting a study to understand how different initiatives impact innovation participation. This study may involve receiving recognition for your contributions, personalized guidance on engaging in innovation, inquiries about collaborators on inventions, and exploring your identity as an innovator.

You may have the opportunity to participate in the study, and your insights on innovation will be shared with researchers anonymously. The findings of the study will enable us to gain valuable insights into the effectiveness of our initiatives, which will in turn help us provide better support to you and other innovators at ACME.

For more information about the studies, feel free to visit the initiative's website or reach out to the Principal Investigator, Colleen Chien, and cchien@berkeley.edu. While we cannot guarantee any direct benefits for you other than sharing your experience, there will be no consequences for opting out.

If you wish to opt-out, simply click on the Opt-Out button below, and you will no longer receive emails regarding research from the ACME Patent Office.

To Opt-Out Click HERE

Example Treatment Emails

Arm 1: Example personalized + intrinsic motivation

Subject: [Name], your innovative ideas can make a difference

Dear [Name],

I wanted to reach out to you personally to let you know the ACME Patent Team thinks your creative approach and ability to think outside the box is inspiring. This dedication to solving complex problems and passion for innovation is exactly what the Patent team is looking for.

I believe your unique perspective and technical expertise can lead to inventive ideas that have a lasting positive impact on society. By working with the patent team to pursue novel patents, you can create a legacy of innovation that can benefit future generations and shape the world for years.

We know that engaging in inventive activities allows you to stretch your creative thinking skills, collaborate with coworkers, and tackle meaningful challenges. Put simply, it's an opportunity for personal growth and to make a lasting difference in your field.

I encourage you to explore the resources available about the patent submission process and discuss your ideas with a member of the patent team or a patent champion. For instance, we have a brainstorming event on XX, YYYY. Your contributions at that event can drive innovation and make a positive difference in the world.

If you have any questions, please reply to this email or contact xx@acme.com or acme-patents on Slack. I'm excited to see the impact you can make through your inventive efforts and am happy to provide feedback on your ideas.

Arm 2: Example personalized + extrinsic motivation

Subject: [Name], unlock prizes through your inventive contributions

Dear [Name],

The ACME Patent Office has recognized your strong technical skills and innovative mindset. I'm reaching out because your ideas can potentially create significant value for ACME.

In case you were not aware, by participating in the ACME Patent Program, you can unlock exciting rewards. Just for submitting an idea through our disclosure portal (1st disclosure per quarter), you'll receive a disclosure award (approx. value US$75, international options vary). And, for each idea approved and filed as a utility patent application, you'll receive a patent filing award (approx. value US$600, international options vary). These rewards are our way of appreciating your hard work and inventive contributions.

Moreover, becoming a named inventor can open new opportunities and offer career advancement.

Please learn more about our idea submission process and once you're ready, submit your idea through the ideas portal. By dedicating time to developing and protecting your inventions, you can enjoy the financial benefits of being a successful inventor at ACME.

If you have any questions, please reply to this email or contact xx@acme.com or acme-patents on Slack. I'm happy to provide you feedback on your ideas and support you in unlocking the rewards of your inventive efforts.

Arm 3: Example generic + intrinsic motivation

Subject: Contribute to innovation and make a difference

Dear Acmeans!

The ACME Patent Office encourages you to participate in our company's patent program. By engaging in inventive activities, you can make a meaningful difference in your field and contribute to advancing technology.

Developing and protecting your ideas allows you to tackle complex challenges, collaborate with talented colleagues, and push the boundaries of what's possible. It's a chance to grow your skills, express your creativity, and leave a lasting impact on our industry and society.

Your ideas can shape the future of our products and services, improve our customers' lives, and drive positive change in society. By participating in the patent process, you'll be at the forefront of innovation, solving problems that will improve society.

I invite you to explore the resources available about the patent submission process and then discuss your ideas with a member of the patent team or a patent champion near you.

In addition, we have a brainstorming event coming up on DD, YYYY. Your contributions can drive innovation and make a positive difference in the world.

Our patent team is here to support you if you have any questions or need guidance. Let's unlock the power of innovation and make a lasting impact together. If you have any questions, please reply to this email or contact xx@acme.com or acme-patents on Slack.

Arm 4: Example generic + extrinsic motivation

Subject: Unlock prizes through patenting

Dear Acmeans!

I'm excited to remind you about the fun awards available through our ACME Patent Program. You can enjoy benefits and recognition by submitting your inventive ideas.

You can unlock exciting rewards for your submitted ideas, for instance, for submitting an idea through our disclosure portal (1st disclosure per quarter), you'll receive a disclosure award (approx. value US$75, international options vary). And, for each idea approved and filed as a utility patent application, you'll receive a patent filing award (approx. value US$600, international options vary). These rewards are our way of appreciating your hard work and inventive contributions.

Furthermore, becoming a named inventor can open new opportunities and career advancement.

You can unlock these financial rewards by dedicating time and effort to developing and protecting your inventions. I encourage you to learn more about our patent submission process and explore your ideas with your colleagues through brainstorming sessions, like the event coming up on DD, YYYY.

We are here to hear all your ideas and look forward to your submission. Take advantage of the opportunity to earn rewards as a successful inventor at ACME! If you have any questions, please reply to this email or contact xx@acme.com or ask-patents on Slack.

Variable Definitions

1. Switch to Opt-in: This is an indicator variable for the firm that switched to an opt-in system as a result of the pandemic.

2. Opt-out: This is an indicator variable for an idea being submitted via an opt-out process, such as at a brainstorming event that a patent professional sits in on to collect ideas.

3. Has a female inventor: This is an indicator variable for having a female inventor on an inventive idea that is submitted for patenting.

4. Has a first-time inventor: This is an indicator variable for having a first-time inventor on an inventive idea that is submitted for patenting.

5. Total number of inventors: This is the total number of inventors on an inventive idea submitted.

6. Patent application: This is an indicator variable for being an inventive idea that the firm's patent attorneys submit as a patent application.

7. Work location: This comes from office location data.

8. Citizenship: This comes from HR data on citizenship and permanent resident status.

9. Job title: There are a variety of job titles; HR helped us to classify them as engineering or not and as a manager or not. The other category is any non-engineer, non-manager.

10. Experience: HR provided us with hiring dates for all STEM professionals; work experience is calculated as the date the active employee data was provided to us (March 2024) less than the hiring date.

11. Gender: HR provided us with data on gender in three buckets (male, female, and other).

12. Ethnicity: HR provided us with some data on ethnicity, but it was incomplete (only about 60% coverage). The statistics are reported only for the employees with the data provided. For the remaining employees, the plan is to use an algorithm on the last names in combination with work location to predict ethnicity. This has not been completed yet.

13. Underrepresented group (URG): In the context of inventors, we use the term "URGs" to refer to individuals from historically, underrepresented groups. This includes individuals with an ethnicity that is not white or Asian and individuals who do not identify with the male gender.

14. Data on idea submitters: Using invention disclosure filing (IDF) data (i.e., inventive ideas submitted) that we received from the collaborating, high-tech firm we are conducting the field experiment with, we identified unique inventors. Then, we merged the unique inventors with the HR data to get the gender, hiring date, and job title. We then calculated the time between

hiring and the first idea submission, and we rounded it to months to ease interpretation. Similarly, we calculated the time between hiring and the second idea submission, and we rounded it to months to ease interpretation. We repeated this exercise conditional on the first idea being rejected or a patent application being applied for.