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Information Constraint of the Patent Office and Examination Quality: Evidence from the effects of initiation lags[1]

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Abstract

We examine how significantly the information constraint of the patent office affects its examination quality in terms of type I and type II errors (wrong grants and wrong rejections). For identification, we exploit the exogenous policy change in Japan which accelerated the timing of examination. Such acceleration increased significantly both the grant rate and the frequency of appeals against the rejections of the patent office, despite the higher examination request rates. These results reveal that more information constraint increases both types of errors, but the increase in wrong grants is dominant, consistent with the design of the patent examination system where an examiner has the burden of proof in rejections and the applicant has the chance to challenge the rejections. These effects become stronger in technology sectors with stronger information constraint: those sectors which have both short technology cycles and early examination requests so that the age of relevant prior art at examination is young. We also show that longer initiation lags for an international application with foreign priority significantly reduces its grant rate. These findings suggest that the patent office is under information constraint and a better information infrastructure will significantly improve patent quality.

Keywords: Information constraint, Patent examination, Prior art, Type I and type II errors
JEL classification: O38, O34, O30

[1]This study is conducted as a part of the "Study on Industrial Innovation Capability and Innovation Infrastructure" project undertaken at the Research Institute of Economy, Trade and Industry (RIETI). This research is partly based on our research "Effects of the initiation lag of examination on the examiner's decision and stability of patent right" in the Study Report on Economic Growth Driven by Industrial Property Rights, commissioned by the Japan Patent Office. This work was also supported by JSPS KAKENHI Grant Number 26285055 and 26780167. The authors are grateful for helpful comments and suggestions by Makoto Yano, Masayuki Morikawa, and Discussion Paper seminar participants at RIETI.

1. Introduction

The quality of patent examination is the cornerstone of the patent system in promoting innovation. It has attracted large policy attentions across major OECD countries, especially in the US (FTC, 2003; Jaffe and Lerner, 2004; National Research Council, 2004; US GAO, 2013 and 2016a,b). Problematic patents with uncertainty in their patent validity can result in a situation where a "weak" patent can obtain strong market power (Farrell and Shapiro, 2008; Lemley and Shapiro, 2005). A large number of potentially invalid patents with ambiguous claims make inadvertent infringement more likely and litigation more frequent (Bessen and Meurer, 2008). Therefore, examination quality has become one of the top priority policy agenda in the USPTO (US Patent and Trademark office), the EPO (European Patent Office) and the JPO (Japan Patent Office).

A patent examiner faces a challenge of acquiring good understanding of technological and scientific progress up to the patent application in evaluating the novelty and the inventive step of such application. Thus, the stock of information available for an examiner at the time of the examination with regard to the relevant prior art and focal patent is likely to be a key determinant for examination quality (Regibeau and Rockett, 2010). However, while there exist a number of recent studies on examination quality, few studies directly investigate the relation between the information available to the patent office at examination and the quality of patent examinations. This study aims at uncovering how the information constraint at patent office matters in examination quality. For our identification, we exploit the exogenous reduction of the initiation lag defined as the length between the filing date of an application and the initiation date of its examination. Shorter initiation lag can be a good measure of stronger information constraint, since early initiation of examination makes it more difficult for an examiner to identify the prior art which can serve as a base for assessing the novelty and inventive step of the focal patent application.

When an examiner has not been able to identify the most relevant prior art to the focal patent application, he/she is likely to grant a patent as the examiner has the burden of proving that the application lacks novelty and/or inventive step. Thus, imperfect information at the patent office tends to increase the probability of type I error (that is, wrong grant). However, the imperfect information can also increase the type II error (wrong refusals) of the examinations, since the examiner may wrongly conclude that the invention is obvious when he/she does not have enough understanding of the technological progress up to the focal invention (e.g. difficulties encountered in the past to achieve the same technical objective as the focal invention). One of the sources of type II error can be a hindsight bias that Mandel (2006) assesses its existence based on experimental studies as well as an analysis of court decisions which examined "Secondary Consideration Evidence" for non-obviousness of the invention. This paper aims at examining how these two types of errors varies with the information stock available to the Patent Office.

For addressing this research question, we investigate whether the acceleration in initiating examination will increase both the grant rate and the rate of appeals against refusal decisions by the Patent Office. Although the past studies often use the grant rate as a measure of examination quality, it is important to note that the increase of the grant rate by itself does not necessarily imply less accurate examination, since the grant rate increases with the reduction of the type II error. Correcting this major problem of the existing literature in measuring the examination quality, we use the combination of the information on grant rate and on the rate of appeals, which helps us to know what drives the changes. The increase of the rate of appeals by the applicants against refusal decisions indicates whether the type II error (wrong refusals) became more serious, given that a substantial share of the appeals result in the overturns of the refusal decisions (around two thirds, to be presented later in Table 2). The increase of the grant rate, on the other hand, indicates whether the type I errors (wrong grant) increased more than the type II errors (wrong refusals).

The effects of reduced initiation lag (less information available) are likely to be stronger in those technology sectors where the information constraint for an examiner is already strong. Thus, this paper will also assess whether the effects are stronger in the sectors with more severe information constraint (short technology cycle and early examination request) on an examiner even before the policy change. We measure the degree of information constraint by the age of prior art at examination which is given by the sum of the average examiner citation lag and initiation lag, for a verification of our interpretation. The examiner citation lag is defined as the duration of time between the application date of the prior art and the focal patent application. Short initiation lag forces an examiner to start examination relatively soon after the application, while short citation lag implies that understanding of the recent prior art is crucial to assess the patentability of the application.

The timing of the examination request and, as a result, the initiation lags are very likely to be endogenous to the quality of the patent application. Thus, we can observe a spurious positive correlation between a short initiation lag and higher grant rate (and or more rate of appeals against refusal decisions), due to the variation of the quality of patent applications rather than due to the variation of the stock of information available for an examiner. In order to identify the causal effect of the information constraint, we exploit the exogenous policy change in Japan that significantly reduced the allowable period for an examination request. Concerns over the uncertainty caused by the pending patent applications led the JPO to shorten the maximum allowed time for examination requests from seven to three years in 2001. This reform radically reduced the interval between applicants' filing patent applications and examiners' initiating their examination.

Furthermore, to demonstrate the importance of the information constraint in international context, we also analyse the effect of the longer initiation lag for the international applications with foreign priority on the examination quality. The application with foreign priority has one year time allowance, so that the initiation lag in examining such application is significantly longer. Whereas there is a well-known puzzle that the grant rate for the applications with foreign priority is lower than domestic applications (see Webster et al., 2014), longer initiation lag may significantly account for the difference.

Briefly, econometric investigations show that a significant reduction of the initiation lag of examination due to the policy change resulted both in higher grant rate and in higher frequency of appeals, despite of the significant increase of the examination request rates after the policy change. These results indicate the increase of both type I errors (wrong grants) and type II errors (wrong rejections) as well as the dominance of wrong grants. We also find that such effects are strong in those technology sectors where the information constraint for an examiner is likely to be more important: that is, the sectors where the sum of the citation lag and the initiation lag was relatively short even before the policy change. Therefore, information constraint of the patent office is a significant determinant of the examination quality.

Moreover, we also find that the difference of the grant rate between international applications with foreign priority and domestic applications is significantly reduced once we control for the initiation lag. This suggests that the longer initiation lag for the applications with foreign priority because of the time allowance for international applications tends to significantly reduce the grant rate of these applications. That is, more accurate examination, rather than discrimination, is an important contributing factor to lower grant rates of international applications with foreign priority.

The rest of the paper is organized as follows. Section 2 surveys related studies, and Section 3 provides the analytical framework for our econometric work. We describe the data in Section 4. Section 5 gives an estimation framework and estimation results. Finally, Section 6 concludes the paper.

2. Related studies

While there exist a number of recent studies on examination quality, few studies directly investigates the relation between the information constraint of the patent office and quality of patent examinations. Regibeau and Rockett (2010) compare the duration of patent examinations and the importance of patents. They assume that examinations gain accuracy as technology matures and that the examination duration is endogenous to applicants' efforts. They show that, controlling for a patent's position in a new technology cycle, more important innovations would be approved more quickly and that duration declines over time for good applications and rises for bad applications. The central assumption of their study is that the examination quality improves with the time elapsed from the beginning of the new innovation cycle to the patent application. However, such assumption itself is not examined. Harhoff and Wagner (2009) find that examination duration and patent quality are interdependent: potentially valuable applications are approved earlier and withdrawn slower. Based on these prior works showing the importance of the endogeneity of the timing of patent examinations, we use instrumental variable for the initiation lag by exploiting the exogenous policy change in Japan, in addition to a large set of control variables.

Encouraging more disclosures from applicants or from third parties might alleviate the information constraint on the patent office. Sampat (2010) finds that while the share of applicant's (backward) citations relative to the examiner's (added) citations increases when the applicant is more committed to the invention, the applicants contribute only a low share of citations to the prior patents. While Sampat's result indicates that the applicants' behavior (disclosing prior art in this case) depends on their eagerness to acquire patents, it does not directly assess the effects of information constraints of the patent office on examination quality. Yamauchi and Nagaoka (2015a) investigate whether outsourcing of prior art search enhances the efficiency of examinations. Controlling for the endogeneity of outsourcing decisions and the examiners' fixed effects, they find that outsourcing prior art search reduces the frequency of appeals and decreases examination duration. Their work does not identify whether the improved examination quality is due to more division of labor between examination and search or due to less information constraint on examination. This paper is the first study directly investigating the effects of information constraint on examination quality, exploiting the exogenous variation of the initiation lags.

Assuming a tradeoff between workload and quality of patent examinations, Caillaud and Duchene (2011) theoretically analyze how patent examiners' workloads affect firms' R&D incentives. They propose a policy of imposing penalties on the applicants whose patent requests are rejected because the penalties discourage firms from pursuing low-promise inventions, thereby reducing examiners' workloads and aiding the quality of their examinations. Empirically, Lemley and Sampat (2012) finds that more experienced examiners cite less prior art and are more likely to grant patents even without any rejections, based on cross sectional variations across examiners. Kim (2013) finds a positive relationship between examiners' workloads and probability of grant decisions. Frakes and Wasserman (2016) show that the promotions of examiners are associated with reductions in examination scrutiny and increases in granting tendencies, as well as that those additional patents being issued on the margin are of below-average quality, suggesting that insufficient examination time due to promotion may hamper examiner search and rejection efforts. However, these studies focusing on examiners' workloads or work efforts do not consider the endogeneity of examination quality with respect to the information available to the patent office, which is the focus of this research. Furthermore, our research controls for workloads by using the significantly overlapped samples in the timing of examination before and after the policy change as well as by using the indicator of the loads.

One major gap of the existing studies on the examination quality including the papers cited above is that these studies exclusively use the grant rates as indicators of the examination quality. This is problematic given that the grant rate can increase with the reduction of the type II error. It is essential to measure both types of errors in assessing the examination quality. Our study assesses the effect of the information constraint on examination quality, covering both type I and type II errors.

There are several studies showing that domestic applications have higher probability of being granted than applications with foreign priority (see Palangkaraya et. al., 2008; Liegsalz and Wagner, 2011; Webster et. al., 2014). Webster et al. (2014) interprets this phenomenon as evidence that national patent offices such as the EPO and the JPO give favorable treatment to domestic applicants, that is a violation of non-discriminatory treatment principle of the TRIPS. de Rassenfosse et al. (2016) shows that one of the major causes of the discrepancy of examination outcomes for an identical invention across Offices is the examiner's mistake. However, these studies do not consider the issue in terms of information constraint, in particular, the effect of longer initiation lag for applications with foreign priority. Since most of the applications with foreign priority take advantage of the benefit of longer time allowance before filing, their initiation lag is much longer than that of domestic applications. This means that examiners have more time to accumulate information useful for assessing the patentability of these applications, including the search results of the other Patent Offices. We thus examine whether this effect of longer initiation lag for applications with foreign priority may significantly contribute to explaining the lower grant rate of these applications.

3. Analytical framework

3.1 Information and examination quality

The examination quality depends on the stock of information which can be used by an examiner for assessing the contribution of the focal patent application to the prior art. Such stock of information would include information useful for understanding the scientific base of the relevant prior art and the technological trajectory starting from the prior art to the focal invention. The examiner will have more access to such information, if the relevant prior art is old when he/she initiates the examination. The age of the prior art at examination has two components: the citation lag between the filing date of the focal patent and the publication date of the relevant prior art, denoted as lag_{prior}, and the initiation lag between the filing date of an application and the initiation date of its examination, denoted by $lag_{initiation}$, as shown later in Figure 1. The stock of information useful for assessing the contribution of the application to the prior art will increase with the citation lag and the accuracy of examination improves, as discussed by Regibeau and Rockett (2010)[2]. Longer lag from the publication date of prior art to the application of the focal patent increases the information useful for understanding the science base of the prior art as well as the technological contribution of such prior art to subsequent inventions. Furthermore, the stock of information will further increase with the initiation lag even after the date of the application of the focal patent. For an example, the examiner will have access to the following sources of information, subsequent to the application of the focal patent: the applications which may cite the focal patent applications as prior patent literature and the search reports for assessing the focal patent, which was made public by the other patent offices, and papers on scientific progress behind the underlying invention. Thus, more time lapses between the application and the date of examination, the examiner will have more information useful for identifying relevant prior art and the development of the technology up to the focal application.

There are two types of examination errors. When an examiner cannot find the relevant prior art rejecting the patentability of the application, a patent is granted, even if the application lacks patentability (type I error). At the same time, insufficient knowledge on

2 Regibeau and Rockett (2010) assumes that the examination accuracy improves with the time elapsed from the beginning of the new innovation cycle to the patent application.

the technological trajectory from the prior art to the focal patent application may make the examiner conclude that the application is obvious, due to hindsight bias, even if the invention is not obvious ex-ante (type II error).We assume that the probability of these examination errors, denoted as $Type_i$ (i indicates type I error or type II error), declines proportionately with addition of new information, so that we have

$$dError_i/Error_i = -\rho_i(new\ \ information)\ \ . \tag{1}$$

If we assume that the probability of the arrival of new information per unit of time is constant, the probability of each error can be specified by the following equation.

$$Error_i = \alpha_i exp(-\theta_i(lag_{prior} + \ \ lag_{initiation}))\ \ , \tag{2}$$

where α is the probability of the error when both lags are zero, which is positive but less than or equal to 1 ($0 < \alpha_i \leq 1$). The parameter θ_i measures the speed of the arrival of new information relevant to the examination. The above equation assumes the common parameter for the two lags for simplicity. This equation implies that the probability of the examination error declines toward zero when the sum of the two lags increases to infinity. In addition, the exogenous one unit reduction of the initiation lag has the following effect on the examination error:

$$-\partial Error_i/\partial lag_{initiation} = \theta_i \alpha_i exp(-\theta_i(lag_{prior} + \ \ lag_{initiation}))\ \ . \tag{3}$$

The reduction of the initiation lag increases the examination error and its size depends negatively on the sum of the two lags. This is because the arrival of new information is more important when the age of the relevant prior art is young at examination.

We denote the grant rate by $Grant$ (relative to examination request), the incidence of trials against refusal decisions by $Trials\_against\_refusal$, the incidence of type I errors (wrong grants) by $Error_{TypeI}$, the incidence of the type II errors (wrong rejections) by $Error_{TypeII}$ and the average quality of patent application to be examined by q. Then, we have the following relationships for the changes of these variables ($0 \leq \beta_1 < 1$), in response to the policy change (accelerated examination requests).

$$\Delta Grant = \Delta(Error_{TypeI} - Error_{TypeII}) + \delta_1 \Delta q\ \ , \tag{4}$$

$$\Delta Trials\_against\_refusal = \beta_1 \Delta Error_{TypeII} + \delta_2 \Delta q\ \ . \tag{5}$$

We know that the policy change increased the examination request rates and reduced the average quality of patent applications ($\Delta q \leq 0$) and we can also assume that lower quality of patent application would result in lower grant rates and less trials against refusal decisions by the patent office. Thus, the two coefficients of the variable for quality change in equations

(4) and (5) have positive coefficients ($\delta_i > 0$). Furthermore, $\beta_1 > 0$, given that the applicant challenges more the rejections if the wrong rejections increase.

Equation (5) shows that the incidence of trials against refusal decisions provides the direct information on the incidence of Type II error. If $\Delta Trials\_against\_refusal$ is significantly positive, it clearly tells us that $\Delta Error_{TypeII}$ is also positive, as $\delta_2 \Delta q < 0$. In addition, if the grant rate of the patent office also increases ($\Delta Grant$ is positive), it clearly tells us that $\Delta\left(Error_{TypeI} - Error_{TypeII}\right) > \Delta Grant > 0$ as $\delta_1 \Delta q < 0$. Therefore, if both $\Delta Trials\_against\_refusal$ and $\Delta Grant$ are positive, the following equation holds.

$$\Delta Error_{TypeI} > \Delta Error_{TypeII} > 0 \quad . \tag{6}$$

Thus, we have the following Proposition which will guide our empirical testing.

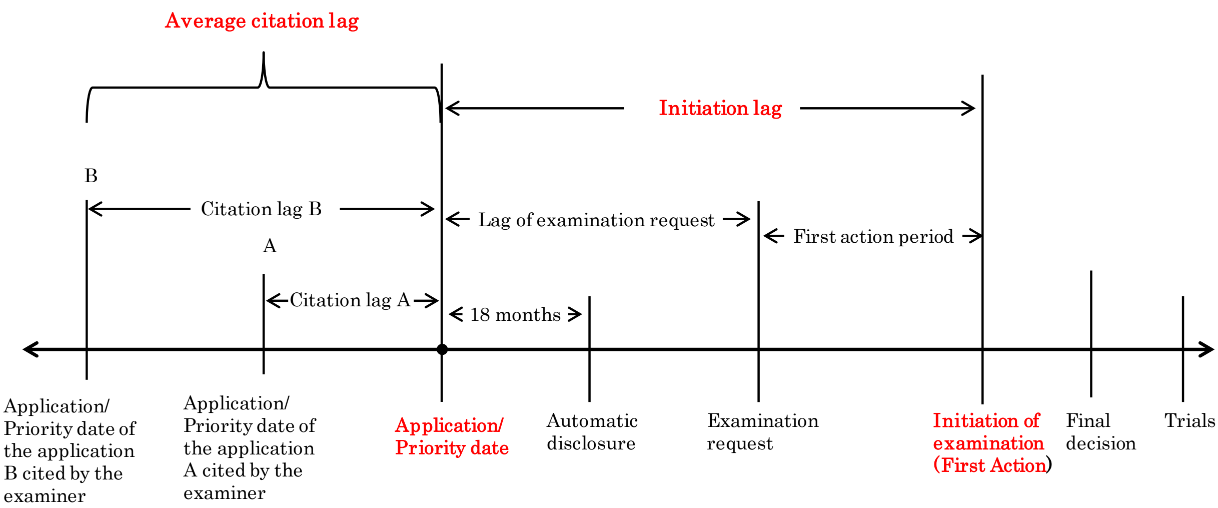
Proposition

When the policy change does not increase the quality of patent applications, the simultaneous increase of the grant rates and the trials against refusal decisions imply that both Type I and II errors increase with the policy change and the increase of Type I error dominates that of Type II error.

3.2 Hypotheses

Before stating the hypotheses, we explain our empirical implementation of measuring the initiation lag and the citation lag. Since information about specific dates when examinations are initiated is unavailable, we define initiation lag as the length between the date of patent application (or priority date if it exists) and the date of examiner's first action, as shown in Figure 1. The first action usually occurs within a week or so after examination commences. We define the citation lag as the average length between the filing date of the examined patent application and the filing date of the patent applications cited by the examiner.

Figure 1. Definition of initiation lag and citation lag



We hypothesize that the exogenous reduction of the initiation lag increases the information constraint on the patent office and makes an examination task more difficult. More specifically, stronger information constraint would result in both higher probability of an error of mistakenly granting a patent (type I error) and that of mistakenly rejecting a good patent application (type II error). At the same time, because the examiner has the burden of proving that the application lacks novelty and/or inventive step and the applicant has the chance to challenge the rejections by presenting any additional evidence favorable to the patentability, including those pointing to the problem of hindsight bias, the increase of type I errors tends to dominate that of the type II errors. Thus, we have the following Hypothesis 1.

Hypothesis 1

The exogenous policy-induced reduction of the initiation lag would increase both type I errors (wrong grants) and type II errors (wrong refusals) of the examinations. However, the increase of type I errors dominates that of the type II errors especially at the stage of the final rejections.

Furthermore, as the prevailing information constraint can differ across technology sectors due to the variations of the age of relevant prior art at examination, the policy change would have heterogeneous effects, depending on the age of prior art at examination or the sum of the two lags (the lag between the relevant prior art and the patent application and the lag between the patent application and the initiation of the examination), as predicted by equation (3). Therefore, we have following Hypothesis 2.

Hypothesis 2

The effect of the reduction of the initiation lag on examination quality is more significant in the sectors where the information constraint on an examiner is strong even before the policy change.

We use the sum of the initiation lag and the citation lag at sector level before the policy change as a measure of information constraint, in light of equation (3). Such effects are strong in those technology sectors where the initiation lag is short due to early examination requests, and the citation lag is short due to rapid technology cycle. This hypothesis provides additional test for the link through information constraint between the reduced initiation lag and examination outcome as specified in the above equation (3).

Finally, this paper extends our analysis to international applications and investigates one potential mechanism of the puzzle that the grant rate for foreign applicants is lower than that for the domestic applicants. The importance of information constraint on the patent office suggests that one important cause of such lower grant rate for foreign applicants is the longer initiation lag due to one year time allowance for an application with foreign priority.

This causes a delay of the initiation of an examination for such application and provides examiners with more time to learn the relevant prior art. Therefore, we have following hypothesis 3.

Hypothesis 3

Controlling for initiation lag has a significantly positive effect on the grant rate for the international applications with foreign priority, relative to that for domestic applications.

4. Overview of general trend

4.1 Data and sample design

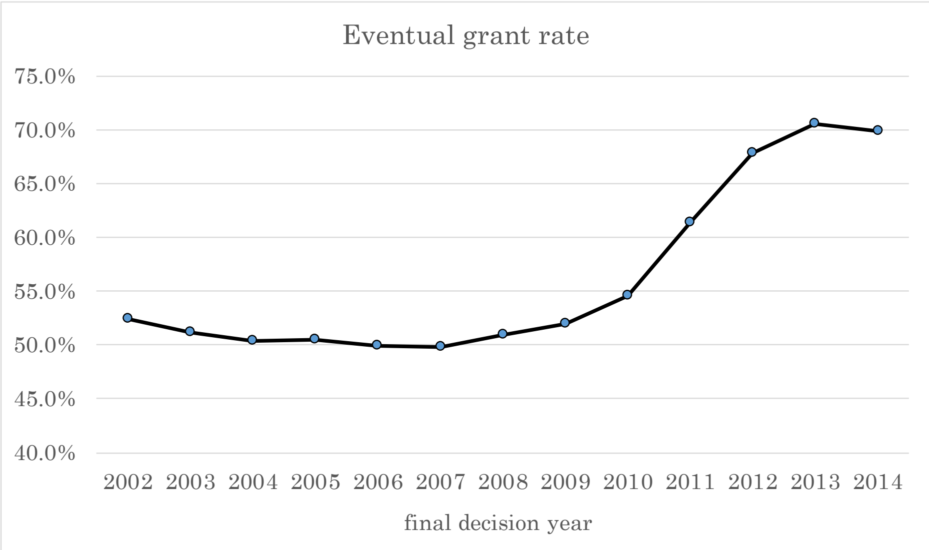
Data used in this study are from the IIP Patent Database, the PAT-R Database and PATSTAT. IIP Patent Database, provided by Institute of Intellectual Property[3], and the PAT-R database developed by the A-life Lab is constructed from standardized data (S*eiri Hyojunka Data*) processed by the Japan Patent Office.

In exploiting the exogenous policy change in October 2001 as an instrumental variable, we need to take into account the fact that the applications filed before the policy change have longer allowance period for examination request (7 years) than the applications after the policy reform (3 years). Since large part of examination requests are submitted toward the end of the allowance period, a significant part of the applications filed before the policy reform can be examined later than the applications filed after the policy change. Thus, we need to design the sample so as to minimize the impact of the changes in the examination standard during the years subsequent to the policy change.

Figure 2 shows the changes in the eventual grant rate by final decision year. We see a significant rise in grant rate from late 2000s to early 2010s. This may bias the grant rate of the applications before the policy change to upward, relative to the applications after the policy change. However, we can assume that the examination standard is stable during the period from 2004 to 2007. To eliminate the bias due to the changes of examination standard, we focus only on the applications examined during this period.

[3] The database comprises patent application files, registration files, applicant files, rights-holder files, citation information files, and inventor files. See Goto and Motohashi (2007) for detailed explanations.

Figure 2. Increasing grant rate



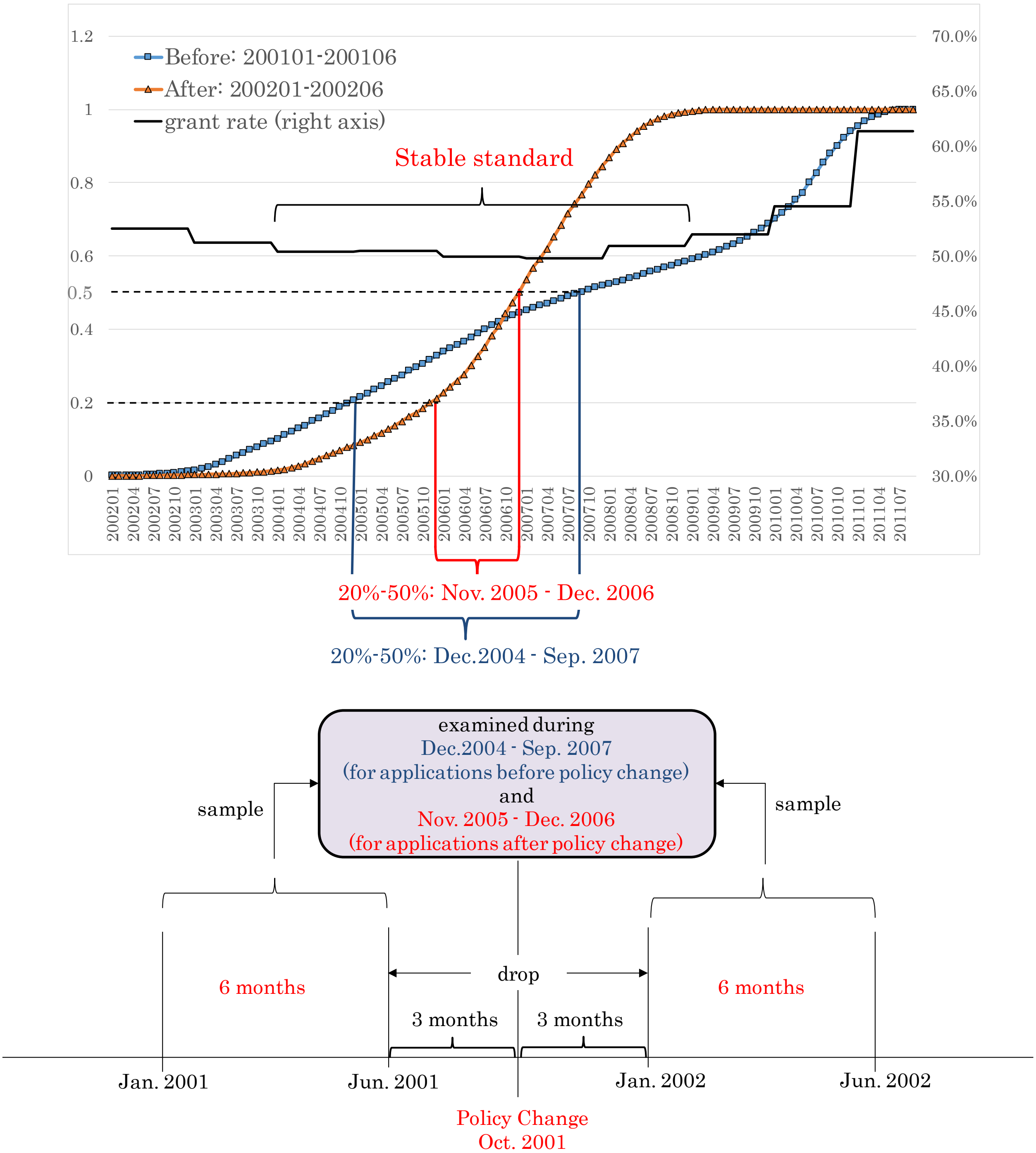
Source: Created based on data from "Japan Patent Office Annual Report"

Moreover, to avoid a possible influence of the strategic timing of the applications by the applicants which have demand for long examination period, we exclude the applications filed just three months before and after the policy change from our sample. At the same time, we compare the examination results of the two cohorts of applications with close filing dates (within 1 year), to minimize the influence of a potential patent application quality change over cohorts by application month. Thus, we restrict our sample to the applications filed during 6 months period from January 2001 and June 2001 (the control group before the policy change) and the applications filed during 6 months period from January 2002 and June 2002 (the treatment group after the policy change). Figure 3 shows the time profile of examinations for these two groups. In sum, we use the 6 months-window before and after policy change, excluding the 3 months just before and after policy reform.

Among those two groups of applications, we extract top 20% to 50% applications of each group in the cumulative distribution function in terms of the timing of examination for our base estimations, as shown in Figure 3: examined during Dec. 2004 and Sep. 2007 for the control group and examined during Nov. 2005 and Dec. 2006 for the treatment group. This restricted sample ("base sample" hereafter) uses only the applications examined between December 2004 and September 2007, which belong to the period where the examination standard is stable, as suggested by Figure 2. Moreover, the window used for the control group is larger than that for the control group in both sides of the ends by almost the same length (12 months and 15 month). Thus, it can significantly avoid a bias due to the changes of examination standard or of the workloads of examiner, that could occur if we used the entire sample with a diffused timing of examinations.

The two groups extract the same part of the cumulative distribution functions of applications in terms of the timing of the examination requests. As more valuable applications are requested for examination earlier in both periods, this sample extraction allows us to compare the applications with similar level of quality. As a robustness check on the sample selection, we will also show the results using the sample without limiting the examination period ("extended sample" hereafter). As shown in Figure 3, the grant rate increased significantly in 2010 and more than 20 % of the applications of the control group were examined in this year while almost none of the treatment group. Thus, there exists a significant bias against finding the increase of Type I error of examination if we use the extended sample.

Figure 3. Cumulative distribution by examination dates and sample extraction for analysis



For an extension of our analysis, we investigate the impact of the longer initiation lag of international applications. For this purpose, we also classify each application as follows: purely "domestic applications" consists of the applications without any priority date, and purely "international applications" consists of the international applications under the PCT or the Paris convention. In order to reduce the influence of inaccuracy of priority data, we limit the sample into the applications of which the interval between the application date and the priority date is within 12 months, since both routes of international application requires an applicant to file within 12 month from the filing date of the first application. Therefore, our sample does not include the divisional applications.

4.2 Overview of data

Figure 4 shows the changes in the number of applications and examination request rate for the extended sample (as we cannot limit the examination date). We see that examination request rate jumped at the policy change by 10.7% (for the 6 months-average before and after policy change), while the number of applications shows similar fluctuation patterns.

Figure 4. Changes in the number of applications and examination request rate

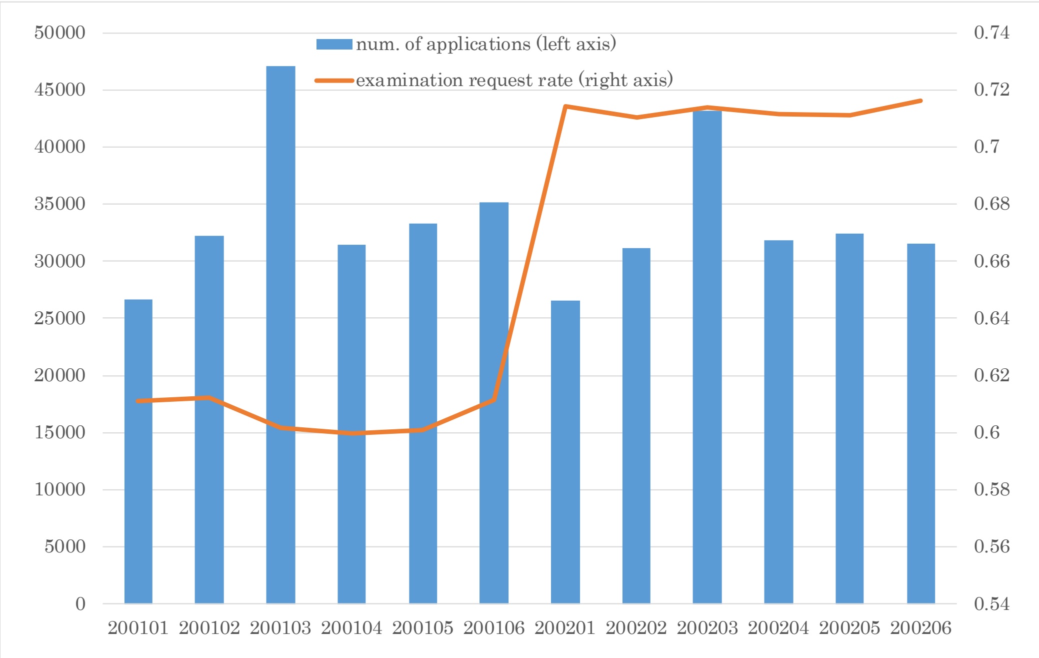


Table 1 shows the basic statistics of initiation lag, examination request lag, grant rate and trials against refusal decisions before and after the policy change, when we restrict the applications based on their timing of examination (base sample), and those when we do not limit the sample (extended sample), respectively. We see that for both samples, the examination request lag declined, being accompanied with the reduction of the initiation lag after the policy change on October 2001. For the base sample, average examination request lag and initiation lag before the policy change was 31.8 and 60.7 months, and they decreased to 27.9 and 52.2 months after policy reform. The magnitude of decrease is larger for the extended sample since restricting the sample only up to those examined by Dec. 2006 limits the basic sample only to those applications examined earlier.

As we saw in Figure 4, in response to the policy change, the examination request rates increased significantly from 60.6% to 71.3%. This large increase of the examination request implied that even the applications with lower patentability were more likely to be requested for examination given uncertainty of the patent value (see Yamauchi and Nagaoka, 2015b for evidence). In spite of this, the initial (eventual) grant rate increased significantly from 43.2% (50.2%) to 44.8% (51.5%) in the base sample. This result suggests a clear possibility that the type I error increased due to the reduction of initiation lag, given that the examination standard was stable during the period (from Dec. 2004 to Sep. 2007) for this sample. In the extended sample under the influence of the change of examination standard, however, the initial grant rate decreased following the policy change presumably because a significant part of applications before the policy change were examined later than the applications after policy reform. At the same time, the trials against refusals increased significantly following the policy reform and eventual grant rate increased.

The "eventual" grant rate reflects the results of the appeal process, whose numerator thus includes the applications firstly rejected but overturned through the appeal process. The "initial" grant only includes the granted applications in the first action. Furthermore, for the base sample in Table 1, the trials against refusal decisions decreased only very slightly, following the policy change. Considering the effects of the quality changes (lower quality of applications after the policy change), these evidences suggest that Type I errors increased with the policy change and it dominate that of the Type II errors, which might have also increased after controls. We will implement more formal statistical testing in Section 5.

Table 1. Initiation lag, examination request rate, grant rate and trials against refusal decisions before and after the policy change

		Before Oct. 2001	After Oct. 2001	Change	Total
Base sample Cumulative examined applications: 20%-50% Before: Dec.2004 - Sep. 2007 After: Nov. 2005 - Dec. 2006	Examination request lag	31.8	27.9	-4.0	29.7
	Initiation lag	60.7	52.2	-8.4	56.0
	Initial grant rate	43.2	44.8	1.6	44.2
	Eventual grant rate	50.2	51.5	1.3	50.9
	Trials against refusal decisions	18.9	18.8	-0.1	18.7
	Success rate of trials	64.9	64.9	0.0	64.9
Extended sample witihout limitation on examination duration	Examination request lag	49.5	27.6	-21.9	37.6
	Initiation lag	78.6	57.0	-21.6	66.8
	Initial grant rate	48.2	47.8	-0.4	48.1
	Eventual grant rate	53.0	54.0	1.0	53.6
	Trials against refusal decisions	13.7	18.5	4.8	16.2
	Success rate of trials	64.9	64.9	0.0	64.9

Table 2 shows the changes of the initiation lag and citation lag by technology sector based on the WIPO technology concordance table. We see a large and uniform reduction of initiation lag due to the policy change across technology fields (more than 10% across the board). The table also shows the degree of information constraint measured by the sum of initiation lag and citation lag before the policy change. Among the fields, we find that the sum of the two lags is smaller in the field of Communication and Computer and Other fields. In these sectors, an examiner may face more severe information constraint; he/she has to start examination earlier and has to refer more recent prior art.

Table 2. Changes of the initiation lag by technology sector (base sample)

	Initiation lag			Citation lag			Initiation lag + Citation lag
	Before	After	Change	Before	After	Change	Before
Electrical engineering	62.1	52.3	-9.8	68.8	71.3	2.5	130.9
Communication and computer	59.9	52.5	-7.5	59.4	60.6	1.2	119.3
Instruments	60.7	52.0	-8.7	63.4	65.5	2.1	124.1
Chemistry	60.6	52.1	-8.5	66.1	71.1	5.0	126.7
Pharmaceutical and Biotechnology	65.6	56.3	-9.3	61.2	68.4	7.2	126.8
Mechanical engineering	61.0	52.4	-8.6	69.4	73.2	3.8	130.4
Other fields	58.7	51.7	-7.0	62.3	67.6	5.3	121.1

Table 3 shows the differences in initiation lag, initial grant rate, eventual grant rate and the number of claims between the domestic applications and international applications with foreign priority. We find that international applications with foreign priority have longer initiation lag (65.5 months) than domestic applications (55.0 months) as international applications have one extra year for applications. At the same time, we find that the initial grant rate (relative to the number of examination requests) is lower for the international applications with foreign priority (40.5%) than domestic applications (44.4%). These results suggest the possibility that examiners have longer learning time to understand the progress of technology for examining international applications with foreign priority, which would decrease the type I error and reduce the initial grant rate.

Another salient finding from this table is that the eventual grant rate (relative to the number of examination requests) is higher for the international applications with foreign priority (53.7%) than domestic applications (50.4%), unlike the initial grant rate. This difference implies that more grants occur to international applications with foreign priority as a result of the appeal process. One potential reason is that the number of claims is much larger for the international applications with foreign priority, especially for the applications based on the US priority. Since the examiner assesses patentability of the invention by each claim, an application with a very large number of claims may run a risk of the initial rejection. At the same time, such application has a large room for amendment so that the decision can be reversed through the amendment of claims during the appeal process. Thus, the difference of claiming practice across applicants of different countries could account for both lower initial grant rate and higher eventual grant rate for the applications with foreign priority. We will examine this possibility in detail in our empirical analysis.

Table 3. Differences between domestic applications and international applications

	Initiation lag		Initial grant rate (%)		Eventual grant rate (%)		Num. of claims	
	N	mean	N	mean	N	mean	N	mean
Total	64170	56.0	64170	44.2	64170	50.9	64170	7.8
Domestic applications	57412	55.0	57412	44.4	57412	50.4	57412	6.7
International applications	6758	64.5	6758	42.3	6758	55.1	6758	17.1
Domestic priority	1154	59.4	1154	50.8	1154	62.0	1154	9.6
Foreign priority	5604	65.5	5604	40.5	5604	53.7	5604	18.7
US priority	2841	65.9	2841	37.6	2841	51.4	2841	22.3
EU priority	326	64.7	326	42.3	326	59.2	326	15.2

5. Estimation strategy and results

5.1 Estimation model

To examine whether the reduction of the initiation lag decreases the examiners' understanding of the relevant prior art and the quality of their examinations, we must control for the endogeneity of initiation lag. For example, when the quality of an invention is high, such invention is requested for examination earlier, as such invention can gain more from longer patent protection. At the same time, the high quality invention is likely to have higher patentability. Therefore, the initiation lag is likely to be correlated negatively with the grant rate, even if this does not indicate the causality.

To control for this endogeneity, we employ two-stage least squares (2SLS) exploiting the exogenous policy change in Japan, which accelerated the timing of examination in October 2001, as an instrumental variable. The policy change significantly reduced the examination request lag and thus decreased the initiation lag (see Table 1). However, it does not directly affect the quality of examiner's decision other than through the impact on the timing of examination.

Our estimations are based on patent application-level monthly panel data. Moreover, as mentioned above, by restricting the sample, we control for the last-minute timing of examination request, for the long-term changes in the quality of patent application across application cohorts, and for the changes of examination standard over examination years. More specifically, we exclude the period three months just before and after the policy change, and restrict the sample to the applications filed during Jan. 2001 and Jun. 2001 and examined during Dec. 2004 and Sep. 2007 for the control group, and the applications filed during Jan. 2002 and Jun. 2002 and examined during Nov.2005 and Dec. 2006 for the treatment group.

The estimation model of the second stage is represented by equation (7), with dependent variable $Y_{i,t}$ measuring the examination quality. The second stage estimation analyzes the effects of initiation lag ($Lag_{i,t}$) on the quality of patent examinations. The first stage estimation identifies the determinants of initiation lag, formulated by Equation (8).

$$Y_{i,t} = \beta_0 + \beta_1 \ Lag_{i,t} + \boldsymbol{\gamma} \ X_{i,t} + \lambda_i + \varepsilon_{i,t}. \tag{7}$$

$$Lag_{i,t} = \alpha_0 + \ \alpha_1 \ Policy \ \ change_{i,t} + \boldsymbol{\eta} \ X_{i,t} + \lambda_i + \epsilon_{i,t}. \tag{8}$$

In Equations (7) and (8), i denotes an individual patent application, and t denotes the monthly application date (or priority date if it exists in the calculation of initiation lag). Vectors $\boldsymbol{\beta}$, $\boldsymbol{\alpha}$, $\boldsymbol{\gamma}$, and $\boldsymbol{\eta}$ are coefficient parameters. We include technology sector dummies λ_i which are 7 categories based on WIPO technology concordance table; Electrical engineering, Communication and computer, Instruments, Chemistry, Pharmaceutical and Biotechnology, Mechanical engineering, and Other fields.

To control for the complexity of inventions, the value of patenting the invention and the applicant's need for early patent protection, we include the number of claims, the number of IPC subclasses of the patent application, the number of inventors listed on an application, and the number of forward citations by examiners. We also include the dummy variable capturing the applications submitted for accelerated examination which have shorter initiation lag. Moreover, we introduce the examiner's workload at the technology sector-first action year level, which is the number of first actions by technology sector in the first action month when the focal application is examined. Furthermore, the dummy variable that takes 1 if the number of claims is larger than 20 (top 5% of the base sample) is included.

Considering potential correlations between variable $Lag_{i,t}$ (initiation lag) and the error term ($\varepsilon_{i,t}$) in Equation (7) such as omitted invention quality variables, we implement instrumental variable estimation, the first stage of which is specified by Equation (8). We use a monthly dummy variable that captures the October 2001 shortening of the maximum period for examination request. This exogenous policy change should markedly reduce the initiation lag but not directly affect examiners' knowledge stock and capability for examining the applications affected.

As dependent variables ($Y_{i,t}$), we use the dummy variables capturing the occurrence of grant decisions (*Eventual grant* and *Initial grant*), the trials sought by the applicants against the rejected applications (*Trials against refusals*), and the trials by the third parties seeking to invalidate the patents (*Trials for invalidations*). Note that while the shorter initiation lag would increase not only Type I errors (wrong grants), but also Type II errors (wrong rejections), Type II errors can be substantially reduced by the trial process. Therefore, we thus differentiate clearly an eventual grant and an initial grant: the former includes the grants firstly rejected but overturned through the appeal process, and the latter covers only grants in the first action. We estimate Equation (7) as a linear probability model.

We focus on the coefficient of the independent variable $Lag_{i,t}$ in the second-stage estimation, which is our indicator of the information constraint. We hypothesize that shorter initiation lag decreases the examination quality measured by the grant probability and the frequency of appeals. If both of the eventual grant rate and the frequency of trials against refusal decisions simultaneously increase, it indicates not only the increases of Type I and II errors but also the relative dominance of Type I error over Type II error (Hypothesis 1). To see whether such effect is more significant in the technology sector under more severe information constraint (Hypothesis 2), we will estimate the effects by technology sector.

As an extension of our analysis, we also investigate how significant the lower grant rate for the applications with foreign priority is explained by the longer initiation lag. To do this, first, we include the dummy variables capturing the applications with foreign priority and the applications with domestic priority. Moreover, we differentiate the priority countries of the applications with foreign priority; US priority, EU priority and other countries priority, given the difference of the patenting practices, especially the large variation of the number of claims across the nationality of applications and by introducing the cross term between the initiation lag and an indicator of the information constraint.

We expect that controlling for the initiation lag which is longer for the applications with foreign priority increases the grant rate of the international applications with foreign priority, relative to that for domestic applications (Hypothesis 3). To test this hypothesis, we compare the magnitude of the effects of the foreign priority between the estimation model including the initiation lag and the one without initiation lag. If the size of the effect is significantly smaller after controlling for the initiation lag, we can infer that the hypothesis 3 is supported.

Table 4 summarizes the descriptive statistics used in the estimations.

Table 4. Descriptive Statistics

	Obs	Mean	Std. Dev.	Min	Max
Initiation lag	69177	56.6	8.93	41	92
Eventual grant*100	69177	51.9	49.96	0	100
Initial grant*100	69177	44.9	49.73	0	100
Trial against refusal decision*100	69177	10.8	31.08	0	100
Trial for patent invalidation*100	69177	0.04	1.90	0	100
Success rate of trials against refusal decision*100	6719	64.9	47.74	0	100
Foreign priority	69177	0.08	0.27	0	1.00
Domestic priority	69177	0.03	0.16	0	1.00
Ln(Number of claims)	69177	1.77	0.80	0	5.50
Ln(Number of IPCs)	69177	1.22	0.80	0	4.96
Ln(Number of inventors)	69177	0.66	0.62	0	3.43
Ln(1+Number of forward citations)	69177	0.79	0.73	0	4.56
Submission for accelerated examination	69177	0.01	0.09	0	1.00
Ln(Workload)	69177	12.1	0.18	11.5	12.37
Large claim	69177	0.07	0.25	0	1.00

	Before Oct. 2001		After Oct. 2001	
	Obs	Mean	Obs	Mean
Initiation lag	30945	61.2	38232	52.9
Eventual grant*100	30945	51.3	38232	52.4
Initial grant*100	30945	44.0	38232	45.5

5.2. Estimation results

(1) Effects of reduced initiation lag on grants and appeals

Table 5 shows the 2SLS estimation results when we use the eventual and initial grant dummies, and the trial dummies as dependent variables in the second stage estimation. This estimation analyzes the effect of initiation lags on the examination quality of patent office. For the robustness check, we show the results for the extended sample (model (3) and (4)) as well as for the base sample, respectively.

In Table 5, the first-stage estimation result shows that the policy change significantly decreased the initiation lag (the first stage estimation for (1) and (2)). In the second-stage estimation results, we find that earlier initiation of examination significantly increased the eventual and initial grant probability and that the effect is slightly larger for the eventual grant probability. We also find that shorter initiation lag increases the frequency of appeals against the refusal decisions (as shown in Table 4, around two thirds of these appeals are successful), which indicates the increase of type II error. These results as a whole reveal the increase of type I error as well as its dominance over the increase of type II error due to the increased information constraint.

According to the estimation results, the eventual grant probability rose by 2.5% (=0.195*12.595) points (average is 51.9%), the initial grant rate increased by 2.3% points (average is 44.9%), and the rate of appeals against the rejections increased by 1.4% points (average is 10.8%), due to the policy change[4]. Given the success rate of appeals is 64.9% on average, the incidence of the examiner's initial rejection being overturned after the appeal process amounts to 0.5% points relative to examination requests (=55.1%*1.4%*64.9%). The magnitude of the effect on the eventual grant is larger than the initial grant by 0.2 % points, which is smaller than the incidence of the examiner's initial rejection being overturned after the appeal process, which is likely to reflect the withdrawals. The initiation lag is statistically insignificant with respect to the frequency of trials for patent invalidations. This might be because the number of trials to invalidate patents is quite small and they occur in a diffused manner over time so that the truncations are severe. Note that the policy change significantly increased the examination request, which should have increased the population of the applications to be examined so that there would have happened the decrease of the quality of the applications requested for examination (Yamauchi and Nagaoka 2015b).

Model (3) and (4) show the results on the eventual and initial grants, based on the extended sample without limiting the timing of examination. The estimated coefficients remain significant and negative. The comparison of the 1st stage estimation results of the two samples show that the initiation lag got reduced by the policy change much more significantly in the extended sample than in the base sample. This is consistent with our sampling strategy for the base sample which only covers the applications of top 20% to 50% in terms of the

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[4] The eventual grant rate is higher than the initial grant rate by the probability of the examiner's initial rejection being overturned after the appeal process but lower than the initial grant rate by the withdrawal of the applications.

timing of initiation of examination (see Figure 3). Nevertheless, the impact on the initial grant rate was estimated to be much lower (0.63%=0.379*1.660) and that on the eventual grant rate to be a bit smaller (1.94%=0.379*5.112). Lower estimated coefficients are likely to reflect apparently less stringent examination standard of the JPO in 2010s, as indicated in Figures 2 and 3. That is, we found significant evidence supporting Hypothesis 1 even if the change of examination standard is against us.

In sum, the results provided in Table 5 strongly suggest that shortening the initiation lag makes it difficult for examiners to identify and understand the relevant prior art properly, which increased both type I and II errors. Moreover the increase of type I errors dominate that of type II errors. The results strongly support Hypothesis 1.

(2) Effects by seven technology sectors

Table 6 reports the estimation results for the eventual grant rates by seven technology sectors. The results for the first stage are very similar across sectors, that is, the initiation lag declined by around 20% in all sectors due to the policy change. However, the effects on the grant rates (the second stage results) differ significantly across sectors. We find that the effect of the policy change is more significant in the *Communication and Computer, Instruments* and *Others* sectors (including game-related technology). The grant rate increased by around 6.0% in *Other*, 5.1% in *Communication and Computer*, and 3.6% in *Instruments.*

Table 5. Effects of initiation lag on grants and on appeals

	Grant_100: base sample Before: Dec.2004 - Sep. 2007 After: Nov. 2005 - Dec. 2006			Grant_100: extended sample			Trial_100: base sample Before: Dec.2004 - Sep. 2007 After: Nov. 2005 - Dec. 2006	
	2nd stage		1st stage	2nd stage		1st stage	2nd stage	2nd stage
	Eventual grant	Initial grant	Ln(Initiation lag)	Eventual grant	Initial grant	Ln(Initiation lag)	against refusal	for invalidation
	(1)	(2)	(1) & (2)	(3)	(4)	(3) & (4)	(5)	(6)
Ln(Initiation lag)	-12.595***	-11.909***		-5.112***	-1.660***		-6.954***	0.135
	(-5.982)	(-5.674)		(-8.462)	(-2.737)		(-3.206)	(0.790)
Reduction of the allowable period			-0.195***			-0.379***		
			(-338.466)			(-226.809)		
Foreign priority (intl. applications)	3.568***	-2.696***	0.190***	0.258	-4.494***	0.238***	20.549***	0.005
	(4.108)	(-3.113)	(175.753)	(0.683)	(-11.858)	(92.389)	(23.397)	(0.071)
Domestic priority (intl. applications)	9.826***	5.271***	0.057***	8.644***	5.473***	0.092***	17.884***	0.100
	(6.666)	(3.588)	(27.498)	(10.841)	(6.837)	(15.925)	(11.082)	(0.896)
Ln(Number of claims)	3.420***	3.240***	0.000	2.061***	1.904***	0.016***	1.088***	0.015
	(11.202)	(10.650)	(1.061)	(12.504)	(11.504)	(13.511)	(3.491)	(0.584)
Ln(Number of IPCs)	3.537***	3.640***	-0.000	3.134***	3.099***	-0.002**	0.727***	-0.000
	(13.650)	(14.093)	(-0.841)	(22.597)	(22.255)	(-2.234)	(2.662)	(-0.001)
Ln(Number of inventors)	3.828***	2.904***	0.000	3.695***	2.762***	0.010***	3.387***	-0.065**
	(11.824)	(9.000)	(0.539)	(21.011)	(15.642)	(8.142)	(10.098)	(-2.484)
Ln(1+Number of forward citations)	5.293***	3.153***	0.002***	3.784***	2.008***	0.001	6.672***	0.068***
	(18.387)	(10.989)	(4.627)	(24.255)	(12.821)	(0.949)	(22.126)	(2.954)
Accelerated examination	15.301***	9.623***	-0.012***	13.536***	8.532***	-0.751***	31.423***	0.661***
	(6.717)	(4.238)	(-3.909)	(12.931)	(8.119)	(-111.733)	(12.114)	(3.962)
Constant	51.428***	36.165***	-2.926***	64.111***	62.953***	1.253***	64.547***	1.199
	(3.792)	(2.675)	(-151.466)	(22.190)	(21.703)	(67.608)	(4.622)	(1.089)
Large claim	yes	yes	yes	yes	yes	yes	yes	yes
workload	yes	yes	yes	yes	yes	yes	yes	yes
Technology sector dummies	yes	yes	yes	yes	yes	yes	yes	yes
Observations	64,170	64,170	64,170	222,590	222,590	222,590	35,838	28,333
F-test	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6. Effects of policy change by 7 technology sectors (base sample, eventual grant)

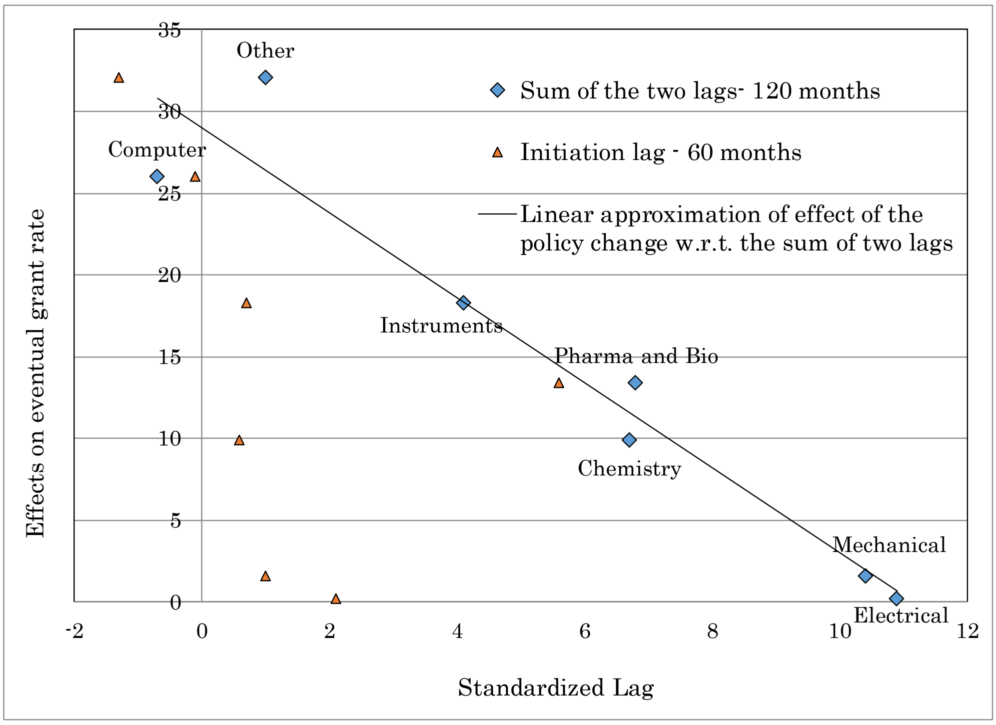
	2nd stage: Eventual grant													
	Electrical engineering		Communication and computer		Instruments		Chemistry		Pharm & Bio		Mechanical engineering		Other fields	
	2nd stage	1st stage	2nd stage	1st stage	2nd stage	1st stage	2nd stage	1st stage	2nd stage	1st stage	2nd stage	1st stage	2nd stage	1st stage
Ln(Initiation lag)	-0.156		-25.961***		-18.262***		-9.870*		13.337		1.539		-32.027***	
	(-0.026)		(-4.940)		(-4.088)		(-1.826)		(0.611)		(0.359)		(-4.581)	
Reduction of the allowable period		-0.199***		-0.195***		-0.197***		-0.196***		-0.180***		-0.193***		-0.187***
		(-115.382)		(-133.599)		(-159.664)		(-132.478)		(-32.831)		(-168.809)		(-103.375)
Foreign priority (intl. applications)	-1.733	0.192***	13.356***	0.192***	1.881	0.192***	5.421**	0.190***	-13.844**	0.186***	-0.051	0.188***	8.019**	0.186***
	(-0.722)	(65.063)	(6.816)	(79.297)	(1.035)	(84.431)	(2.384)	(66.859)	(-2.179)	(28.442)	(-0.026)	(75.917)	(2.177)	(39.336)
Domestic priority (intl. applications)	9.634**	0.094***	13.577***	0.042***	14.101***	0.042***	7.111**	0.064***	-10.427	0.050***	5.631**	0.055***	7.037	0.032***
	(2.486)	(16.999)	(3.554)	(7.744)	(4.463)	(9.452)	(2.020)	(13.053)	(-0.794)	(2.742)	(1.972)	(13.992)	(0.872)	(2.908)
Ln(Number of claims)	1.908**	0.001	3.062***	0.000	6.569***	-0.000	2.331***	0.001	2.329	-0.002	2.631***	0.001	3.481***	0.002*
	(2.078)	(0.487)	(3.874)	(0.008)	(10.154)	(-0.123)	(2.949)	(0.737)	(0.735)	(-0.552)	(4.315)	(0.705)	(3.665)	(1.896)
Ln(Number of IPCs)	5.483***	0.001	2.407***	0.000	3.110***	-0.001	1.285**	-0.001	1.971	-0.000	4.891***	-0.001	5.381***	-0.000
	(7.607)	(0.904)	(3.646)	(0.125)	(5.567)	(-0.808)	(1.980)	(-1.559)	(0.837)	(-0.133)	(9.396)	(-0.878)	(5.780)	(-0.081)
Ln(Number of inventors)	5.137***	-0.000	3.641***	-0.001	3.470***	0.002*	3.117***	0.002	14.202***	-0.003	1.988***	-0.002*	6.692***	0.000
	(5.337)	(-0.168)	(4.536)	(-0.553)	(4.969)	(1.664)	(3.877)	(1.621)	(4.542)	(-0.647)	(2.975)	(-1.688)	(6.520)	(0.052)
Ln(1+Number of forward citations)	6.367***	0.004***	4.005***	0.002**	5.019***	0.002***	7.155***	0.001	6.078**	0.002	5.203***	0.004***	3.993***	-0.004***
	(7.591)	(2.969)	(5.794)	(2.258)	(8.370)	(2.905)	(9.742)	(0.860)	(2.080)	(0.548)	(8.377)	(4.297)	(4.369)	(-3.399)
Accelerated examination	19.573***	-0.024***	7.177	-0.005	17.737***	-0.013*	13.284*	-0.001	27.800**	-0.011	17.754***	-0.010	11.235**	-0.017**
	(3.658)	(-3.142)	(1.166)	(-0.583)	(3.208)	(-1.739)	(1.925)	(-0.115)	(2.550)	(-0.719)	(3.369)	(-1.402)	(2.053)	(-2.271)
Constant	84.909**	-2.743***	-57.493*	-2.927***	79.306***	-2.915***	33.775	-2.981***	-189.089	-2.627***	108.725***	-2.992***	20.792	-2.902***
	(2.086)	(-46.263)	(-1.796)	(-61.907)	(2.711)	(-70.496)	(0.975)	(-60.830)	(-1.512)	(-15.111)	(3.795)	(-75.124)	(0.507)	(-48.785)
Large claim	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
workload	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	7,445	7,445	10,220	10,220	13,846	13,846	9,771	9,771	686	686	15,470	15,470	6,732	6,732
F-test	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figure 5 shows that such effects are stronger with the degree of information constraint across technology sectors, supporting Hypothesis 2. In this figure, the vertical axis measures the effects on eventual grant rate as estimated in Table 6 for 7 technology sectors, while the horizontal axis measures the sector-level average age of prior art at examination, which is our indicator of the information constraint and is given by the sum of the citation lag and the initiation lag before the policy change. Short initiation lag forces an examiner to start examination relatively soon after the application, while short citation lag implies that understanding of the recent literature is critical for an examiner to assess the novelty and inventive step of the application.

This figure clearly shows that as the average age of prior art at examination before the policy change is shorter, the policy change had more negative effects on examination quality (more significantly increased grant rate), while the initiation lag by itself is not correlated with the effects on examination quality. More specifically, in Chemistry sector the initiation lag is short but the citation lag is long, so that the age of prior art at examination is not as short as that in Communication and Computer sector (see Appendix for more specific values). In the Pharmaceutical and Biotechnology sector, the citation lag is short but the initiation lag is the longest, so that the age of prior art at examination is again not as short as that in Communication and Computer sector.

Figure 5. Effect on eventual grant rate and the average age of prior art at examination (measured by the sum of the citation and initiation lags before the policy change)



Note: Each dot represents one of the 7 technology sectors. In the top 4 sectors in terms of the standardized lag, Communications & Computers, Others (such as game), Instruments, and Chemistry, have significant coefficients (see Table 6).

The three technology sectors which had the highest increase of grant rates, Communication and Computer, Instruments and Others sectors, have both below the average citation lag and the initiation lag before the policy change. In these three sectors, the lag between the invention and its commercialization seems to be short so that the request for examination is made early. At the same time, technological progress is quick and technological competition is high, so that the recent prior art relative to the application is critical for assessing the contribution of an invention. The combination of these two factors makes information constraint on the patent office stronger. Thus, these findings provide additional evidence that stronger information constraint on examiners due to earlier initiation of examination is an underlying mechanism for increasing grant rate after the policy change, which supports Hypothesis 2.

To test Hypothesis 2 econometrically, covering both type I and type II errors, we introduce the cross term of the initiation lag and the age of the prior art at examination before the policy change as an additional explanatory variable in the second stage estimation in the previous model. For this estimation, we add the cross term of the policy change dummy and the age of prior art at examination as another instrumental variable in the first stage estimation.

Table 7 shows the results. We find that the coefficients of the cross term are positive and statistically significant for both the grant rate and the frequency of the appeals against the initial rejections. These results mean that in the technology sectors with stronger information constraint (younger prior art at examination before the policy change) the effect of the reduction of the initiation lag is more significant, which supports Hypothesis 2. The first stage estimation results also show that the magnitude of the effect of policy change on initiation lag itself is small though it varies by technology sector with different information constraint, consistent with our earlier finding from the estimations by sectors (Table 6).

Table 7. Influence of the information constraint on the effect of initiation lag (base sample)

	Grant_100: base sample				Trial_100: base sample	
	2nd stage		1st stage		2nd stage	2nd stage
	Eventual grant	Initial grant	Ln(Initiation lag)	Ln(Initiation lag)*av. two lag	against refusal	for invalidation
	(1)	(2)	(1) & (2)		(3)	(4)
Ln(Initiation lag)	-575.446***	-497.324***			-332.640***	2.448
	(-6.679)	(-5.793)			(-3.817)	(0.339)
*Ln(Initiation lag)*av. two lag*	4.459***	3.846***			2.589***	-0.018
	(6.536)	(5.657)			(3.739)	(-0.320)
Reduction of the allowable period			-0.167***	-4.197**		
			(-10.342)	(-2.058)		
*Reduction of the allowable period*av. two lag*			-0.0002*	-0.162***		
			(-1.703)	(-9.990)		
Foreign priority (intl. applications)	3.530***	-2.729***	0.190***	24.008***	20.483***	0.005
	(4.057)	(-3.148)	(175.725)	(175.642)	(23.300)	(0.067)
Domestic priority (intl. applications)	9.417***	4.919***	0.057***	7.224***	17.619***	0.102
	(6.373)	(3.341)	(27.489)	(27.792)	(10.899)	(0.908)
Ln(Number of claims)	3.373***	3.200***	0.000	0.077	1.057***	0.015
	(11.028)	(10.501)	(1.088)	(1.417)	(3.386)	(0.591)
Ln(Number of IPCs)	3.494***	3.603***	-0.000	-0.031	0.696**	0.000
	(13.457)	(13.926)	(-0.849)	(-0.674)	(2.543)	(0.007)
Ln(Number of inventors)	3.915***	2.979***	0.000	0.010	3.441***	-0.065**
	(12.064)	(9.214)	(0.534)	(0.167)	(10.240)	(-2.492)
Ln(1+Number of forward citations)	5.271***	3.134***	0.002***	0.243***	6.658***	0.068***
	(18.280)	(10.909)	(4.634)	(4.766)	(22.061)	(2.958)
Accelerated examination	15.148***	9.491***	-0.013***	-1.557***	31.296***	0.661***
	(6.639)	(4.174)	(-3.915)	(-3.856)	(12.054)	(3.961)
Constant	-43.215**	-45.458**	-2.924***	-346.610***	4.070	1.538
	(-2.176)	(-2.297)	(-151.072)	(-141.830)	(0.190)	(1.006)
Large claim	yes	yes	yes	yes	yes	yes
workload	yes	yes	yes	yes	yes	yes
Technology sector dummies	yes	yes	yes	yes	yes	yes
Observations	64,170	64,170	64,170	64,170	35,838	28,333
F-test	0.000	0.000	0.000	0.000	0.000	0.000

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

(3) Implication of longer initiation lag for the international applications with foreign priority

Lastly, using the base sample, we examine how significantly the longer initiation lag can explain the lower grant rate for the international applications with foreign priority. Table 8 presents the results of the initial grant rate, and we compare the results with the control for the initiation lag (model (1) to (4)) and those without its control (model (5) to (8)). In addition to the dummy variables capturing the international applications with foreign priority and domestic priority, we include the dummies for priority countries (and region) of the international applications in model (3) and (7): US, EU and other countries. Moreover, to capture a potentially differential effect of the number of claims on the grant rates across priority countries, we include the cross term of the number of claims and the priority country (model (2), (4), (6) and (8)). The base line of the estimations is purely domestic applications.

The result of model (5) without controlling for initiation lag nor for the potentially different effects of the number of claims by priority countries, shows a negative and significant coefficient of international applications claiming the foreign priority (*Foreign priority*). It indicates that the initial grant rate is lower for such applications compared with those with domestic applications by 5.6% points, despite of the fact that the applications with foreign priority are more selected due to the higher cost for international applications. On the other hand, the international applications with domestic priority have higher grant rate than the domestic applications (by 4.4%), perhaps mainly reflecting the selections.

Looking at the result of model (1) which controls for the initiation lag, however, we see that the coefficients of *Foreign priority* is reduced to -3.3%, which is significantly lower (by 2.3% points in the absolute value) than that in model (5). This result supports Hypothesis 3 and suggests that the longer initiation lag for the applications with foreign priority because of the time allowance for such application is a significant factor of the lower grant rate for the foreign application relative to the domestic application.

In a further detail in terms of foreign countries with priority, the comparison between model (3) and (7) shows that taking into account the initiation lag reduces the gap from -8.6% down to -6.2% for the applications with US priority, while the grant rate for the applications with EU priority is statistically indifferent from domestic applications in both models.

Table 8. Importance of controlling for the initiation lag (base sample)

	2SLS with initiation lag				OLS without initiation lag			
	2nd stage				Initial grant_100			
	Initial grant_100							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln(Initiation lag)	-11.989***	-11.845***	-11.850***	-11.689***				
	(-5.712)	(-5.644)	(-5.643)	(-5.569)				
Foreign priority (internatoinal applications)	-3.345***	4.699**			-5.627***	2.604		
	(-3.948)	(2.067)			(-7.530)	(1.161)		
Domestic priority (internatoinal applications)	5.205***	10.385***	5.362***	9.360**	4.385***	9.509**	4.658***	8.285**
	(3.542)	(2.620)	(3.657)	(2.360)	(2.998)	(2.400)	(3.188)	(2.091)
*Foreign priority*ln(Number of claims)*		-3.233***				-3.296***		
		(-3.839)				(-3.914)		
*Dometic priority*ln(Number of claims)*		-2.718		-2.050		-2.685		-1.855
		(-1.441)		(-1.087)		(-1.424)		(-0.984)
US priority			-6.248***	3.139			-8.572***	0.897
			(-5.795)	(1.043)			(-8.601)	(0.301)
EU priority			-1.555	29.094**			-3.446	27.111**
			(-0.564)	(2.507)			(-1.259)	(2.336)
Other priority			-0.959	1.059			-3.092***	-0.956
			(-0.864)	(0.291)			(-2.965)	(-0.264)
*US priority*ln(Number of claims)*				-3.538***				-3.556***
				(-3.378)				(-3.395)
*EU priority*ln(Number of claims)*				-12.155***				-12.113***
				(-2.734)				(-2.724)
*Other priority*ln(Number of claims)*				-0.956				-0.992
				(-0.674)				(-0.699)
Ln(Number of claims)	2.766***	3.189***	2.852***	3.222***	2.796***	3.226***	2.880***	3.248***
	(10.063)	(10.841)	(10.364)	(10.980)	(10.171)	(10.964)	(10.466)	(11.070)
Ln(Number of IPCs)	3.643***	3.626***	3.626***	3.609***	3.551***	3.535***	3.534***	3.518***
	(14.103)	(14.037)	(14.038)	(13.971)	(13.770)	(13.708)	(13.704)	(13.642)
Ln(Number of inventors)	2.897***	2.905***	2.920***	2.917***	2.910***	2.918***	2.931***	2.929***
	(8.977)	(9.004)	(9.048)	(9.040)	(9.014)	(9.041)	(9.082)	(9.074)
Ln(1+Number of forward citations)	3.148***	3.121***	3.137***	3.113***	3.014***	2.988***	3.006***	2.984***
	(10.969)	(10.874)	(10.936)	(10.848)	(10.535)	(10.445)	(10.511)	(10.430)
Submission for accelerated examination	9.568***	9.684***	9.558***	9.707***	9.206***	9.328***	9.202***	9.353***
	(4.213)	(4.264)	(4.210)	(4.275)	(4.055)	(4.108)	(4.053)	(4.120)
Constant	37.040***	36.496***	37.544***	37.156***	51.979***	51.253***	52.293***	51.728***
	(2.740)	(2.700)	(2.778)	(2.749)	(3.919)	(3.864)	(3.943)	(3.900)
workload	yes	yes	yes	yes	yes	yes	yes	yes
Technology field dummies	yes	yes	yes	yes	yes	yes	yes	yes
Observations	64,170	64,170	64,170	64,170	64,170	64,170	64,170	64,170
F-test	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Moreover, when we introduce the cross term between the priority country and the number of claims, the coefficient of the *Foreign priority* (model (6)) and *US priority* (model (8)) are no longer statistically significant even in the OLS estimation results, and have positive values, since the cross term has significantly negative effects. This result implies that the number of claims in applications with foreign priority and with the US priority has a significantly negative effect on the initial grant rate. That is, the difference of the grant rate is significantly driven by a large number of claims of the applications with foreign priority. According to the results of model (4), the effect of the average number of claims of the application with US priority is calculated as -9.3 (=-3.538*ln(22.3)), while using model (8) it is calculated as -11.0 (=-3.556*ln(22.3)), given that the average number of claims for US priority applications is 22.3. Given these effects, the control for the initiation lag makes the coefficient of foreign priority significantly positive: 4.7% according to model (2) which is statistically significant and significantly larger than 2.6% of model (6) which is not significant. Although the coefficient of the US priority remains insignificant, it rises from 0.9% to 3.1% according to model (4) and (8).

Finally, Table 9 presents the estimation results using the same specifications for the eventual grant rates. Unlike the results for initial grant rate, the difference between the domestic applications and the international applications with foreign priority are small (see model (5) and (7)). Such difference in differences implies that the amendments through appeals overturn more the initial rejections of the applications with foreign priority. Controlling for the initiation lag makes the coefficient of the foreign priority significantly positive (*Foreign priority,* 3.2% in model (1)). Introducing the differential effects of the number of claims by country of priority further increases the positive coefficient of *Foreign priority* to 6.4% (model (2)). Under these two controls over the initiation lag and the differential effect of the number of claims, the application with a US priority has the positive coefficient of 5.9% which is statistically significant, consistent with high costs for international applications.

The coefficients of the cross term of the number of claims and foreign priority for the eventual grant rates are significantly smaller than those for the initial grant rates. This result suggests that the applications with foreign priority faces a relatively higher probability of initial rejections when they have large number of claims, and such difference significantly gets reduced through the appeal process.

Taking into account the effect of the initiation lag alone, we find that the effect of foreign priority on the eventual grant rate becomes positive (compare Model (1) and (5)), given that the initial rejections for the applications with foreign priority get reversed substantially in the appeal process. That is, longer initiation lag for the applications with foreign priority is a significant cause of less occurrence of Type I error in the eventual grant stage for such applications. That is, longer initiation lag for the international applications with foreign priority enables more informed examination, which in turn results in their lower grant rates than those for the domestic applications with domestic priority with the same invention quality.

Table 9. Importance of controlling for the initiation lag (eventual grant rate)

	2SLS with initiation lag				OLS without initiation lag			
	2nd stage							
	eventual grant_100				eventual grant_100			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Ln(Initiation lag)	-12.637***	-12.595***	-12.497***	-12.425***				
	(-6.001)	(-5.981)	(-5.932)	(-5.898)				
Foreign priority (internatoinal applications)	3.232***	6.386***			0.827	4.158*		
	(3.803)	(2.800)			(1.102)	(1.847)		
Domestic priority (internatoinal applications)	9.791***	9.152**	9.578***	9.586***	8.927***	8.221**	8.836***	8.847***
	(6.643)	(2.301)	(6.511)	(6.514)	(6.083)	(2.068)	(6.026)	(6.032)
*Foreign priority*ln(Number of claims)*		-1.256				-1.323		
		(-1.486)				(-1.565)		
*Dometic priority*ln(Number of claims)*		0.302				0.337		
		(0.160)				(0.178)		
US priority			0.711	5.941**			-1.741*	3.563
			(0.657)	(1.967)			(-1.740)	(1.190)
EU priority			8.036***	21.315*			6.042**	19.161*
			(2.906)	(1.831)			(2.200)	(1.646)
Other priority			4.834***	1.548			2.584**	-0.588
			(4.344)	(0.423)			(2.469)	(-0.161)
*US priority*ln(Number of claims)*				-1.938*				-1.960*
				(-1.844)				(-1.865)
*EU priority*ln(Number of claims)*				-5.272				-5.205
				(-1.183)				(-1.168)
*Other priority*ln(Number of claims)*				1.278				1.236
				(0.898)				(0.868)
Ln(Number of claims)	3.174***	3.311***	3.246***	3.358***	3.206***	3.349***	3.275***	3.390***
	(11.509)	(11.217)	(11.757)	(11.499)	(11.620)	(11.345)	(11.861)	(11.607)
Ln(Number of IPCs)	3.539***	3.533***	3.528***	3.519***	3.442***	3.436***	3.431***	3.422***
	(13.656)	(13.633)	(13.613)	(13.578)	(13.302)	(13.279)	(13.258)	(13.225)
Ln(Number of inventors)	3.824***	3.828***	3.844***	3.840***	3.837***	3.841***	3.857***	3.853***
	(11.812)	(11.823)	(11.875)	(11.862)	(11.848)	(11.860)	(11.907)	(11.895)
Ln(1+Number of forward citations)	5.290***	5.282***	5.281***	5.268***	5.149***	5.141***	5.143***	5.131***
	(18.377)	(18.344)	(18.347)	(18.296)	(17.938)	(17.907)	(17.918)	(17.870)
Submission for accelerated examination	15.273***	15.298***	15.224***	15.283***	14.892***	14.920***	14.848***	14.909***
	(6.704)	(6.715)	(6.683)	(6.708)	(6.536)	(6.548)	(6.517)	(6.544)
Constant	51.882***	51.828***	52.455***	52.570***	67.628***	67.519***	68.010***	68.032***
	(3.826)	(3.822)	(3.869)	(3.877)	(5.081)	(5.072)	(5.110)	(5.112)
workload	yes	yes	yes	yes	yes	yes	yes	yes
Technology field dummies	yes	yes	yes	yes	yes	yes	yes	yes
Observations	64,170	64,170	64,170	64,170	64,170	64,170	64,170	64,170
F-test	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6. Conclusions

This study examined how significantly the information constraint of the patent office affects its examination quality, by assessing the effects of initiation lag which is the lag between the filing date of an application and the initiation date of the examination. The results of this study allow a causal interpretation, since it instruments the initiation lag by an exogenous policy change (reduction of the allowable period for an examination request) in Japan. The study complements the existing literature on the effects of workloads on examination quality, in addition to clarifying the relevancy of information constraint as a source of lower grant rate of patent applications with foreign priority. It also corrected the major problem of the existing literature in measuring the examination quality by covering both type I and type II errors.

More specifically, we found that reducing the initiation lag raised the initial grant rate by 2.3% points (average is 45%) and simultaneously the rate of trials based on the appeals against reject decisions by 1.4% points (average is10.8%), which led to the increase of the eventual grant rate by 2.5% points (average is 52%). These results reveal that the policy change increased both type I and type II errors of examination as well as the dominance of the former as the consequences of more information constraint on the patent office. These results are consistent with the design of the patent examination system in which an examiner has the burden of proof in rejections and the applicant has the chance to challenge the rejections, including those based on hindsight bias. It is important to note that our estimates can be underestimates, because they do not fully reflect the quality deteriorations of the patent applications requested for examination (the policy change significantly increased the examination requests which in turn reduced the average quality of patent applications.)

We also found that the negative effects of information constraint on examination quality became stronger with the degree of information constraint across technology sectors, when we measure the information constraint by the age of prior art at examination (the sum of the citation lag and the initiation lag) before the policy change. Short citation lag implies that understanding of the recent literature is critical for an examiner to assess the novelty and inventive step of the application, and short initiation lag forces an examiner to start examination relatively soon after the application. Therefore, the results show that the combination of short initiation lag and short citation lag makes information constraint more severe so that the policy change had more significant negative effects on examination quality in the following sectors: Communication and Computer, Instruments and Others sectors (including game-related technology).

Moreover, this paper also found that a longer initiation lag for the international applications with foreign priority significantly implies a lower grant rate for those applications, due to more informed examination.

The results in this paper suggest that early initiation of examination can strengthen the information constraint in patent examinations and reduces examination quality both in terms of type I and type II errors (wrong grants and wrong rejections). While a timely completion of patent examinations keeps patent system functional and promotes innovation, examination quality is also crucial. This study suggests a clear evidence of a tradeoff between the two goals, unless adequate investment and patent system design are made.

One measure to prevent the erosion of the quality of examinations while accelerating examination would be to gather more information from third parties through voluntary information submission system as well as through post-grant opposition system. From this perspective, the recent re-introduction of the post-grant opposition system in Japan is an important policy change from which favorable effects can be expected. More international collaborations of patent offices in prior art search and the improvement of prior art database would also contribute to this objective. Examination fees combined with more choices for applicants with respect to examination requests could be used more actively: higher fees for early examination requests, reflecting larger resource costs for examining such application and higher fees also for very late examination requests, reflecting the third-party costs of monitoring and waiting.

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Appendix

Figure A1. Citation lag and Initiation lag before the policy change by technology sector