RIETI Discussion Paper Series 25-E-071

Applicant Prior Art Disclosure and Examination Performance: Evidence from Japan

KADOWAKI, Makoto
Hitotsubashi University

NAGAOKA, Sadao
RIETI

MAEDA, Takahiro
Ambience

RIETI
Research Institute of Economy, Trade & Industry, IAA

The Research Institute of Economy, Trade and Industry
https://www.rieti.go.jp/en/

RIETI Discussion Paper Series 25-E-071

August 2025

Applicant Prior Art Disclosure and Examination Performance: Evidence from Japan*

Makoto Kadowaki, Hitotsubashi University†

Sadao Nagaoka, RIETI‡

Takahiro Maeda, Ambience

Abstract

The identification of relevant prior art is a key step in assessing an invention's contribution; however, it remains unclear whether and how applicants can contribute to this process through prior art disclosure. This study investigates how applicant disclosures causally affect patent examination performance using the Japanese Patent Office's 2002 policy reform requiring applicant disclosure as a natural experiment. We find that this reform has significantly improved the quality of applicant disclosure (as measured by its coverage of examiner citations of prior art), especially for high-quality inventions. The reform led to faster grant processing, a narrower initial patent scope, and fewer amendments between applications and grants, primarily through higher-quality disclosure. While the reform also led to a greater number of disclosures not used by examiners, which had the effect of slowing the grant process, this effect was dominated by the effect of higher quality. The reform also increased the total amount of prior art used by examiners and reduced both invalidation and rejection appeal trials through higher disclosure quality. Applicant disclosures complemented examiner search efforts, thereby enhancing the overall prior art base used in patent examinations.

Key words: prior art, applicant disclosure, patent examination

JEL: O33, O31, O38

* This study is conducted as a part of the project "Assessment of Innovation Capability of Japanese Industry from an International Perspective (Part2)" undertaken at the Research Institute of Economy, Trade and Industry (RIETI). The draft of this paper was presented at the DP seminar of the Research Institute of Economy, Trade and Industry (RIETI). We would like to thank participants of the RIETI DP Seminar, and Kaori Hatanaka and Noriaki Matsushima at the Japan Association for Applied Economics conference for their helpful comments. This research was also supported by the JSPS KAKENHI Grant Number JP19K23190 and JP23KK0027. Takahiro Maeda contributed to the early stage of this project while he was at Hitotsubashi University.

† kadowaki.makoto@r.hit-u.ac.jp

‡ nagaoka-sadao@rieti.go.jp

1. Introduction

The identification of relevant prior art is a key step in assessing the contribution of the invention to prior art, that is, its novelty and inventive step. Applicants (particularly inventors) are often knowledgeable about prior art in their field, given their active participation in the highly competitive process of cumulative technical progress. Therefore, applicant disclosure of such knowledge could potentially enhance the efficiency and quality of patent examinations and enrich public knowledge about the relevant prior art. Applicants themselves may have an incentive to disclose known prior art to quickly obtain a stable patent right. However, they may have an incentive to conceal critical prior art to obtain a patent right for an invention that lacks novelty or inventive step. A weak patent acquired through such a strategy can still be valuable because of free-rider problems in establishing invalidity (see Farrell and Shapiro (2008)). Given these conflicting incentives, whether applicants can effectively contribute to the examination process remains an unresolved issue.

Applicant disclosure policies vary significantly across major patent offices. The United States Patent and Trademark Office (USPTO) imposes extensive disclosure requirements on applicants, carrying a significant penalty for dishonest disclosure; a patent granted under dishonest disclosure may not be enforced. The examiner's work at the USPTO adds prior art that the applicant is not aware of. However, the European Patent Office (EPO) does not have such requirements, and a prior art search is the task of an EPO examiner. The EPO conducts significant in-house work to identify prior art in its search reports. The Japanese Patent Office (JPO) made a disclosure of prior art mandatory in September 2002, although such regulations are only formal, and there is no penalty for low-quality disclosures.

Few empirical studies have examined the impact of applicants' disclosure of prior art on patent examination outcomes. Cotropia, Lemley, and Sampat (2013) question the contribution of applicant disclosures by pointing out that examiners rarely use applicant-submitted art-in-office actions that narrow claims before these patents were issued, relying almost exclusively on prior art they find themselves. Earlier research has suggested that applicants might withhold relevant prior art to enhance patent value (Lampe, 2012). However, recent work suggests that evidence of widespread strategic withholding is limited (Kuhn, Younge, and Marco, 2023). Their work also reports that applicant citations in the USPTO have increased significantly in recent years, owing to a small minority of patent applications with a large majority of patent citations. Moreover, the mean technological similarity between citing and cited patents has decreased considerably (Kuhn, Younge, and Marco, 2020). However, these studies do not assess whether and how applicant disclosure affects examination efficiency and quality.

This study investigates how applicant disclosures of prior art causally affect patent examinations, specifically addressing the following questions: (1) Do disclosures by applicants improve examination efficiency in terms of grant lag and the extent of the amendment? and (2) Do they improve examination quality in terms of the frequency of challenges through trials? (3) Do they complement or substitute for the examiners' own search and examination processes? These questions are central to assessing policies that require applicants to disclose prior art of which they are aware. As illustrative examples of the implications of addressing these questions, even if applicant disclosures are not frequently used by examiners for narrowing claims, they can significantly contribute to examination efficiency if higher-quality disclosures are accompanied by the initial claims prepared by the applicants so that they are more consistent with prior art, and/or if they expedite the grant process. Moreover, even if the volume of applicant disclosures increases significantly due to a policy change, they may not contribute to examination performance if they are accompanied by a reduction in the examiner's search efforts. Furthermore, an applicant may increase disclosures that examiners can easily identify themselves (e.g., widely known prior art), so that the scope of prior art may not expand due to policy-enhancing applicant disclosures.

To address these questions, we utilize the policy reform implemented by the Japanese Patent Office (JPO) in September 2002 as a natural experiment. The Japanese patent law was revised in 2002, requiring applicants to disclose prior art when submitting patent applications. Using instruments based on such policy changes helps us overcome a key empirical challenge: Unmeasured invention or R&D project characteristics can be correlated with both examination outcomes and disclosure. Specifically, we expect higher-quality inventions to have higher-quality disclosures, which could create a potential bias in assessing how disclosures affect examinations. Moreover, a more extensive ex-ante prior art search for costly R&D projects can cause a correlation between the quality of R&D projects and high-quality disclosure (see Atal and Bar (2010)), while the quality of R&D projects is likely to be correlated with examination outcomes. Furthermore, the examiner's search efforts affect not only the applicant disclosures but also the examination outcomes. Our instrumental variable estimation controlled for endogeneity.

In implementing our research, we have developed a comprehensive dataset on disclosure quality, examinations, and trials against examination outcomes. Exploiting the in-text information on applicant disclosures, we identified prior art references that were later used by examiners in patent examinations and by other applicants. We use the former count relative to the total number of examiner citations (i.e., the coverage of examiner citations by applicant citations) as a measure of disclosure quality. For examination outcomes, we analyzed the grant lag, patent scope at application, the reduction in scope between application and grant, and the grant rate. Furthermore, we used the number of examiner citations of prior art, invalidation trials, and rejection appeal trials to measure examination quality. The effect on invalidation trials gives us critical information to assess whether the effect of the reform has promoted examination quality from the third-party perspective.

Briefly, we find that policy reforms that mildly required applicants to disclose prior art significantly improved disclosure quality, especially for high-quality inventions. The reform led to faster grants, smaller patent scopes at the application stage, and fewer amendments between the application and grant stages by inducing higher-quality disclosures. While the reform also led to more disclosures not used by the examiners, which slowed the grant process, more disclosures did not result in a higher grant rate. Furthermore, the effect of slowing the grant was dominated by the effect of higher quality on the grant lag. The reform led to reduced invalidation trials and rejection appeal trials through higher-quality disclosure. It increased the amount of prior art used by the examiner in its examination, suggesting that applicant disclosures significantly complemented examiner search efforts. Thus, our study provides the first causal evidence on how applicant disclosure quality affects examinations, including the stability of granted patent rights.

The remainder of this paper is organized as follows. Section 2 provides a brief review of existing literature on applicants' prior art disclosures. Section 3 describes the disclosure requirements introduced in Japan and the responses of the applicants. Section 4 provides a theoretical framework on the choice of disclosure and its quality, as well as the hypotheses for empirical testing. Section 5 explains the data construction and basic statistics, as well as econometric findings on the reduced-form effects of the reform on disclosure behaviors. Section 6 presents the findings on the causal effects of applicants' prior art disclosure on examinations based on instrumental variables estimation. Section 7 concludes.

2. Existing literature on prior art disclosure by applicants

The U.S. patent system imposes comprehensive disclosure requirements on applicants, and a significant body of empirical literature has analyzed the usefulness of such applicant citations.

When filing a patent application with the USPTO, an applicant must disclose all known information relevant to patentability. To fulfill this duty, applicants submit an Information Disclosure Statement (IDS), which is the formal mechanism for disclosing prior art references in the U.S. patent system. The submission of an IDS has two distinct legal effects. First, it significantly reduces the risk of patent unenforceability in future litigation due to allegations of inequitable conduct (Cotropia, Lemley, and Sampat, 2013; Bryan, Ozcan, and Sampat, 2020). Second, it allows applicants to acquire a strengthened presumption of validity against validity challenges (Juneau and MacAlpine, 2000; Buchanan, 2006; Allison and Lemley, 1998; KSR International Co. v. Teleflex, Inc., 2007). This strengthened presumption applies specifically to prior art that was considered by the patent examiner during prosecution, as compared to prior art that was not considered. Prior art disclosed in the IDS becomes part of the examination record and is subsequently reflected in applicant citations on the patent's front page.

Despite strong disclosure requirements on the applicants for the U.S. patents, examiners play a significant role in identifying prior art in the U.S.: two-thirds of citations in the average patent are inserted by examiners, and 40% of all patents have all citations added by examiners (Alcacer, Gittelman, and Sampat, 2009). Cotropia, Lemley, and Sampat (2013) assess the usefulness of such disclosures for examination by the USPTO. They find that patent examiners rarely use applicant-submitted art in rejections that narrow claims before patents are issued, relying almost exclusively on the prior art they find themselves. Specifically, they report that "of the references examiners use to reject claims, only 12.7% come from the applicants, while 87.2% come from examiners" for patents issued in 2007. This finding may not be surprising, given that applicants typically design claims to avoid overlapping with known prior art.

Several studies have examined the strategic behavior of applicants during prior art disclosures. Lampe (2012) suggests that applicants may strategically undercite prior art to enhance the value of their patents, estimating that applicants withhold between 21% and 33% of relevant citations for strategic reasons. However, Kuhn et al. (2023) cast doubt on its empirical design and find no significant evidence of strategic withholding on a new empirical basis consistent with legal standards and examiner citation practices. Using a game-theoretic framework, Langinier and Marcoul (2016) analyzes how low cost of concealing prior art makes it difficult to design a system that prevents applicants from strategically concealing information.

Kuhn et al. (2020) report that applicant citations to the USPTO have undergone significant changes in recent years. They find that a small minority of patent applications now generate the most patent citations, whereas the mean technological similarity between citing and cited patents has declined considerably. This decline in technological similarity suggests an increase in potentially irrelevant references that may complicate rather than facilitate the examination process. Okada and Nagaoka (2017) show the potential impact of disclosure quality on examination outcomes. They show that the patent scope narrowed during examinations in two-thirds of the granted patents. Importantly, they find negative correlations between the incidence and extent of amendments (scope narrowing) and the quality of the applicant's prior art disclosure, although this is not causal evidence. Our causal approach enable us to identify the mechanisms through which higher-quality applicant disclosures enhance patent examination performance in terms of the efficiency and stability of examination outcomes.

The relationship between applicant disclosures and examiner search efforts is a key factor that influences the contribution of applicant disclosures to examination performance. Since the examiner would need to screen applicant disclosures for useful prior art, the increase in applicant disclosures induced by the policy may crowd out the examiner's time that could otherwise be spent on substantive examinations (see Frakes and Wasserman (2017) for the significance of the allocation of time by U.S. examiners in examination quality). Conversely, examiners may be able to devote more search effort to applications that they perceive as weak in response to increased disclosures (see Lei and Wright (2017) for evidence of rational search efforts by USPTO examiners). In the theoretical literature, Langinier and Marcoul (2008) assume that prior art disclosure by the innovator lowers the examiner's search cost and that the examiner exerts more search effort the more prior art the innovator discloses. They argue that an examiner should maintain an equal screening intensity across all applications, under such an assumption, to induce honest information transmission from applicants. Atal and Bar (2010) find that search intensity by an applicant increases with R&D cost, the examiners' expected search effort, and with patenting fees, and that innovators prefer to correlate their search technology with that of the patent office, so as to reduce the probability of finding prior art negative to the patentability of its invention when such "bad patent" has high value. Both theoretical studies assume that applicants and examiners use identical search technologies. However, they may actually possess a different knowledge base, as analyzed in this study.

Our empirical analysis, without assuming a particular behavioral model of an examiner, addresses how examiners respond to the reform enhancing applicant disclosures—specifically whether the total prior art used by examiners increases in response to such reform. In Japan, a significant proportion of prior-art searches are outsourced. Yamauchi and Nagaoka (2015) find that outsourcing prior art search significantly decreased the frequency of appeals against both examiners' rejection and grant decisions while reducing examination duration. These findings suggest that prior art disclosure by applicants, induced by policy reform, may potentially improve examination performance.

In summary, existing research has primarily focused on the nature of applicant disclosures and whether examiners utilize applicant citations. However, they did not examine the causal effects of applicant disclosure on the examination process. We control for the endogeneity of disclosure quality with respect to invention quality and examiner search efforts by using exogenous policy changes and identify the mechanisms through which the quality and quantity of applicant disclosures may enhance patent examination performance in terms of efficiency and quality.

3. Applicant's prior art disclosure in Japan

The Japanese patent law was revised in 2002, requiring applicants to disclose prior art when submitting patent applications, with the law taking effect on September 1, 2002. This policy was introduced to enhance the examination efficiency and strengthen the stability of patent rights in an environment with a large backlog of patent applications. The JPO expected that the disclosure of prior art would enable examiners to conduct examinations more quickly and adequately. Additionally, the JPO anticipated that applications with thorough descriptions of prior art would help the office grant a patent that is less likely to face invalidity challenges and more likely to be enforceable.

If disclosure is not made or is made without an adequate explanation, an examiner can issue a notice for correction. Failure to comply with such a notice can constitute grounds for rejecting the application. However, this regulation is largely formal. Typically, the disclosure of just one piece of prior art satisfies the requirement, meaning that there is no mechanism to enforce the disclosure of all relevant prior art known to the applicant. Unlike in the U.S., insufficient disclosure does not constitute grounds for invalidity. Thus, through the reform, the JPO sent a credible signal to applicants that their disclosures would be reviewed and utilized in examinations, but did not introduce incentives directly linked to the content of the disclosures.

To evaluate the effects of this reform, we classified the citations by applicants and examiners into the following categories: As shown in Figure 1, we classify the applicant citations disclosed in application documents (in text)[4] and the examiner citations recorded in office actions into three distinct categories: (a) citations made by applicants but not used by examiners in their examination, (b) common citations that were disclosed by applicants and cited by examiners, and (c) examiner citations not covered by applicant disclosures. This classification framework allows us to quantitatively assess how effectively applicants identify prior art relevant to examination decisions. Note that all applicant citations are disclosed to the JPO at the application stage and made public at the pre-grant publication stage.

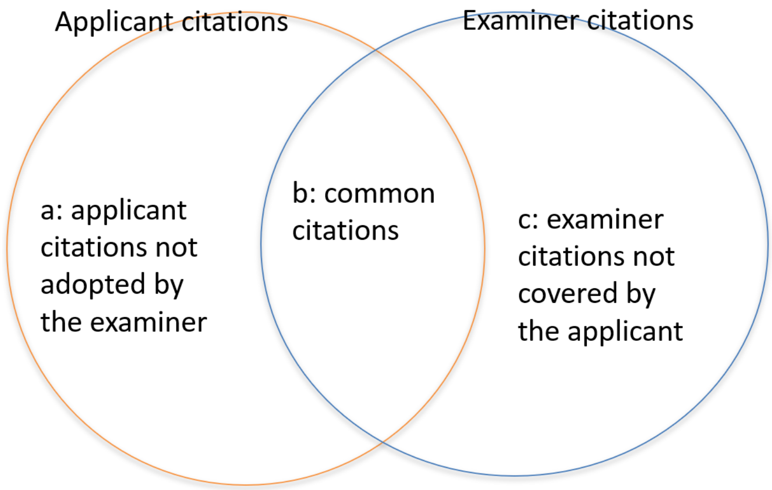

Figure 1: Structures of citations

Figure 2 shows the distribution of the number of applications requested for examination by the number of applicant citations over time for both total applicant citations ($a+b$) and common citations (b). This reform triggered a substantial increase in disclosures. For total applicant citations, zero-citation applications decreased dramatically from 56% before the reform to just 9.5% afterward. Conversely, applications with one citation increased from 23.2% to 46.1% post-reform. Applications with two or more citations more than doubled from 20.6% to 44.4% (with

[4] There are no "front –page" for a collection of applicant and examiner citations in the JPO patent application documents. We do not use patent grant documents for applicant citations, since they can reflect the prior art newly discovered by an examiner.

21.9% having exactly two citations and 22.5% having three or more). These significant shifts suggest that inventors responded strongly to the legal reform. The increase in common citations was more modest, but still significant. Specifically, the share of applications with no examiner-adopted applicant citations decreased from 85% pre-reform to 70% post-reform, applications with one common citation increased from 12.5% to 25%, and those with two or more common citations increased from 2.5% to 5.3%.

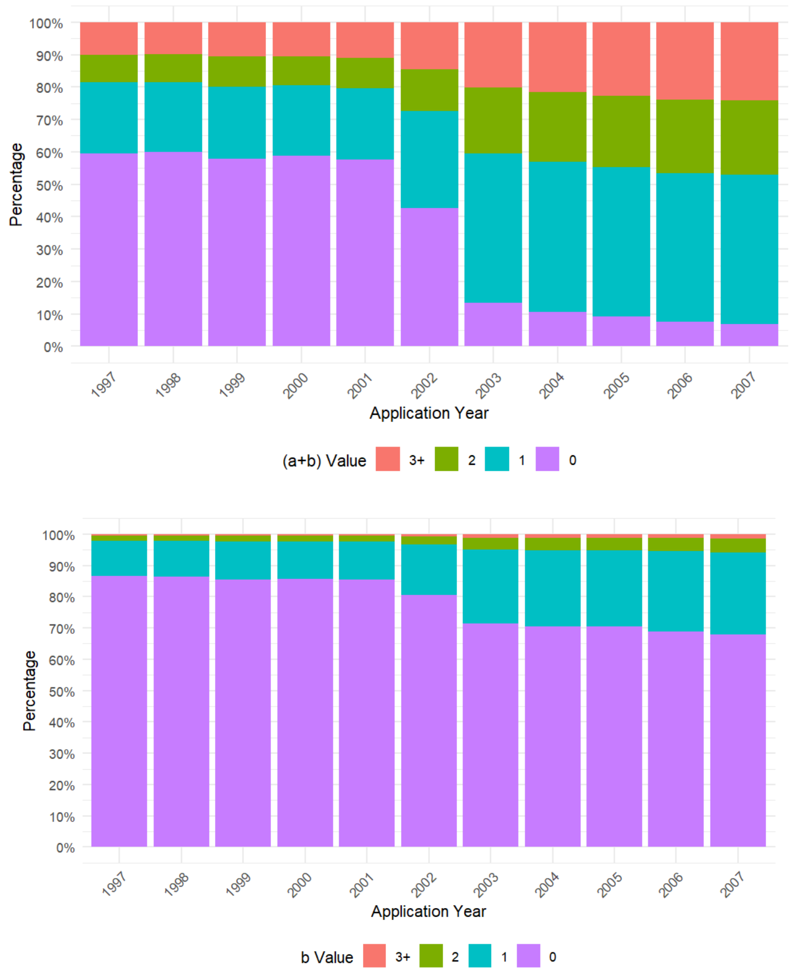

Figure 2: The compositions of the total number of applicant citations (a+b) and common citations (b)

Note: The data consist of 1,808,700 patent applications filed between 1997 and 2007 that requested examination at the JPO, for which both the firm ID from the National Institute of Science and Technology Policy (NISTEP) dictionary of Japanese firm names and the World Intellectual Property Organization (WIPO) 35 technology fields could be identified.

Figure 3 summarizes the direct impact of the policy change on the average levels of citations in three categories (*a*, *b*, and *c*). From 2001 to 2003, the number of applicant citations (*a*+*b*) increased by an average of 0.87 per patent. During this period, the number of examiner citations (*b*+*c*) increased by 0.45 per patent, whereas the number of common citations (*b*) shared by both applicants and examiners increased by 0.17 per patent. Consequently, the proportion of examiner citations that overlapped with applicant citations rose from 4.2-5.5% before the reform to 7.6-8.2% in the years following the reform.

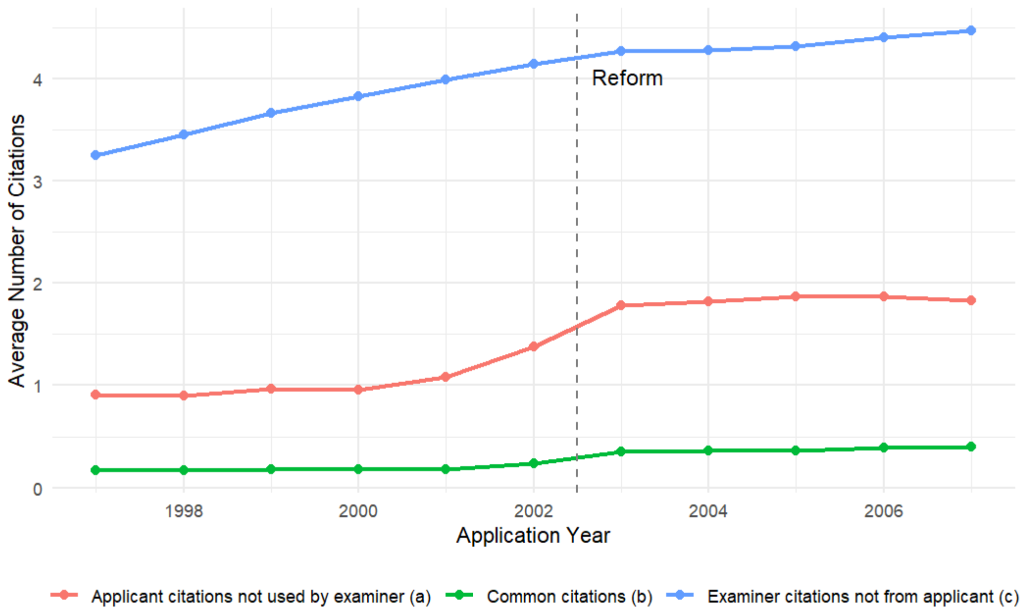

Figure 3: Average citations by type and application year: Applicant-only (*a*), Examiner-only (*c*), and Common citations (*b*)

Note: The data consist of 1,808,700 patent applications filed between 1997 and 2007 that requested examination at the JPO, for which both the firm ID from the National Institute of Science and Technology Policy (NISTEP) dictionary of Japanese firm names and the World Intellectual Property Organization (WIPO) 35 technology fields could be identified.

Figure 4 shows our measure of applicant disclosure quality—the share of common citations in examiner citations b/(b+c)—across WIPO 35 technology sectors, comparing the pre-reform (1999-2001) and post-reform (2003-2005) periods. While disclosure quality improved across all sectors, its magnitude varied significantly. Sectors with high pre-reform disclosure quality also show significant improvements. Disclosure quality in Food chemistry and Pharmaceuticals increased from 6.9% to 11.4% and 10.6%, respectively. In contrast, those in Digital communication and Telecommunications started at lower levels (2.2% and 2.0%), rising to 3.9% and 4.8%, respectively. These patterns are consistent with the findings of Corsino et al. (2019), who, using a different classification system (Observatoire des Sciences et des Techniques, OST) and U.S. data, demonstrated that discrete technologies (such as Biotechnology, Pharmaceuticals, and Organic Chemistry) show systematically higher incentives for prior art disclosure than complex technologies (such as Computers and Telecommunications). They attributed this pattern to the nature of discrete technologies, where a single patent may be crucial for protecting an entire innovation, thereby creating stronger incentives for applicants to thoroughly cite prior art to reduce invalidation risks. The systematic differences in disclosure quality and their response to the reform across sectors in our Japanese data also suggest that they are responses to significant variations in how an individual patent contributes to the appropriation of R&D investments (higher-quality disclosure if an individual patent matters) and how rapidly competing new inventions emerge (lower-quality disclosure when such an emergence is rapid). Although we do not analyze the sources of such variations across sectors, we use them as mediators of the effects of the reform on incentives for higher disclosure quality.

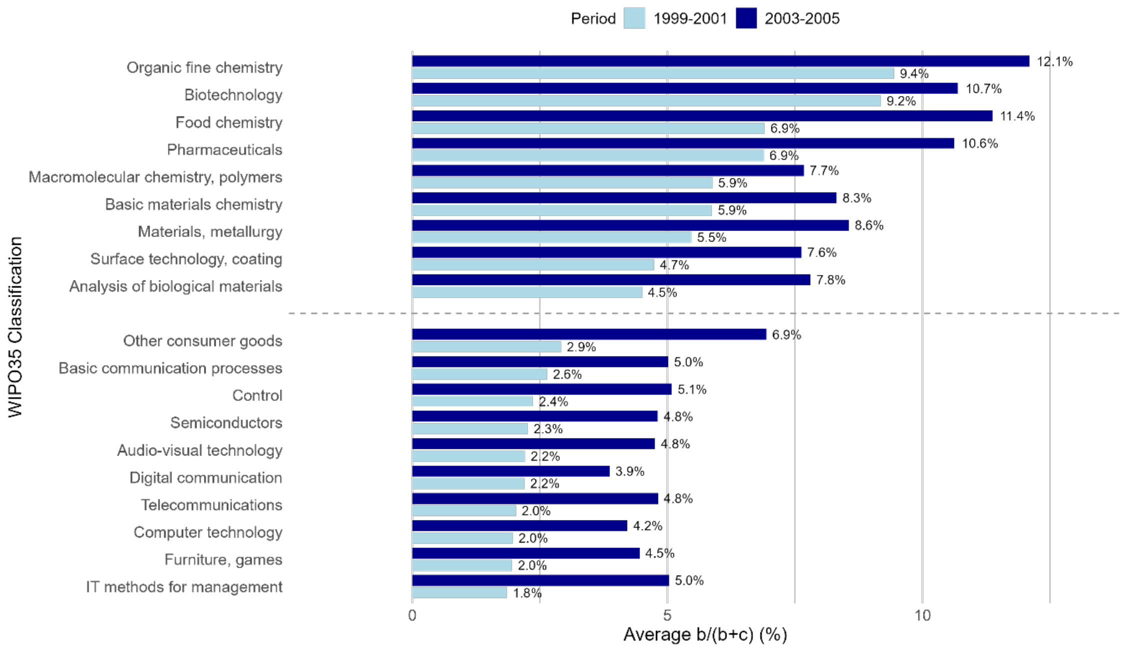

Figure 4: Disclosure quality (b/(b+c)) before and after the reform by WIPO35 technology sectors

Note: The figure compares disclosure quality between the pre-reform (1999-2001) and post-reform (2003-2005) periods, showing the 10 highest and 10 lowest sectors ordered by their pre-reform values.

4. Theoretical framework and hypotheses

4.1 Theoretical framework on choice of disclosure and its quality

To motivate our empirical analysis, we offer a simple theoretical framework for applicant disclosure. We focus exclusively on the applicant's disclosure decision and analyze how invention quality (q) and its effect on patent value (A) affect disclosure decision, as well as its quality (θ).

An applicant's disclosure decision is endogenous and significantly influenced by the quality of the invention. This decision involves weighing the potential benefits against the costs. For inventions with quality below a certain inventive step threshold (q_{thre},), any granted patent would be technically invalid if all relevant prior art were known. In these cases, disclosing prior art reveals this invalidity, creating a strong disincentive for thorough disclosure. Conversely, when a firm has a higher-quality invention, it can benefit from optimal disclosure quality (θ) in three key ways: 1) Enhanced enforceability against infringements: High-quality disclosure helps establish claims consistent with relevant prior art, reducing future invalidation risks; 2) Faster patent grant: Thorough disclosure assists examiners in identifying relevant prior art early, enabling faster grants and securing first-mover market advantages; 3) Reduced information asymmetry ("Lemon's discount"): Comprehensive disclosure signals patent quality to market participants, allowing high-quality patents to receive more gains from appropriate valuation. This relationship between invention quality and disclosure decisions creates a self-selection mechanism in which higher-quality inventions receive more thorough disclosures. This self-selection generates an endogeneity problem when empirically examining the causal effects of disclosures on examination outcomes, which we address in our analysis.

In our model, disclosure quality (θ) represents how thoroughly an applicant reveals relevant prior art, which conceptually corresponds to our empirical measure b/(b+c)—the proportion of examiner citations that are disclosed by the applicant upon application.

Importantly, all these benefits increase with patent value (v), which in turn depends on the underlying quality of the invention (for simplicity, we assume that these two are equal). We formalize this relationship by expressing the total benefit (B) from disclosure quality, which increases proportionally with the patent value (v) as well as with the disclosure quality (θ):

$$B = A\theta v = A\theta q. \quad (1)$$

where A is a parameter that measures how effectively an applicant's disclosure quality translates into disclosure value. The 2002 reform increased this parameter A by enhancing the recognition and utilization of applicant disclosure.

The marginal cost of disclosure (such as search cost) increases with the level of disclosure, so that the cost of disclosure is given by

$$C = \frac{1}{2}(\theta - \theta_{min})^2. \quad (2)$$

where θ_{min} is the level of disclosure of the prior art even if the applicant discloses minimally. Given equations (1) and (2), the profit maximizing level of disclosure θ (denoted by θ_*) is given by

$$(\text{MC=})\ \theta_* - \theta_{min} = \text{Aq}\ (= \text{MB}). \quad (3)$$

In other words, the level of disclosure θ_* increases with *A* and *q*. There is a larger response in disclosure quality to reforms by firms with higher invention quality.

We now consider the choice between disclosure and non-disclosure. Figure 5 illustrates this decision by plotting the expected profits against invention quality for both the disclosure and non-disclosure strategies. The figure shows that when an invention has a small or no inventive step ($q < q_{thre}$), it does not qualify as a patent under proper examination. By avoiding disclosure, the applicant may obtain a patent for the invention. Although such a patent is too weak for a patentee to rely on for investment protection, it may still function as a deterrent to competing investments due to the free-rider problem of invalidation (Farrell and Shapiro, 2008; Lemley and Shapiro, 2005). However, disclosure eliminates this potential gain by revealing the invention's lack of patentability. Thus, as this Figure demonstrates, applicants can gain more from non-disclosure for low-quality inventions (the non-disclosure profit line is higher than the disclosure line for $q < q_{thre}$).

The value of choosing the disclosure strategy increases with invention quality more than the value of choosing non-disclosure when invention quality is above the threshold (q_{thre}), as shown in Figure 5. This is because when a firm discloses the prior art, we have the following slope for the expected value of the patent ($\pi = B - C$), due to the envelope theorem:

$$\partial \pi_{disclosure}(q, \theta_*)/\, \partial q = \partial\{A\theta_* q - \frac{1}{2}(\theta_* - \theta_{min})^2\}/\, \partial q = A\theta_*. \quad (4)$$

Given that we have an optimal quality choice, as shown in Equation (3). Conversely, when a firm does not disclose the prior art, the disclosure quality remains at the minimal level $\theta = \theta_{min}$, which is lower than the optimal disclosure level θ. Thus, we have

$$\partial \pi_{non-disclosure}(q, \theta_*)/\, \partial q = A\theta_{min} < A\theta_*. \quad (5)$$

As this figure indicates, an applicant with a higher-quality invention is more likely to choose disclosure. Additionally, the level of disclosure increases with both invention quality and reform, thereby enhancing the recognition and utilization of applicant disclosures.

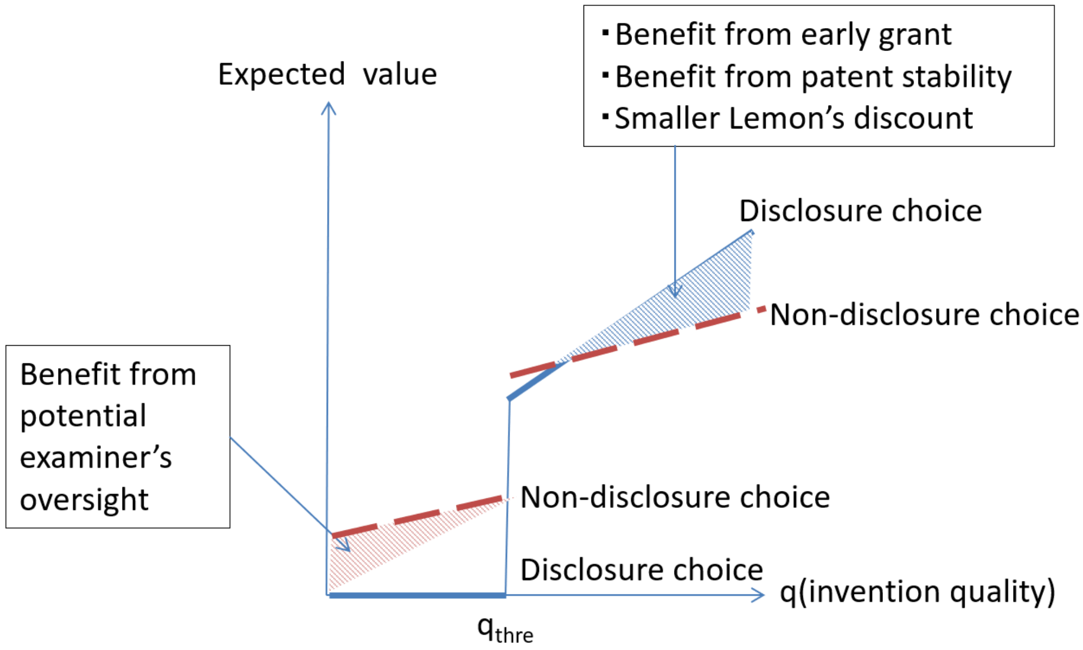

Figure 5: Disclosure vs. non-disclosure of prior art

4.2 Hypotheses

The analytical framework developed above motivates the testable hypotheses regarding applicants' disclosure of prior art. First, as Equation (3) suggests, disclosure quality improves with policy changes, enhancing the value of disclosure for the applicant (parameter A). The 2002 reform in Japan signaled that examiners would actively use applicant disclosures in patent examinations, effectively increasing parameter A. This leads to the following hypothesis regarding disclosure quality:

Hypothesis 1: Quality of applicant disclosure

The policy reform enhancing the value of applicant disclosure improves disclosure quality more for high-quality inventions.

If the knowledge bases (including search technology) of an examiner and applicant completely overlap, applicants identify prior art that the examiners would have otherwise found independently. In this case, the prior art that an examiner will use for their examination is not affected by the applicant's disclosures, meaning that only the composition of the prior art (b+c) changes, and its level does not. However, if an applicant adds new prior art that the examiner cannot, the amount of prior art used for an examination would increase. Such a possibility is high if a firm with high invention quality improves its disclosure quality. Thus, we have the following hypothesis regarding the total number of prior arts used in the examination:

Hypothesis 2: Applicant disclosure and the number of prior art used for examination

The policy reform will increase the number of prior art references used by the examiner in examinations, if an applicant adds new prior art that the examiner cannot. Such an increase in the number of prior art will be stronger when the reform significantly increases the disclosure quality by a firm with high invention quality.

When a policy change leads to higher-quality disclosure by applicants, examination efficiency improves. First, applicants with a better understanding of the relevant prior art will proactively adjust their claims to accommodate prior art constraints, resulting in a narrower patent scope. Second, when applicants and examiners share an understanding of the prior art landscape, examinations should proceed more efficiently, leading to faster grants and fewer amendments to claims between applications and grants.

However, the effect of higher-quality disclosures on grant rates is theoretically ambiguous. On the one hand, applicant-provided prior art may reveal limiting prior art that examiners might otherwise miss, thereby reducing grant rates. On the other hand, narrower initial claims that account for known prior art constraints are more likely to satisfy patentability requirements. Importantly, even if higher disclosure quality reduces the grant rates for marginal inventions, applicants with valuable inventions can still benefit from increased patent stability and reduced litigation risks.

Hypothesis 3: Quality of applicant disclosure and examination efficiency

Higher quality disclosures induced by the policy reform will lead to: (1) Shorter time to grant, (2) Narrower patent scope at application, (3) Fewer amendments to patent scope between application and grant.

These effects should be stronger for applications with higher underlying invention quality, as suggested by the complementarity between invention quality and disclosure quality identified in Hypothesis 1.

There are two types of errors in examinations: Type 1 errors, which involve granting patents that do not meet the novelty and inventive step requirements, and Type II errors, which involve rejecting applications that satisfy these patentability criteria. Higher-quality applicant disclosures can reduce these two types of examination errors unless they significantly hinder the examiner's search efforts. However, if an examiner begins to depend strongly on the applicant's disclosure, they may overlook an important novelty-negating prior art not covered by the applicant's disclosure, causing a Type I error. Furthermore, if an examiner fails to understand the technological trajectory leading to that invention, they may see only a small inventive step between the invention and the prior art supplied by the applicant due to hindsight bias, causing Type II errors. However, such negative outcomes would not occur if an examiner behaved rationally and used applicant disclosures as a channel for searching for prior art. Lei and Wright

(2017) provide interesting evidence on such rational search efforts by USPTO examiners; they devote more search effort to applications they perceive as weak.

We can assess these possibilities by analyzing the effects of the reform on examination quality using data on the rates of invalidation and rejection appeal trials. We propose the following hypothesis regarding examination quality in terms of trials against examination outcomes:

Hypothesis 4: Quality of applicant disclosure and examination quality

Higher-quality disclosures induced by the policy reform will reduce both invalidation trial rates and rejection appeal trial rates.

To test *Hypothesis 4 (reduced invalidation trial rate),* we assume that when the quality of applicant disclosure is high from the examination perspective, the quality of applicant disclosure is also high from the third-party perspective.

The reform will also increase the number of applicant disclosures, some of which are useful as prior art, while others are not. Because the examiner would need to screen applicant disclosures for useful prior art, an increase in applicant disclosures can increase the time necessary for examination, in contrast to the effect of higher quality. It can also increase the grant rate if the increase in irrelevant disclosures by applicants consumes examiner time that could otherwise be spent on substantive examinations (see Frakes and Wasserman (2017) in the context of the allocation of time by U.S. examiners). Thus, we propose the following hypotheses:

Hypothesis 5: Volume of applicant disclosure and examination quality

In contrast to the positive effects of higher quality disclosure (Hypotheses 3-4), a larger number of applicant disclosures induced by the policy reform can have opposite effects: increasing grant *lag and potentially raising grant rates if more disclosures divert examiner time from substantive examination.*

5. Estimating the reduced-form effects of reform on applicant disclosure behaviors

5.1 Data construction and basic statistics

We utilize several comprehensive databases in this study. The core patent publication data and patent prosecution information come from the official publication and "Seiri-Hyoujyunka" databases of the JPO, maintained by Artificial Life Laboratory, Inc. These databases provide detailed information on patent applications with extracted in-text citations, prosecution histories, and examiner citation information. To accurately identify applicants (companies) across patent applications, we employed the company name dictionary developed by the National Institute of Science and Technology Policy (NISTEP). We develop a comprehensive dataset that enables us to track patent applications from filing through examination to granting, and subsequently to trials, while accurately identifying both applicant and examiner citations throughout the process.

Our analysis focused on the specific time window surrounding the 2002 policy reforms. The sample period for the estimation starts in October 2001, when a preceding policy change reduced the maximum period for examination requests from seven to three years, followed by a discontinuous increase in examination requests. Our sample period ended in August 2003, covering 11 months before the reform (implemented on September 1, 2002) and 12 months thereafter. We use only the patent applications requested for examination as our sample, which includes both granted and rejected applications, providing a comprehensive analysis of the examination process.

Our unit of analysis is a combination of Japanese firms and technology fields (WIPO35 technology fields), rather than individual patents. This aggregation strategy enables us to control for unobservable heterogeneities in invention-specific quality by introducing firm × WIPO35 field fixed effects. We construct a monthly panel based on the average values for these firm × WIPO35 combinations, using the number of observations in each cell as weights in our regressions to reflect the precision of these averages.

For our empirical analysis, we identify applicant disclosures of prior art from the textual information of the patent application documents and assess the policy reform by the JPO regarding applicant disclosures. Since applicant disclosures are fixed at the time of application, they are fully exogenous to the examinations, unlike U.S. applicant citations on the front page, which are based on the IDS, which collects all submissions from applicants up to the grant stage.

Table 1 presents the basic statistics of the variables used in the estimation. Our main control variables consist of several measures that capture invention size and quality (collectively denoted $q_{i,t}$). These include *nipc*: number of International Patent Classification (IPC) codes assigned to the patent application; *nclaims*: number of claims in the patent application; *napplicant*: size of the applicant team (number of applicants); *ninventors*: size of the inventor team (number of inventors); *citing_count_npl*: number of scientific literature (non-patent literature) citations made by the application; *cited_count*: number of forward citations received from subsequent patent examinations; and *ln_request_number*: logarithm of the number of patent examination requests at the firm × WIPO35 x month level. The last variable controls for the monthly variation in invention quality due to seasonal or long-term variation in the propensities for examination requests.

To test *Hypotheses* 2–5, we analyzed eight variables characterizing examination performance. We used the total number of examiner citations (*b*+*c*), indicating the total number of prior art used in the examination, as well as its components: the sum of common citations (b) and examiner-only citations (c).

To assess the examination efficiency, we used the following variables. *Grant lag* is the time between the examination request date and patent registration date (in days). *Patent scope application* is the inverse of claim length (number of characters) at application, *Patent scope registration* is the inverse of claim length at registration, and *the Size of scope reduction* is the difference between the application and registration scope measures multiplied by 100. To analyze these patent scope-related measures, we exclude chemical-related fields (WIPO35 classification fields 14-19) where Markush-type claims make character counts an inappropriate proxy for scope. These scope measures are computed only for patents with complete scope information for both applications and registrations. We also used *the Grant rate*, which is the proportion of the examined applications that received patents, multiplied by 100.

We constructed two measures of examination quality: *the Invalidation trials rate*–the ratio of third-party appeals for invalidation to total granted patents–and *the Rejection appeals trials rate*, the ratio of applicants' appeals against refusal to total rejected patents (including those later granted through appeals), both multiplied by 100. The JPO abolished its opposition system on January 1, 2004, while simultaneously expanding the invalidation trial system to allow anyone to request such trials. Consequently, our sample covers only new invalidation proceedings under the new system.

To identify the policy reform effect, we include a dummy variable that equals zero for applications filed before September 2002 and one for those filed after the reform took effect. Table 1 also provides the basic statistics for the IV and dependent variables, which are explained later.

Table 1: Basic statistics for estimation data

	Before					After				
	Mean	Sd	Min	Max	N	Mean	Sd	Min	Max	N
Control variables										
nipc	3.422	2.154	1	33	52233	3.312	2.100	1	67	55525
nclaim	5.294	3.844	1	82	52233	5.361	3.725	1	78	55525
napplicants	1.164	0.453	1	12	52233	1.167	0.466	1	15	55525
ninventors	2.351	1.373	1	23	52233	2.349	1.381	1	18	55525
citing_count_npl	0.722	2.203	0	153	52233	0.909	2.374	0	85	55525
cited_count	2.820	3.081	0	70	52233	2.528	2.889	0	141	55525
ln_request_number	0.647	0.891	0	5	52233	0.646	0.891	0	6	55525
Endogenous variables										
a	0.913	2.506	0	134	52233	1.564	2.934	0	98	55525
b	0.209	0.474	0	10	52233	0.381	0.620	0	27	55525
c	3.972	2.530	0	43	52233	4.167	2.585	0	48	55525
b + c	4.181	2.665	0	43	52233	4.549	2.818	0	59	55525
b/(b+c) (x100)	4.183	8.819	0	50	52233	7.331	10.686	0	50	55525
IV variables										
ab_iv	0.000	0.000	0	0	52233	1.033	1.932	0	66	45470
cited_inventor_iv	0.000	0.000	0	0	52233	0.708	0.403	0	5	45465
Dependent variables										
Grant rate (x100)	54.069	43.189	0	100	52233	55.259	43.238	0	100	55525
Grant lag	1039.920	322.762	39	3277	35186	1075.931	303.016	50	2955	37785
Patent scope application (x100)	0.516	0.316	0	6	31805	0.501	0.306	0	6	34316
Patent scope registration (x100)	0.348	0.211	0	4	31805	0.334	0.203	0	5	34316
Size of scope reduction (x100)	0.183	0.254	-2	4	31805	0.178	0.238	-2	5	34316
Invalidation trials rate (x100)	0.120	3.173	0	100	35186	0.081	2.639	0	100	37785
Rejection appeals trials rate (x100)	16.082	32.616	0	100	34283	14.459	31.479	0	100	35510

Note: "Before" and "After" refer to 11 months preceding the reform (September 1, 2002) and 12 months following the reform, respectively. All the statistics are based on observations aggregated at the firm × WIPO35 technology field level, with each observation representing the monthly average for that combination. Patent scope variables and trial rates exclude chemical-related fields (WIPO35 fields 14-19) and are computed only for patents with scope information at the application and registration stages. The validation and rejection appeal trial rates are expressed as ratios of the total number of granted and total number of rejected patents, respectively.

5.2 Reduced form model on disclosures and examiner citations

Using a reduced-form estimation, we examine how applicant disclosure behaviors and examiner citations vary with measures of invention size and quality, as well as how they responded to the 2002 policy reform. The dependent variables in our analysis are four distinct indicators of prior art disclosures and examiner citations that appear in Japanese patent applications and patent prosecution data from the JPO: applicant-alone citations(a), common citations (b), examiner citations alone (c), and the coverage of examiner citations by applicant citations ($b/(b+c)$ in terms of percentage). Comparing the coefficients for applicant- and examiner-alone citations would inform us about the sources of the comparative advantage of applicants and examiners in identifying prior art.

All our models include firm × WIPO35 field-fixed effects, which are crucial for our identification strategy. These fixed effects absorb time-invariant heterogeneity in disclosure practices across firms and technological domains, ensuring that our results identify within-firm and within-technology field changes in disclosure behavior rather than cross-sectional differences in firm policies or technology-specific practices. These controls help isolate the causal effect of the reform from confounding factors related to firm-specific disclosure strategies or technology-dependent disclosure patterns.

Designating a disclosure variable by $d_{i,t}$, the vector of the explanatory indicators by $q_{i,t}$, the firm by technology field fixed effect by u_i, and the error term by $\varepsilon_{i,t}$, we have the following Equation for estimation:

$$\mathrm{d}_{i,t} = \beta_0 + \beta_1 q_{i,t} + \beta_2 Reform_t + u_i + \varepsilon_{i,t}. \quad (6)$$

We account for preexisting time trends by estimating each dependent and endogenous variable using pre-reform period data with monthly trend dummies and control variables ($q_{i,t}$). We then detrended our data based on these estimates to isolate the true policy impact from the underlying temporal patterns if the pre-trend was significant.[5] The validity of this pre-trend subtraction approach is examined in detail in Appendix C, where we show that our reduced firm results for

[5]For invalidation trials, the rarity and high monthly volatility of non-zero observations (monthly means of 0.001-0.002) lead to unstable estimation (an estimation of the pre-trend using only the 11-month pre-reform period gives us the pre-trend coefficient of -0.012 per month, many times more than the average). Therefore, for this variable, we estimate the trend using the entire sample period to detrend the data (trend coefficient of -0.0052). This approach is conservative in estimating the reform effect, since it assumes that the reform has only a discontinuous (ladder) effect starting from its first month.

the policy effect are generally consistent with those obtained by the IV estimations, which are likely to be less dependent on the pre-trend estimates.

5.3 Response of applicant disclosures and examiner citations

Table 2A presents our estimation results of how the policy reform affected both applicant disclosure and examiner citations. First, we examined the effects of invention characteristics on size and quality. According to Models (1) to (3), based on within-firm by technology variations, a larger team or higher quality of inventions, as measured by any of five key indicators (*nipc*, *ninventors*, *citing_count_npl*, *cited_count*, and *nclaims*), are associated with an increase in citations of all types: applicant-alone citations (*a*), common citations (*b*), and examiner-alone citations (*c*), controlling for firm × WIPO35 fixed effects. Moreover, a larger number of examination requests (*ln_request_number*) is associated with a significantly lower number of common citations (b). This is expected, as more examination requests are associated with lower average invention quality.

The estimated coefficients are generally larger for examiner-only citations than for applicant-only citations, with one major exception: the number of scientific literature citations made by the application (*citing_count_npl*). To compare the relative importance of the different variables for these two citations, we assessed each indicator's impact by multiplying its estimated coefficient by its standard deviation. This analysis reveals that *citing_count_npl* has the greatest impact on applicant-only citations, whereas *nipc* and *cited_count* have the greatest influence on examiner-only citations (*c*). These findings suggest that applicants and examiners have different knowledge bases for identifying prior art.

Table 2A: Invention quality, policy reform, and disclosures, Fixed effects estimation (October 2001 – August 2003 monthly)

	(1)	(2)	(3)	(4)	(5)
	a	b	c	b / (b + c) (x100)	b + c
nipc	0.029***	0.003***	0.111***	−0.061***	0.114***
	(0.006)	(0.001)	(0.005)	(0.019)	(0.005)
napplicants	−0.081***	0.000	0.016	0.072	0.016
	(0.030)	(0.005)	(0.024)	(0.098)	(0.026)
ninventors	0.025***	0.007***	0.063***	0.069**	0.070***
	(0.009)	(0.002)	(0.007)	(0.029)	(0.008)
citing_count_npl	0.227***	0.006***	0.006	0.069***	0.012***
	(0.005)	(0.001)	(0.004)	(0.016)	(0.004)
cited_count	0.018***	0.005***	0.073***	0.031***	0.078***
	(0.004)	(0.001)	(0.003)	(0.012)	(0.003)
nclaim	0.029***	0.002***	0.028***	−0.008	0.030***
	(0.003)	(0.001)	(0.003)	(0.010)	(0.003)
ln_request_number	−0.007	−0.009***	0.003	0.131***	−0.006
	(0.013)	(0.002)	(0.011)	(0.043)	(0.011)
reform	0.527***	0.127***	−0.080***	2.723***	0.048***
	(0.013)	(0.002)	(0.011)	(0.043)	(0.011)
Num.Obs.	107 758	107 758	107 758	107 758	107 758
Firm x WIPO35 FE	Yes	Yes	Yes	Yes	Yes
Subtract Pre-Trend	Yes	Yes	Yes	Yes	Yes
R2	0.804	0.368	0.413	0.352	0.412
R2 Adj.	0.744	0.177	0.235	0.157	0.234
RMSE	1.82	0.45	2.00	8.05	2.14

According to Model (4), our measure of applicant disclosure quality (the share of examiner citations anticipated by applicant citations, *b/(b+c)*) increases significantly with *citing_count_npl* but declines with *nipc*. When the invention builds on scientific knowledge, the applicant is more capable of contributing to the prior art that is relevant to the examination. As Models (2) and (3) show, examiner-alone citations did not increase with *citing_count_npl*, whereas common citations increased significantly. Conversely, disclosure quality decreases with *nipc*. This negative relationship may indicate that as the technological scope of the invention becomes more diverse, the gap between the applicant's and examiner's perceptions of relevant prior art widens, such that the number of common citations does not increase. In contrast, the number of examiner citations increases significantly.

The coefficient of the reform dummy in Table 2A shows the impact of the 2002 policy change, controlling for invention characteristics, the number of examination requests, monthly pre-trends, and firm × WIPO35 fixed effects. Applicant disclosure measures have increased significantly following the reform. Specifically, common citations (*b*) increased by 0.127 (representing a 60.8% increase from the pre-reform average of 0.209), suggesting that the applicant added more prior art which are also later cited by the examiner. Applicant-only citations (*a*) increased by 0.527 (a 57.7% increase from the pre-reform average of 0.913). Importantly, Model (3) shows that examiner-only citations (c) decreased significantly by 0.080 after the reform, indicating that more examiner citations were predicted by applicant citations; thus, some substitution between applicant and examiner search efforts occurred. At the same time, Model (5) reveals that the total prior art used in examination (*b*+*c*) still increased significantly by 0.048, suggesting that the overall effect of increased applicant disclosure was complementary to the examiner's search efforts in the aggregate, supporting Hypothesis 2.

6 Assessing the causal effects of disclosure quality

6.1 Instrumental variable estimation model

In this section, we examine the causal effects of disclosure quality on examination outcomes using instrumental variables based on the September 2002 policy changes. Our analysis includes two endogenous variables that serve as quality and quantity measures of applicant disclosure: disclosure quality (*b/(b+c)*), which measures the proportion of examiner citations anticipated by applicants, and applicant-only citations (*a*), which represent the number of disclosures not utilized in the examination process (See Figure 1). These are likely to be endogenous to both the quality of invention and examiner search efforts.

We employed two instrumental variables to identify the causal mechanisms. The first instrument (*inventor_cited_iv*) is based on the invention quality at the firm × WIPO35 technology field level. This instrument is constructed by interacting the *reform dummy* with the total forward citations received by each firm-technology unit during the pre-sample period (1998-2000). We expect firms capable of generating high invention quality to respond more strongly to reform by improving their disclosure quality. The second instrument (*ab_iv*) is based on the firm's propensity to disclose. It is constructed by interacting the *reform dummy* with the total number of applicant citations made by each firm-technology unit during the pre-sample period (1998-2000). This instrument reflects our expectation that firms with high-level disclosures before the reform would have stronger incentives and capabilities to enhance their disclosures following policy changes.

Since our estimation includes firm × WIPO35 fixed effects as controls, these instruments are not correlated with the missing variables at the firm × WIPO35 level. Therefore, they are likely to satisfy the exclusion restriction for valid instruments. As a check, we compare the policy effect estimates based on the reduced-form model using only the reform dummy with those based on the above IVs in Appendix B. These results are broadly consistent. Since our IV estimation mainly uses the variations in the changes in disclosure behaviors before and after the policy change across firm×WIPO35 sectors, it also tends to be robust to variations in a common pre-trend estimate of each dependent variable. As in our previous analyses, we used monthly panel data for the same period with the same weighting approach and detrending method.

Designating the examination outcome by $y_{i,t}$, a vector of two disclosure variables by $d_{i,t}$, the vector of invention size and quality indicators by $q_{i,t}$, the firm x WIPO35 fixed effect by α_i, the vector of instrumental variables by $z_{i,t}$, and the error term by $\varepsilon_{i,t}$, we have the following first and second stage equations for estimation:

$$\mathrm{d}_{i,t} = \beta_0 + \beta_1 q_{i,t} + \beta_2 z_{i,t} + \alpha_i + \varepsilon_{i,t}^{d}. \quad (7)$$

$$y_{i,t} = \delta_0 + \delta_1 \hat{d}_{i,t} + \delta_2 \mathrm{q}_{i,t} + \alpha_i + \varepsilon^{y}_{i,t}. \quad (8)$$

6.2 Instrumental variable estimation results

Table 3a presents the first stage results of the instrumental variable estimations based on Equation (7). Invention quality IV ($cited\_inventor\_IV$) strongly accounts for the improvement in disclosure quality, implying that the policy reform increases the disclosure quality of applicants in the technology sector with higher quality inventions, supporting Hypothesis 1. This instrument also significantly accounts for an increase in the number of applicant citations (a). Disclosure propensity IV (ab_IV) strongly accounts for the increase in applicant-alone citations, implying that policy reform increases the number of applicants disclosing alone more when they had a high disclosure propensity before the reform. Disclosure propensity IV has a negative effect on applicant disclosure quality. This may not be surprising, as a greater number of applicant disclosures will likely reduce the average quality of applicant disclosures when controlling for invention quality. The positive effect of invention quality dominates this negative effect; thus, the two instruments imply significant positive effects of the policy change on both the quality and quantity of applicant disclosures. These two instruments are not weak according to the weak instrument test reported below (Table 3b).

Table 3a: IV estimation, first stage

	a	b/(b+c) (x100)
ab_iv	0.260***	−0.079***
	(0.005)	(0.016)
cited_inventor_iv	0.239***	3.495***
	(0.019)	(0.065)
nipc	0.034***	−0.067***
	(0.006)	(0.019)
napplicants	−0.080***	0.149
	(0.031)	(0.103)
ninventors	0.032***	0.066**
	(0.009)	(0.030)
citing_count_npl	0.196***	0.071***
	(0.005)	(0.017)
nclaim	0.026***	0.006
	(0.003)	(0.011)
ln_request_number	−0.007	0.097**
	(0.013)	(0.044)
Num.Obs.	97 698	97 698
R2	0.816	0.332
R2 Adj.	0.766	0.152
RMSE	1.79	8.11

Table 3b presents the results of the second-stage estimation. Before discussing this, we summarize the effects of the invention quality. Inventions of higher quality, as measured by any of the following three key indicators (*nipc*, *cited_count*, and *nclaims*), tend to be associated with a longer grant lag, larger reduction in patent scope during examination, higher grant rate, and more challenges against examination outcomes. Moreover, a larger number of examination requests (*ln_request_number*) is associated with a significantly lower grant rate and fewer challenges to the examination outcomes.

Models (1) to (3) show the effects of higher disclosure quality and a larger number of disclosures by applicants on the number and composition of examiner citations of prior art. We evaluated these effects by combining the predicted changes in the endogenous variables through both IVs and their estimated coefficients.[6] The higher disclosure quality induced by the

[6] It is calculated based on the average values of *cited_inventor_iv* and *ab_iv* in the post-reform period (Table1) and their effects through the first stage estimation. See Table C1 for the comparison with the reduced form effects.

reform increased the number of citations used by the examiner (0.029, Model (1)). This significantly reduced the number of examiner-alone citations (0.081, Model (3)); however, this effect was dominated by a significant increase in the number of common citations (0.11, Model (2)). These effects are stronger in the firm by technology sectors high-quality inventions. These results show that increased applicant disclosures substitute examiner citations but there are also a significant number of applicant disclosures of new prior art, so that the number of prior art used by examiners increased. These results strongly support Hypothesis 2.

However, controlling for disclosure quality, a greater number of applicant disclosures does not increase the amount of prior art used by examiners (Model 1). This invites a significantly greater number of common citations (Model 2) but also a reduction in examiner-alone citations of the same size (although not significant). The effects induced by a larger number of applicant disclosures are dominated by the effects of higher disclosure quality. The results of the reduced-form estimation show that the aggregate effect of the policy reform is significantly positive for the number of prior arts used by examiners (see Appendix C).

Model (4) on Grant lag shows that while the higher applicant disclosure quality induced by the policy reform reduced the Grant lag, a larger number of applicant-alone citations (*a*) increased the Grant lag. These findings support Hypotheses 3 and 5 regarding the effects of reform on Grant lag through disclosure quality and quantity. Importantly, the former effect from higher quality is significantly larger than the latter (-26.1 days vs. 4.0 days, for the firm with average invention quality and disclosure propensity), and the net effect is consistent with the result from a reduced form estimation for the policy change (Table Appendix B1).

As shown in Models (5)–(7) on patent scope, higher applicant disclosure quality significantly reduces the patent scope at application and registration. In comparison, higher applicant disclosure quality also reduces the scope of reduction, implying fewer amendments. Higher invention quality led to a more consistent patent scope, aligning with its improved disclosure, resulting in a decline of 0.010 from 0.516, or 1.9%, for the firm with the average invention quality and disclosure propensity. The examiner reflected a higher consistency of the patent scope with prior art at the application stage in her examination, resulting in a smaller amendment and a smaller patent scope at registration. These findings on grant lag and patent scope strongly support Hypothesis 3, although the magnitudes are relatively modest.

Models (5) to (7) also suggest that more applicant citations expanded the initial patent scope after the reform (although not significantly), but the examiners increased the amendments significantly so that the patent scope at registration did not significantly change, controlling for disclosure quality. These results are consistent with the results on the grant rate. Model (8) shows that while disclosure quality had no significant effect on grant rate, more applicant-alone citations significantly reduced it. This latter finding does not support Hypothesis 5, which suggests that a larger number of disclosures might increase the grant rate by hampering substantive examinations. Thus, more applicant disclosures apparently did not increase Type I errors by overloading the examiner, as will be confirmed by the following findings on invalidation trials.

Turning to the assessment of examination performance by trials, based on Models (9) and (10), higher disclosure quality led to a significantly lower rate of invalidation trials (by -0.036% for firms with average invention quality and disclosure propensity), but a greater number of disclosures did not. This decrease in invalidation trials initiated by third parties challenging granted patents confirms our prediction of fewer Type I errors (improper grants) following improved disclosure quality. For rejection appeal trial rates, which measure applicants' challenges in rejected applications, we observed a significant negative effect of disclosure quality (-1.76% for firms with average invention quality and disclosure propensity). Still, a greater number of disclosures did not. These results suggest that improved disclosure quality reduces the rate of applicant rejection appeals. These findings on examination quality support Hypothesis 4.

Comparing the IV results with the OLS results in Table 4 enabled us to assess the contribution of the instrumental variable estimation. The two approaches yield broadly similar results in terms of the signs of the coefficients of disclosure quality and quantity. However, significant differences are likely to reflect the endogeneity of these variables. Variations in examiner search effort directly affect the number of examiner-alone citations. If such search efforts are low, our disclosure quality variable (*b/(b+c)*) increases, resulting in a positive correlation with the grant rate and the two trial rates. Indeed, the coefficient of disclosure quality for the grant rate is significantly larger and more positive in the OLS estimation than in the IV estimation (the coefficient is insignificant). Similarly, the coefficient of disclosure quality for invalidation trials and rejection appeal trials is significantly smaller in the OLS estimation than in the IV estimation (the coefficient is negative and significant). These comparisons between the IV and OLS estimates confirm the importance of addressing endogeneity concerns when estimating the causal effects of disclosure quality.

Table 3b: IV estimation, second stage

	Examiner citation of prior art			Examination efficiency	
	(1)	(2)	(3)	(4)	(5)
	b + c	b	c	Grant lag	Patent scope (at application) (x100)
nipc	0.114***	0.006***	0.108***	3.118***	−0.001
	(0.005)	(0.001)	(0.005)	(0.871)	(0.001)
napplicants	0.019	−0.002	0.022	14.074***	−0.004
	(0.027)	(0.003)	(0.026)	(4.420)	(0.003)
ninventors	0.067***	0.004***	0.063***	2.441*	−0.001
	(0.008)	(0.001)	(0.008)	(1.290)	(0.001)
citing_count_npl	0.014***	0.001*	0.013***	−1.696**	−0.001**
	(0.005)	(0.001)	(0.005)	(0.865)	(0.001)
cited_count	0.077***	0.004***	0.074***	2.769***	0.000
	(0.003)	(0.000)	(0.003)	(0.498)	(0.000)
nclaim	0.030***	0.002***	0.028***	−3.969***	−0.002***
	(0.003)	(0.000)	(0.003)	(0.478)	(0.000)
ln_request_number	−0.005	−0.015***	0.011	0.424	−0.023***
	(0.012)	(0.001)	(0.011)	(1.790)	(0.001)
a(fit)	−0.001	0.009***	−0.010	9.223***	0.003**
	(0.015)	(0.002)	(0.014)	(1.904)	(0.001)
b/(b+c) (x100) (fit)	0.012**	0.046***	−0.034***	−10.917***	−0.004***
	(0.005)	(0.001)	(0.005)	(0.753)	(0.001)
Num.Obs.	97 698	97 698	97 698	67 201	60 912
Firm x WIPO FE	Yes	Yes	Yes	Yes	Yes
Subtract Pre-Trend	Yes	Yes	Yes	Yes	n.s.
Weak IV test	922.23	922.23	922.23	867.49	936.66
R2	0.406	0.778	0.397	0.448	0.603
R2 Adj.	0.246	0.719	0.234	0.281	0.486
RMSE	2.14	0.27	2.02	241.90	0.20

	Examination efficiency			Patent rights stability	
	(6)	(7)	(8)	(9)	(10)
	Patent scope (at registration) (x100)	Size of scope reduction (x100)	Grant rate (x100)	Invalidation trials rate(x100)	Rejection appeals trials rate (x100)
nipc	−0.001***	0.002***	−1.049***	−0.009	−0.233**
	(0.000)	(0.001)	(0.081)	(0.008)	(0.099)
napplicants	−0.003	0.004	2.427***	−0.025	0.688
	(0.002)	(0.003)	(0.425)	(0.041)	(0.546)
ninventors	−0.002**	0.001	1.427***	0.006	1.477***
	(0.001)	(0.001)	(0.126)	(0.012)	(0.151)
citing_count_npl	0.000	0.000	0.853***	−0.005	0.474***
	(0.000)	(0.001)	(0.084)	(0.008)	(0.100)
cited_count	−0.002***	0.002***	1.071***	0.015***	1.180***
	(0.000)	(0.000)	(0.050)	(0.005)	(0.061)
nclaim	0.002***	−0.005***	−0.550***	0.014***	−0.629***
	(0.000)	(0.000)	(0.045)	(0.004)	(0.054)
ln_request_number	−0.015***	−0.002	−0.522***	−0.040**	0.275
	(0.001)	(0.001)	(0.184)	(0.016)	(0.207)
a(fit)	0.000	0.006***	−0.792***	0.000	−0.329
	(0.001)	(0.001)	(0.233)	(0.018)	(0.229)
b/(b+c) (x100) (fit)	−0.001*	−0.002***	−0.007	−0.015**	−0.676***
	(0.000)	(0.001)	(0.085)	(0.007)	(0.091)
Num.Obs.	60 912	60 912	97 698	67 201	63 708
Firm x WIPO FE	Yes	Yes	Yes	Yes	Yes
Subtract Pre-Trend	Yes	n.s.	Yes	Subtract Trend	n.s.
Weak IV test	936.66	936.66	922.23	226.43	234.373
R2	0.571	0.371	0.417	0.232	0.366
R2 Adj.	0.444	0.186	0.260	0.001	0.154
RMSE	0.14	0.19	33.86	2.36	25.15

Note: n.s. indicates no pre-trend adjustment due to statistical insignificance. IV test is the F-value by Stock and Yogo (2005) weak IV test.

Table 4: OLS results based on non-instrumented applicant disclosure variables

	Examiner citation of prior art			Examination efficiency	
	(1)	(2)	(3)	(4)	(5)
	b + c	b	c	Grant lag	Patent scope (at application) (x100)
nipc	0.117***	0.006***	0.112***	4.721***	−0.001
	(0.005)	(0.001)	(0.005)	(0.800)	(0.001)
napplicants	0.012	−0.003	0.015	9.572**	−0.005
	(0.026)	(0.003)	(0.024)	(4.059)	(0.003)
ninventors	0.068***	0.004***	0.064***	2.505**	−0.001
	(0.008)	(0.001)	(0.007)	(1.198)	(0.001)
citing_count_npl	0.012***	0.003***	0.009**	−0.644	−0.001**
	(0.004)	(0.001)	(0.004)	(0.684)	(0.001)
cited_count	0.078***	0.004***	0.075***	3.379***	0.000
	(0.003)	(0.000)	(0.003)	(0.459)	(0.000)
nclaim	0.031***	0.002***	0.029***	−3.735***	−0.002***
	(0.003)	(0.000)	(0.003)	(0.438)	(0.000)
ln_request_number	−0.010	−0.015***	0.005	−0.111	−0.023***
	(0.011)	(0.001)	(0.011)	(1.666)	(0.001)
a	−0.014***	0.000	−0.014***	−0.037	0.000
	(0.003)	(0.000)	(0.003)	(0.429)	(0.000)
b/b+c (x100)	0.033***	0.044***	−0.011***	−1.395***	−0.002***
	(0.001)	(0.000)	(0.001)	(0.139)	(0.000)
Firm x WIPO35 FE	Yes	Yes	Yes	Yes	Yes
Subtract Pre-Trend	Yes	Yes	Yes	Yes	n.s.
Num.Obs.	107 758	107 758	107 758	72 971	66 121
R2	0.422	0.786	0.413	0.499	0.620
R2 Adj.	0.247	0.721	0.236	0.332	0.496
RMSE	2.12	0.27	2.00	226.75	0.20

	Examination efficiency			Patent rights stability	
	(6)	(7)	(8)	(9)	(10)
	Patent scope (at registration) (x100)	Size of scope reduction (x100)	Grant rate	Invalidation trials rate(x100)	Rejection appeals trials rate (x100)
nipc	−0.002***	0.002***	−1.001***	−0.005	−0.186**
	(0.000)	(0.001)	(0.077)	(0.008)	(0.093)
napplicants	−0.003	0.003	2.326***	−0.024	0.723
	(0.002)	(0.003)	(0.404)	(0.039)	(0.514)
ninventors	−0.001**	0.001	1.413***	0.002	1.459***
	(0.001)	(0.001)	(0.122)	(0.011)	(0.143)
citing_count_npl	0.000	0.000	0.676***	−0.005	0.325***
	(0.000)	(0.001)	(0.068)	(0.007)	(0.080)
cited_count	−0.002***	0.002***	1.061***	0.017***	1.210***
	(0.000)	(0.000)	(0.048)	(0.004)	(0.058)
nclaim	0.002***	−0.005***	−0.588***	0.014***	−0.640***
	(0.000)	(0.000)	(0.043)	(0.004)	(0.050)
ln_request_number	−0.015***	−0.002*	−0.519***	−0.039**	0.104
	(0.001)	(0.001)	(0.178)	(0.016)	(0.196)
a	0.000	0.002***	−0.106**	−0.004	−0.118**
	(0.000)	(0.000)	(0.046)	(0.004)	(0.049)
b/b+c (x100)	0.000***	−0.001***	0.196***	−0.002	0.009
	(0.000)	(0.000)	(0.014)	(0.001)	(0.017)
Firm x WIPO35 FE	Yes	Yes	Yes	Yes	Yes
Subtract Pre-Trend	Yes	n.s.	Yes	Subtract Trend	n.s.
Num.Obs.	66 121	66 121	107 758	72 971	69 793
R2	0.581	0.387	0.432	0.259	0.393
R2 Adj.	0.445	0.188	0.260	0.011	0.167
RMSE	0.14	0.19	33.55	2.36	24.32

Note: n.s. indicates no pre-trend adjustment due to statistical insignificance.

7. Conclusions

This study investigates how applicant disclosures of prior art causally affect patent examinations by exploiting the policy reform of the Japanese Patent Office (JPO) in September 2002 as a natural experiment. We find that the policy reform significantly improved the applicant's disclosure quality (measured by the coverage of examiner citations of prior art by applicant citations), and this effect was stronger for high-quality inventions, which is consistent with the theoretical prediction. The policy reform that only mildly requires disclosure seems to have had a significant effect on applicant disclosure behaviors, presumably because there are inherent incentives for applicants with high-quality inventions to signal such quality through high-quality disclosure.

Higher-quality disclosures have brought about significant improvements in examination efficiency and performance. This has led to faster grants, smaller patent scopes at application, and fewer amendments between applications and grants. It also reduces the rates of invalidation and rejection of appeal trials. Although the sizes of the estimated effects were modest in many cases, we obtained consistent results across important aspects of the examination process and outcomes. These changes would have improved the incentives for high-quality inventions and reduced patent protection costs.

The reform also increases the number of applicant disclosures not used by examiners, leading to a longer grant lag. However, the effect is much smaller than that of increased disclosure quality on grant lag. Moreover, a larger number of applicant disclosures did not cause a higher grant rate (rather, it led to a lower grant rate) or significantly increased the invalidation trial rate. Thus, the aforementioned positive effect of reform through higher quality is more important. Moreover, applicant disclosures that are unused in the focal patent examination are not useless because many of them are used in subsequent examinations and applications. These "applicant" disclosed prior art is slightly more cited by applicants and examiners together (that is, as common citations) than "examiner" disclosed prior art (Appendix C).

One important reason for the above positive effect of the reform is that the policy change made more prior art available to examiners, which was disclosed by applicants and then cited by the examiners of focal patent applications. Our instrumental variable analysis reveals that this effect is stronger for higher-quality inventions. Furthermore, the increase in high-quality disclosures by applicants complemented examiner search efforts, resulting in a higher total volume of prior art used in examinations. Our analysis further shows that applicants have an advantage in identifying prior art for science-based inventions used by examiners in their examinations. The reform appeared to promote a combination of the different capabilities of applicants and examiners. The primary policy implication of our research is that applicant disclosures of prior art should be encouraged, with the aim of utilizing them for examination purposes.

There were several limitations to our research and the study. First, as shown in Figure 4, there are significant differences across technology sectors in terms of the level of disclosure quality and its response to the reform. They may reflect systematic differences across sectors in the contribution of a single patent to the appropriation of R&D investment, the speed of the emergence of competing inventions, and the number and heterogeneities of competing inventions. An assessment of the significance of such differences would further inform us of the constraints on disclosure quality. Second, our study did not directly address the issue of the strategic hiding of prior art. However, as shown in Figure 2, approximately 70% of the applications have no common citations (our disclosure quality index is zero), which may suggest the possibility of a strategic hiding of the prior art. Assessing their significance and policy responses are important research issues.

Appendix A: Disclosure Variables by Technology Field

Table A1: Disclosure variables before and after the reform by technology

	Disclosure quality (%)		Common citation		Applicant citation		N	
	(b/b+c)1999-2001	(b/b+c)2003-2005	(b)1999-2001	(b)2003-2005	(a+b)1999-2001	(a+b)2003-2005	1999-2001	2003-2005
Electrical machinery, apparatus, energy	3.03	6.02	0.16	0.33	0.85	1.83	40118	44148
Audio-visual technology	2.21	4.75	0.12	0.27	0.80	1.78	33933	38402
Telecommunications	2.02	4.81	0.11	0.29	0.60	1.57	22473	22561
Digital communication	2.20	3.87	0.11	0.20	0.48	1.26	7443	8804
Basic communication processes	2.64	5.02	0.13	0.30	0.53	1.41	5394	5303
Computer technology	1.97	4.21	0.10	0.24	0.61	1.56	37146	35088
IT methods for management	1.85	5.03	0.10	0.31	0.38	1.65	1314	2495
Semiconductors	2.26	4.81	0.13	0.30	0.80	1.93	23936	26801
Optics	3.34	5.48	0.20	0.35	3.89	4.71	32282	37923
Measurement	3.38	7.04	0.19	0.44	0.65	1.56	22087	25356
Analysis of biological materials	4.50	7.81	0.21	0.41	1.51	2.54	766	925
Control	2.37	5.08	0.12	0.28	0.53	1.50	10821	10615
Medical technology	4.19	7.97	0.23	0.48	0.91	1.87	9602	12129
Organic fine chemistry	9.44	12.09	0.53	0.74	2.66	3.94	4427	4308
Biotechnology	9.19	10.70	0.39	0.46	2.11	2.73	1659	2268
Pharmaceuticals	6.89	10.62	0.42	0.68	2.48	4.22	1471	2029
Macromolecular chemistry, polymers	5.88	7.68	0.39	0.56	3.34	4.99	9820	9760
Food chemistry	6.91	11.37	0.39	0.70	1.91	3.36	3034	2739
Basic materials chemistry	5.87	8.32	0.38	0.55	3.24	5.32	8778	8397
Materials, metallurgy	5.47	8.56	0.30	0.51	1.82	2.72	12111	10798
Surface technology, coating	4.74	7.63	0.27	0.47	1.74	3.27	9567	10084
Micro-structural and nano-technology	3.47	4.35	0.17	0.28	0.80	1.50	113	283
Chemical engineering	4.37	7.98	0.23	0.48	1.22	2.25	7495	6827
Environmental technology	3.36	6.41	0.19	0.40	0.92	1.94	9041	8276
Handling	3.28	7.34	0.15	0.36	0.60	1.50	19684	18445
Machine tools	3.95	7.78	0.18	0.38	0.82	1.74	14110	12381
Engines, pumps, turbines	4.46	7.51	0.22	0.39	0.97	1.59	14404	16887
Textile and paper machines	3.72	6.75	0.22	0.41	3.03	4.43	15446	16223
Other special machines	4.21	8.27	0.21	0.46	1.21	2.45	15383	13672
Thermal processes and apparatus	3.04	6.98	0.16	0.39	0.53	1.43	10781	10984
Mechanical elements	3.76	7.46	0.18	0.37	0.63	1.49	16398	17267
Transport	4.15	7.10	0.21	0.38	0.67	1.42	20382	27145
Furniture, games	1.95	4.46	0.09	0.23	0.43	1.43	19628	25029
Other consumer goods	2.91	6.94	0.15	0.38	0.65	1.60	8417	8039
Civil engineering	3.25	7.68	0.14	0.37	0.52	1.45	22852	19780

Appendix B: Reduced-form effects of the reform and consistency with the IV effects

We estimate the impacts of policy reform using the reduced-form model (the same estimation model as in Equation (6) in Section 5.2). The coefficient of the reform dummy provides an estimate of the average change that occurred in the post-reform period relative to the pre-reform period, controlling for invention characteristics and firm-specific technology effects. The reform dummy captures all the reform effects that may not be fully captured by the instrumental variable regressions reported in the main section. Table Appendix B1 presents these results.

Table Appendix B1. Examination outcomes: Reduced form estimation with FE effects (2001, 10 – 2003, 8 & monthly)

	Examination efficiency				
	(1)	(2)	(3)	(4)	(5)
	Grant lag	Patent scope (at application) (x100)	Patent scope (at registration) (x100)	Size of scope reduction (x100)	Grant rate
nipc	4.372***	−0.001	−0.002***	0.002***	−1.030***
	(0.799)	(0.001)	(0.000)	(0.001)	(0.077)
napplicants	9.665**	−0.005	−0.003	0.003	2.360***
	(4.053)	(0.003)	(0.002)	(0.003)	(0.405)
ninventors	2.562**	−0.001	−0.001**	0.001	1.427***
	(1.197)	(0.001)	(0.001)	(0.001)	(0.122)
citing_count_npl	−0.038	−0.001*	0.000	0.001	0.689***
	(0.674)	(0.001)	(0.000)	(0.001)	(0.067)
cited_count	2.702***	−0.001	−0.002***	0.002***	1.043***
	(0.461)	(0.000)	(0.000)	(0.000)	(0.048)
nclaim	−3.663***	−0.002***	0.002***	−0.005***	−0.590***
	(0.437)	(0.000)	(0.000)	(0.000)	(0.043)
ln_request_number	−0.210	−0.023***	−0.015***	−0.002*	−0.502***
	(1.664)	(0.001)	(0.001)	(0.001)	(0.178)
reform	−24.684***	−0.011***	−0.002**	−0.004***	−0.368**
	(1.594)	(0.001)	(0.001)	(0.001)	(0.178)
Firm x WIPO35 FE	Yes	Yes	Yes	Yes	Yes
Subtract Pre-Trend	Yes	n.s.	Yes	n.s.	Yes
Num.Obs.	72 971	66 121	66 121	66 121	107 758
R2	0.500	0.619	0.581	0.386	0.430
R2 Adj.	0.333	0.494	0.445	0.186	0.258
RMSE	226.61	0.20	0.14	0.19	33.59

	Patent rights stability	
	(6)	(7)
	Invalidation trials rate(x100)	Rejection appeals trials rate (x100)
nipc	−0.005	−0.231**
	(0.008)	(0.093)
napplicants	−0.024	0.771
	(0.039)	(0.514)
ninventors	0.002	1.470***
	(0.011)	(0.143)
citing_count_npl	−0.007	0.354***
	(0.006)	(0.079)
cited_count	0.017***	1.147***
	(0.004)	(0.058)
nclaim	0.014***	−0.635***
	(0.004)	(0.050)
ln_request_number	−0.039**	0.091
	(0.016)	(0.196)
reform	−0.002	−1.856***
	(0.015)	(0.187)
Firm x WIPO35 FE	Yes	Yes
Subtract Pre-Trend	Subtract Trend	n.s.
Num.Obs.	72 971	69 793
R2	0.259	0.394
R2 Adj.	0.011	0.169
RMSE	2.36	24.31

Note: n.s. indicates no pre-trend adjustment due to statistical insignificance.

Model (1) shows that the Grant lag declined significantly, 24.7 days after the reform, representing approximately 2% of the average Grant lag. The Grant lag tends to be longer when the underlying invention covers many technologies and is highly cited. Models (2)–(4) show that *Patent scope at application* declined significantly by 0.011 (2.1% from a pre-reform average of 0.516), *Patent scope at registration* decreased by 0.002 (from a pre-reform average of 0.348), and *Size of scope reduction* (amendment) decreased by 0.004 (2.2% from a pre-reform average of 0.183). Model (5) shows a significant reduction in the Grant rate (-.368% from 54.07%).

Model (7) shows that the Rejection appeal trial rate significantly declined by 1.86 percentage points from a pre-reform average of 16.08. In contrast, Model (6) shows that the Invalidation trial rate also decreased by 0.002 but not significantly.[7]

We can assess the consistency of the results between the reduced form and the IV results reported in the main text. This will help us assess the pre-trends estimated, as well as how our IV results capture the full effect of the reform and their potential biases, assuming that the pre-trend estimated is correct. The IV approach uses reform-based instruments (*ab_iv* and *inventor_cited_iv*) that exploit the variations in the outcome change before and after the reform across firms by technology sector, which, by construction, do not depend significantly on time trends.

Table B2 presents this comparison with ten variables. The IV-predicted changes were calculated by combining the first stage effects of our instruments on the disclosure measures (*a* and *b/(b+c)*) with their second-stage coefficients. For the reduced-form, we use reform dummy coefficients that directly capture the average changes between the pre- and post-reform periods.

The results show a general consistency between the two approaches, although with some variations. For instance, the IV predicts a reduction in Grant lag of 22.07 days, with the reduced

[7] When we do not subtract the trend from Invalidation trials rate, the Reform coefficient is -0.062 and significant. The negative trend of -0.0052 might be somewhat conservative.

form showing a slightly larger effect (-24.68 days, 11.8% difference). For most examination efficiency measures (grant lag, patent scope measures, and grant rates), the differences between the two approaches are relatively small (less than 20%). The citation patterns (b, c, and b+c) also showed reasonable consistency, with differences ranging from -5.9% to 65.5%. However, we observe larger discrepancies in some measures: the size of scope reduction shows a 100% difference, and the invalidation trials rate shows a -94.4% difference. Despite these exceptions, the overall pattern suggests that our pre-trend subtraction adequately captured the underlying trends of most key examination outcomes.

Table B2: Comparison between IV and Reduced Form Predictions for Pre-trend Validation

	IV Estimation Components		Predicted Changes		
Dependent Variable	**Through a**	**Through b/(b+c)**	**IV**	**RF**	**Difference (%)**
b + c	0.000	0.029	0.029	0.048	65.5
b	0.004	0.110	0.114	0.127	11.4
c	-0.004	-0.081	-0.085	-0.080	-5.9
Grant lag	4.030	-26.104	-22.074	-24.684	11.8
Patent scope (at application) (×100)	0.001	-0.010	-0.009	-0.011	22.2
Patent scope (at registration) (×100)	0.000	-0.002	-0.002	-0.002	0.0
Size of scope reduction (×100)	0.003	-0.005	-0.002	-0.004	100.0
Grant rate (×100)	-0.347	-0.017	-0.364	-0.368	1.1
Invalidation trials rate (×100)	0.000	-0.036	-0.036	-0.002	-94.4
Rejection appeals trials rate (×100)	-0.144	-1.617	-1.761	-1.856	5.4

Note: IV Predicted Change calculated using first stage effects (ab_iv and cited_inventor_iv) combined with second-stage coefficients. Difference (%) = (RF - IV)/IV × 100.

Appendix C: Use of Applicant-Disclosed Prior Art through Future Examinations and Inventions

This Appendix investigates how frequently prior art initially disclosed only by applicants (a), cited by both applicants and examiners (b), and cited by examiners alone are subsequently utilized as knowledge sources in future patent examinations and new patent applications. This analysis aims to verify whether applicant disclosures contribute not only to the focal patent examination but also serve as useful prior art for future examinations and new patent applications.

We analyzed the citation patterns between two groups of patents: citing patents (those with examination requests between 2010 and 2015) and cited patents (those with applications from 2005 onwards). For each cited patent, we identify who first cited the prior art: applicants only ("applicant"), both applicants and examiners ("common"), or examiners only ("examiner"). Table C1 shows how patents in these three citation type groups were subsequently cited, breaking down citations by the examination request year of cited patents and cited type: citations by applicants only (a), by both applicants and examiners (b), and by examiners only (c). To focus on knowledge diffusion, we exclude the first citation of each patent from our count.

Table C1 shows that the number of patent prior arts first identified by applicants and examiners is 113, 71, and 319 in thousands for the "applicant," "common," and "examiner" categories, respectively. Prior arts are identified by "applicant" and "common" and account for 23% and 14% of the total, respectively. They received approximately 166, 130, and 589 thousand citations between 2005 and 2015, respectively. Thus, "examiner" prior arts are most cited (1.85 per prior art), followed by "common" prior arts (1.83) and then "applicant" prior art (1.46). While "examiner" prior arts are most cited by examiners (1.34 per prior art), "applicant" prior arts are also cited by examiners (0.46 per prior art). Interestingly, "applicant" prior art is slightly more cited by applicants and examiners (b) together than "examiner" prior art (0.15>0.11).

The utilization of applicant-disclosed prior art by both examiners and applicants demonstrates that enhanced disclosure requirements create knowledge spillovers beyond the focal patent examination. Improved applicant disclosure appears to have enriched the available knowledge base for future examinations and inventions.

Table C1: Citation counts by first citation type and cited patent's examination request year (2005-2015)

	First cite types		Reference
	applicant	**common**	**examiner**
Unique cited patent	113366	71250	318775
a			
2005	12	1	0
2006	18	11	3
2007	64	26	19
2008	239	105	144
2009	779	298	650
2010	1866	766	1695
2011	4319	1854	4041
2012	13413	6303	13766
2013	25718	12538	31141
2014	27112	13900	37545
2015	23684	11883	37488
Sum citations	97224	47685	126492
Avg citations	0.86	0.67	0.40
b			
2005	3	0	0
2006	1	0	0
2007	17	8	8
2008	35	38	44
2009	174	183	225
2010	365	491	559
2011	829	1067	1322
2012	2282	3685	4474
2013	4529	5289	8981
2014	4458	4386	9279
2015	4350	3995	10299
Sum citations	17043	19142	35191
Avg citations	0.15	0.27	0.11
c			
2005	0	0	1
2006	0	0	22
2007	4	15	189
2008	41	126	1003
2009	171	542	3479
2010	535	1069	9087
2011	1610	2849	22379
2012	5348	8756	64430
2013	12435	15924	110343
2014	15537	17714	112900
2015	15976	16539	102996
Sum citations	51657	63534	426829
Avg citations	0.46	0.89	1.34
Total			
Sum citations	165924	130361	588512
Avg citations	1.46	1.83	1.85

Note: This table analyzes prior art patents categorized by their first citation source: "applicant" (first cited by applicants only), "common" (first cited by both applicants and examiners), and "examiner" (first cited by examiners only). The analysis covers cited patents with examination requests from 2005 onwards, which were cited by newer patents with examination requests from 2010 to 2015 (citing patents). For each cited patent group, the citations were broken down by the cited patent's examination request year and citation type (a: applicant only, b: both applicant and examiner, and c: examiner only). Initial citations were excluded from the counts to focus on subsequent knowledge utilization. "Unique Count" shows the total number of unique patents in each category, "Sum" represents total citations across years, and "Avg" indicates the average number of citations per patent.

Reference

Alcacer, J., Gittelman, M., and Sampat, B. (2009). “Applicant and examiner citations in US patents: An overview and analysis.” Research Policy, 38(2), 415-427.

Allison, J. R., and Lemley, M. A. (1998). “Empirical evidence on the validity of litigated patents.” American Intellectual Property Law Association (AIPLA) Quarterly Journal, 26, 185-, SSRN: http://ssrn.com/abstract=118149.

Atal, V., and Bar, T. (2010). “Prior art: To search or not to search.” International Journal of Industrial Organization, 28(5), 507–521.

Buchanan, J. M. (2006). “Deference overcome: Courts’ invalidation of patent claims as anticipated by art considered by the PTO.” STAN. TECH. L. REV. 2 https://journals.law.stanford.edu/sites/default/files/stanford-technology-law-review/online/buchananj-deference.pdf

Bryan, K. A., Ozcan, Y., and Sampat, B. (2020). “In-Text Patent Citations: A User’s Guide,” Research Policy, 49 (4), 103946.

Cotropia, C. A., Lemley, M. A., and Sampat, B. (2013). “Do applicant patent citations matter?” Research Policy, 42(4), 844-854.

Corsino, M., Mariani, M., and Torrisi, S. (2019). “Firm Strategic Behavior and the Measurement of Knowledge Flows with Patent Citations,” Strategic Management Journal, 40 (7), 1040–1069.

Farrell, J. and Shapiro, C. (2008). “How Strong Are Weak Patents?” American Economic Review, 98(4), 1347-1369.

Frakes, Michael D. and Melissa F. W. (2017). “Is the Time Allocated to Review Patent Applications Inducing Examiners to Grant Invalid Patents? Evidence from Microlevel Application Data,” The Review of Economics and Statistics, 99 (3), 550–563.

Hegde, D., and Sampat, B. (2009). “Examiner citations, applicant citations, and the private value of patents,” Economics Letters, 105(3), 287–289.

Kuhn, J., Younge, K., and Marco, A. (2020). "Patent citations reexamined," The RAND Journal of Economics, 51(1), 109-132.

Kuhn, J., Younge, K., and Marco, A. (2023). "Strategic Citation: A Reassessment," The Review of Economics and Statistics, 105 (2), 458–466.

Juneau, T. L., and MacAlpine, J. K. (2000). "Protecting patents from the beginning: The importance of information disclosure statements during patent prosecution," Journal of the Patent and Trademark Office Society, 82(8), 577-595.

Lampe, R. (2012). "Strategic citation. Review of Economics and Statistics," 94(1), 320–333.

Langinier, C., Marcoul, P., (2016). "Patents, Search of Prior Art and Revelation of Information," Review of Industrial Organization, Vol. 49, No. 3. pp. 399-427.

Lei, Zhen and Brian D. Wright. (2017). "Why Weak Patents? Testing the Examiner Ignorance Hypothesis," Journal of Public Economics, 148, 43–56.

Lemley, M. A. and Shapiro, C. (2005). "Probabilistic patents," The Journal of Economic Perspectives, 19(2), 75-98.

Okada, Y., Nagaoka, S. (2018). "Making the patent scope consistent with the invention: Evidence from Japan," Journal of Economics and Management Strategy, 27,607–625.

KSR International, Co. v. Teleflex, Inc. (2007). 127 S. Ct. 1727 (2007) (No. 04-1350), 22-23.

Stock, J. and Yogo. M. (2005). "Testing for Weak Instruments in Linear IV Regression. Identification and Inference for Econometric Models", Cambridge University Press.

Yamauchi I and Nagaoka, S. (2015). "Does the outsourcing of prior art search increase the efficiency of patent examination?" with Isamu Yamauchi, Research Policy, 2015.