(Preliminary)

Use of grace period and its impact on knowledge flow: evidence from Japan*

Sadao Nagaoka[a] and Yoichiro Nishimura[b]

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One of the most important differences among the national patent systems lies in the grace period system: in the US it is automatic for one year while there is almost none in Europe, and Japan in between. This paper examines what determines the use of the grace period as well as its effect on knowledge flow, based on data from Japan, which allows 6 months grace period upon the notification of the specific earlier disclosure. Knowledge flow effect is critical for us to discriminate which of the three alternative views (acceleration of disclosure, deferral of domestic patent filing and promotion of domestic patenting) best explains the economic effect of the grace period. Major findings are the following. The exception is more used for the inventions with strong science linkage in high technology sectors, but with a smaller number of claims. The use of the grace period has significantly declined since the middle part of 2000s, despite the jump of its use in early 2000s, following its liberalization. According to our analysis, the globalization of the applications, especially, the PCT reform in January 2004 for automatic designation of all PCT contracting states, had a significantly negative impact on the use of the grace period. In addition, the use of the grace period increased significantly the levels of non-self forward citations, relative to those of self-citations, suggesting that it promotes knowledge diffusion.

a Professor, Institute of Innovation Research, Hitotsubashi University, 2-1, Naka, Kunitachi Tokyo 186-8601 Japan, and Program Director, Research Institute of Economy, Trade and Industry, Email nagaoka@iir.hit-u.ac.jp

b Kanagawa University, Department of Economics, 3-27-1, Rokkakubashi, Kanagawa-ku, Yokohama City, Kanagawa Prefecture 221-8686, Japan
E-mail address: yoichiro@kanagawa-u.ac.jp

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1. Introduction

Although international harmonization of patent systems has made significant progress over the past decades, especially though the implementation of the TRIPS agreement and the AIA (American Invents Act) in the USA, important national/regional differences still remain. One of the most important differences is the rule on the grace period[1]. In general, a patent system based on first-to-file principle requires the inventor to file the patent application prior to revealing his or her invention to the public if he or she does not want to lose the novelty of the invention. A grace period is the period before the patent application, during which the applicant can disclose his or her invention, without its novelty being lost by that disclosure. The grace period up to one year is automatic in the USA. In fact a publication before the application may become more important in the US system for establishing priority under the AIA. On the other hand, the grace period barely exists in most European countries (disclosure only though approved exhibitions[2]). Japan stands in-between: 6 months grace period and the prior disclosures need to be reported to the JPO.

The increasing globalization of the patent applications has made the search for

[1] The "Tegernsee Group", a consortia of national and regional patent offices, identified the following 5 issues: first-inventor-to-file, grace period, prior user rights, scope of prior art, definition of novelty and non-obviousness/ inventive step, and 18 months publication, as key to the substantive patent law harmonization process (Tegernsee Group, 2014).

[2] An un-intended disclosure as a consequence of an abuse by a third party is also covered as an exception.

the best system and the harmonization of the patent systems toward that goal more urgent. Given that earlier disclosure in any county causes the loss of the novelty of the invention in the country without the grace period exception, the applicant cannot use the grace period even if a home country allows it, when it wishes to obtain a patent in such foreign country with no grace period exception. That is, in such case, as Franzoni and Scellato (2010) points out, a lack of patent law harmonization is likely to cause the most restrictive law to prevail, no matter what the relative efficiency of patent system is. The use of the grace period in Japan has started to decline since the middle part of 2000s, despite the jump of its use in early 2000s, following the significant reform in 2000. The first objective of this paper is to assess how significantly the globalization of the patent applications by Japanese organizations can account for such decline.

A grace period allows the inventors more flexibility to cope with different rules set by scientific publications and by the patenting procedures. In particular, it allows them to seek patent rights, without the fear of the prior disclosure constraining the patentability and the scope of protection. Thus, clearly those inventors gain from the grace period system. The question is the effects on third parties. Third parties as a whole may also actually gain from the grace period if prior academic disclosure through conferences and academic publications significantly accelerates the diffusion of

knowledge. That is, if an inventor postpones the submission of the academic disclosure to the date of the patent application or, later, to the date of its publication, the disclosure of the underlying research for the invention would be delayed significantly. We call such view as the disclosure acceleration view of the grace period system.

At the same time, there exists and alternative view of the effect of the grace period system, held by its critics, who pointing out the possibility that the grace period actually allows the applicant to postpone the filing of the patent application, so that it is used for the delaying the filing for the purpose of enjoying a longer period of patent protection. Note that the count of the length of patent protection starts with the date of patent application or with its priority date. We call such view a “deferral of domestic patent filing view” of the grace period system. A grace period system does not enhance knowledge flow under this view. The second objective of this paper is to discriminate these two views by assessing the effects of the grace period on knowledge flow to the third parties. There is a third view (“Promotion of domestic patenting view”), according to which the grace period encourages the university researcher with primary interest on academic publication to obtain the patent on the invention after the disclosure of the output of scientific research. A grace period system under this view does not enhance knowledge flow either. Since we can assess only the knowledge flow as reflected in

patent citations, we cannot directly assess the relevancy of the third view from knowledge flow effect. However, we will assess the third view based on our investigation of the determinants of the use of the grace period.

For this study, we have constructed a novel and comprehensive data of the use of the grace period in Japan, matched with applicants data and the bibliographic data, to analyze the determinants of its use, and in particular, whether its use has been negatively affected by an increasing globalization of patent applications, as well as whether the use of a grace period enhanced the knowledge flow to the third parties. We exploit an exogenous policy change (PCT reform in 2004), which has enabled a single PCT application to gives its applicant a bundle of options to apply for a patent in any number of countries if it is done within 30 months from the priority date, and the difference in differences approach in examining these issues, to control for endogeneity of the use of the grace period.

The rest of the paper is organized as follows. Section 2 briefly reviews prior literature and Section 3 develops hypotheses based on three alternative views on the effects of the grace period. In section 4, we present descriptive statistics on the data that we use for testing hypotheses and provide the estimation strategy. Section 5 presents the empirical results and section 6 concludes and discusses policy implications. Appendix

describes grace period exception in Japan from a historical perspective and the international comparative viewpoint.

2. Prior Literature

To best of our knowledge, economic analysis on the use and the effects of the grace period system is very rare. There exists substantial body of theoretical analysis of disclosure in the context of cumulative innovations (see Scotchmer (2004) for a comprehensive analysis). One key message from the theoretical analysis is that if ideas are scarce, disclosure increases the probability in each period that there will be an idea for further advance by expanding the existing public knowledge stock. From this perspective, if the grace period accelerates the disclosure by inventors who are willing to do so, it will promote technical progress. The main empirical question, then, is whether the grace period accelerates the disclosure.

Exiting empirical research on the grace period is very limited, significantly due to the design of the grace period. No records on the use of the grace period exist in the US, since the grace period is automatic. Such records also do not exist in Europe, where the grace period other than for exhibition barely exists. However, Japan is an exception, since it has a 6 months grace period system and it requires the notification of the

specific disclosure made by the applicant against which the application does not wish to lose its priority.

An important exception in empirical analysis of the grace period system is Franzoni and Scellato (2010). They developed the data set of patent and publication pairs (through inventor- author matching and through documents matching), in order to assess how often the grace period exception is used in the US and how significantly the patent-publication lags varies between the US and Europe. Their sample size, however, is small (299 for the US and 62 for Europe).They found that the grace period exception is used by nearly one third of academic inventors in the US, even though there is a substantial risk of international extensions being denied. They also found that an extension abroad from the US increases publication delay, as does the presence of a firm among the assignees, for the patents which do not use the grace period. Furthermore, they found that the publication lags are shorter when priority of the patent is claimed in the US than in Europe, which shows that the absence of the grace period in Europe makes Europe-based researchers less competitive in getting scientific priority, according to their interpretation.

Their study did not attempt to measure the impact of the grace period system on knowledge flow, which is critical for assessing the economic role of the grace period

system. While their study focuses on the patent-publication delay, it is important to note that such delay itself does not necessarily inform us of the effect of the grace period on knowledge flow. Consider an example where an European researcher publicly disclose hit research just after the patent filing, while a US researcher files for an patent in one year from the date of disclosure of the research, using the grace period. In this case, the patent publication delay is 0 for the European researcher while it is – 12 months for the US researcher, so that it looks as though the grace period accelerate knowledge spillover. However, if the US researcher simply delayed his filing by 12 months, taking advantage of the grace period, there will be no such effect. This example clearly shows that it is important for us to directly assess the knowledge flow effect of the grace period, to unde4rstand its economic role, which is one of our central objectives.

While they point out clearly the importance of cross-border effects of the grace period system, their empirical analysis does not directly cover how the globalization of patent filing affects the use of the grace period[3]. This would be substantially due to the fact that they have developed only cross section data. Our research assesses the question of how the globalizations of the patent applications have affected the use of the grace period, using a large scale panel data in terms of the

[3] They, however, assessed the effects of international extension of the patent right on publication delay, based on those publication-patent pairs which do not apparently use the grace period.

coverage of the sectors and application years in Japan.

de Saint-Georges and van Pottelsberghe de la Potterie (2013) argue that grace period introduces uncertainty by allowing "the authors of published material to "reserve" their inventions for a certain period of time without the inconvenience or cost of filing a patent". In their study, grace period is one of nine components of which the aggregated index of the quality of patent systems is comprised. According to their findings, the higher the quality index, the lower the demand for patent rights (the number of claims filed, the number of patents filed).

There are a number of informative surveys on the grace period. The most recent one is done by "Tegernsee Group" (2014), the respondents of which were the applicants (412 respondents to the JPO survey, 289 to the USPTO survey and 147 to the European surveys). The survey results sharply differed among the regions, depending on whether the resident country of the respondents has the grace period system or not. In Japan and the U.S, the vast majority of the respondents supported the grace period system, while there was only a slim majority favoring the grace period in Europe as a whole[4]. As for the implications of grace period, a large fraction of the respondents in Japan and the US think that the grace period are either user-friendly for SMEs (Japan

[4] There are significant heterogeneity within Europe.

40%, the U.S. 70%), or they encourage early publication of inventions for public interest (Japan 46%, the U.S. 65%). Only minority of the European respondents appreciate these positive impacts (37% for the SME and 28% for the public interest). On the other hand, Europe respondents think that a grace period system may undermine the legal certainty of the patent system (61%), while such respondents are minorities in Japan (14%) and in the US (30%).

There is another recent survey on the views of the technology transfer professionals of European research universities toward grace period (Edmondson et al., 2013). According to the survey, two third of the respondents replied that European patent system should adopt a grace period. As for the reasons, 49% of them points out "Because it enhances academic freedom to speak early about discoveries." Another 45% of the respondents points out "To avoid potential economic loss and social benefits from a patent." Around 50% of the respondents reported that the loss of patent protection due to premature public disclosure occurred "very often" or "fairly often". On the other hand, among the minority respondents against a grace period, 59% of them mentioned that: "it would create unnecessary uncertainty about patent priority" as a reason for objection.

The report by the European Commission (2002) reports that publication delays

do occur in Europe which does not have the grace period, but less so (less than 20%) with more experienced users of the patent system[5], based on the results of the survey. The survey covers public and commercial researchers in the genetic engineering. According to the survey, there was a clear preference of the academic sector for a grace period in order to avoid and/or minimize any delays of publication of research results that may be the subject of a patent application. Based on the review of this survey as well as other survey evidence, Geuna and Nesta (2006) argues that the introduction of a grace period in Europe is likely to have a considerable impact in reducing the conflict between scientific publication and patenting for exploitation, especially in those disciplines where the distinction between basic and applied sciences is more blurred (e.g. biotechnology).

While there is a grace period for one year in the US, there exit views that such exception should be further expanded. Grushcow (2004) argues that scientists who seek patents are more secretive, withholding publication or presentation of their data so as not to jeopardize patentability. It recommends increasing the rewards for early data sharing while providing an explicit experimental disclosure exception. Bagley (2008) emphasizes the importance of globalizing the grace period.

[5] According to Owen-Smith and Powell(2001), past experience with the legal aspects of patenting reduces future cost of patenting.

3. Three views on the effects of the grace period and hypotheses

3.1 Three views on the effects of the grace period

As suggested in the literature survey, there are three views on the effects of the grace period system. One view is that it promotes an early academic disclosure of the research output ("*Acceleration of disclosure view*"), since early disclosure does not constrain the patentability of the associated invention, consistent with the policy objective of allowing the grace period exception. According to this view, the preparation of the domestic patent filing document takes extra time so that the disclosure of research results to scientific community is delayed if there is a risk that such disclosure causes the loss of the patentability, as long as the applicant would like to obtain the patent right. In this case the grace period exception promotes early disclosure of the scientific research: In Figure 1, it accelerates the academic disclosure from point B to point A in calendar time.

(Figure 1)

The second view, which is held by the critics of the grace period system, is that the grace period allows the applicant to postpone the filing of the patent application ("*Deferral of domestic patent filing view*"). If such view holds, the grace period system has no effect of accelerating the disclosure, since a firm (or a university) would have

simultaneously filed for a patent application as the academic disclosure, if there were no grace period, as illustrated in Figure 1. The first and the second views have quite different implications on the effect of grace period on knowledge spillover to the third parties as well as on what type of inventions are applied for grace period exception. We will investigate these differences to identify which view is more consistent with the observed behaviors of the applicants.

The third view, which is especially relevant to a university researcher with primary interest on academic publication, is that the grace period encourages such researcher to obtain the patent on the invention based on the scientific research after the disclosure of the output of scientific research ("*Promotion of domestic patenting view*"). In this case the grace period system has no effect of accelerating the disclosure, since the academic disclosure without filing a patent is the choice under no grace period, and the benefit from the grace period is the commercial value of patenting in the home country. The cost from the grace period is that the disclosure needs to be done in consistent with the rule of the grace period, which may constrain the timely academic disclosure.

3.2 Use of the grace period

We consider a decision of an academic or corporate researcher on whether it would apply for the grace period exception in the county with such exception. The alternative to the use of the grace period is either to postpone the publication, to accelerate the domestic patent filing and to forgo the domestic patent filing, corresponding to the above three hypotheses. Under the acceleration of disclosure view, the benefit from the grace period is a larger chance to establish scientific priority by an early disclosure of the research to the scientific research community (we call it "*Benefit from priority in science*"). Such benefit is larger when the research project generates an important scientific discovery. We assume that such chance increases with the science linkage (θ) of the research project, that is, how intensively the invention exploits the scientific knowledge sources, as well as with the size of the inventor team (x). In the disciplines where the science linkage of the invention is strong (e.g. biotechnology), the research more often belongs to "Pasteur" quadrant (Stokes, 1997) and the distinction between basic research and applied research is blurred (Geuna and Nesta, 2006)), so that a patentable invention and a scientific discovery are more likely to be jointly produced.

The cost of using the grace period on the basis of academic disclosure is the loss of patenting opportunities in those countries with no grace period exception on that basis (we call it "Cost from foreign patents loss"). We assume that such cost rises with

the decline of foreign patent application cost (c_f), with the (average) patenting value in a foreign country (v_f) as well as with the number of those countries (*n*). Given these benefits and costs and linearizing the benefit function, the researcher will seek a grace period exception for the invention (*i*), if

$$\textit{Benefit from more chances for priority in science}_i = \alpha\theta_i + \delta x_i >$$

$$\textit{Cost from foreign patents loss}_i = n(v_{f_i} - c_{f_i}) \qquad (1)$$

Under the *deferral of domestic patent filing* view, the benefit of the use of the grace period is the deferral of the domestic patent filing, and there is no effect on the timing of academic disclosure. The benefit from the grace period is instead a longer protection of the invention in the country with such exemption, which rises with the commercial value of patenting in the domestic market (v_d_i). The cost of using the grace period is foreign patent loss. Thus, the researcher will seek a grace period exception for an invention (*i*), if

$$\textit{Benefit from deferral of domestic patent filing}_i = v\_d_i >$$

$$\textit{Cost from foreign patents loss}_i = \quad n(v\_f_i - c_{f_i}) \qquad (2)$$

,subject to the existence of scientific output from the research project.

Under the promotion of domestic patenting view, a university researcher putting high priority on academic publication forgoes the patenting under no grace

period. The benefit from the grace period is that the extra time gained for patent application enables the researcher to obtain a patent in the domestic market, while the cost is some inflexibility imposed on academic disclosure from following the rule of the grace period (the researcher has to coordinate the disclosure and patenting), which is larger for a . Thus, the researcher will seek the grace period if

$$Cost\ from\ inflexibility\ in\ disclosure\ for\ priority\ in\ science_i = \alpha'\theta_i + \delta' x_i <$$

$$Beneifit\ fom\ domestic\ patenting = v\_d_i \quad (3)$$

The above framework provides the following testable hypotheses on the use of the grace period among the patent applications as well as on the knowledge flow effects. Since we observe only the patent applications with or without the use of the grace but not the entire combinations of academic output with patentable inventions, what we can assess is the probability of the use of grace period conditional on patent application, which can be decomposed in the following manner: the probability that a patent application is associated with a scientific discovery, multiplied by, the probability that the disclosure of the discovery will be made under the grace period system:

$$Probability(Grace\ period|Patent)_i = Probability(Discovery|Patent)_i *$$

$$Probability(Grace\ period|Discovery)_i \quad (4)$$

Our first hypothesis is on the effects of globalization of the domestic patent

applications, driven by the exogenous policy change, on the use of the grace period on the basis of academic disclosure. More chances to apply patents to those countries with no grace period and lower marginal cost of such applications affects only equation (1) and (2). In addition, since the period on the basis of exhibitions is widely recognized internationally, we also anticipate that more chances to make global patent applications do not affect the use of the grace period on the basis of exhibitions. Assuming that the grace period does not affect the probability that a patent application is associated with a scientific discovery, we have the following hypothesis.

Hypothesis 1-1 (Hypothesis on globalization)

(1) More chance to make global applications reduces the use of grace period more in those technology fields with high global patent applications, when the effect of grace period is either acceleration of disclosure or the deferral of domestic patent filing. On the other hand, it does not affect the use of grace period if the effect of the grace period system is the promotion of domestic patenting.

(2) More chance of using global applications does not affect the use of the grace period on the basis of exhibition.

We will use the PCT reform introduced in 2004 as an exogenous change to test

this hypothesis.

When the focal invention uses scientific knowledge intensively either for the idea for the R&D or for the implementation of the R&D, it is more likely that the patent is associated with a scientific discovery and there will be an opportunity for using the grace period under any view. Furthermore, high science intensity project is more likely to generate the scientific output with high value, which in turn enhances the value of early disclosure. This latter effect influences the decision on the grace period only under the acceleration of disclosure view, where the tradeoff is between the cost of foreign patent loss and the academic disclosure. On the other hand, the enhanced value of early disclosure does not increase the grace period under the “deferral of domestic patent filing view”, where the tradeoff is between the cost of foreign patent loss and the gain of longer domestic protection, nor under “the promotion of domestic patenting view”, where the tradeoff is between some inflexibility of academic disclosure imposed by the rule of the grace period and the gain from domestic patenting. Thus, we have the following hypothesis.

Hypothesis 1-2 (Hypothesis on science linkage)

The use of the grace period increases monotonically with its science linkage under

the acceleration of disclosure view. However, the effect of higher science linkage may turn to becoming flat or negative under the "deferral of domestic patent filing view or under "promotion of domestic patenting view".

Higher commercial value of a patent increases the cost of foreign patent loss due to the use of the grace period. Thus, it reduces the use of the grace period under the acceleration of disclosure view, where the tradeoff is the cost of foreign patent loss and the academic disclosure, controlling for the probability that the patent is associated with the scientific discovery. On the other hand it increases the value of deferring a domestic patent filing so that it can increase the of the grace period under the "deferral of domestic patent filing view", where the tradeoff is between the cost of foreign patent loss and the gain of longer domestic protection. It increases the use under "the promotion of domestic patenting view", where the tradeoff is between some inflexibility of academic disclosure imposed by the rule of the grace period and the gain from domestic patenting.

Hypothesis 1-3 (Hypothesis on the commercial value of a patent)

The use of the grace period declines with commercial value of the focal patents under the "acceleration of disclosure view". On the other hand, higher commercial value of

the focal patent can cause more use of the grace period under the "deferral of domestic patent filing view" and does so **under "the promotion of domestic patenting view".**

The implications of these hypotheses are summarized in the following Table 1.

(Table 1)

Academic researchers recognize more benefit from priority in science than corporate or industrial researchers, while they recognizes less the cost from foreign patents and the gain from domestic patenting than corporate researchers. Thus, under acceleration of disclosure view, the above equation (1) immediately implies that academic researchers use the grace period exception more than the corporate researchers, for a given type of the invention. Moreover, deferral of domestic patent filing view, if valid, is more likely to hold for the corporate researchers while the promotion of domestic patenting view, if valid, is more likely to hold for university researchers.

3.3 The impact of grace period exception on knowledge flow

According to the "*acceleration of disclosure view*," those inventions subject to grace period exception are revealed through academic disclosure to the public earlier than

those inventions the disclosure of which come only later than the date of domestic filing. On the other hand, according to the "*deferral of domestic patent filing view*," the adoption of grace period is used to delay the filing but not for accelerating the academic disclosure. According to "*promotion of domestic patenting view*", the adoption of grace period does not accelerate the disclosure either, although we cannot measure that effect since we do not have data on academic disclosure without domestic patent filing.

Hypothesis 2 (Hypothesis on knowledge flow)

A grace period accelerates the knowledge flow to the third parties, according to the "acceleration of disclosure view", but it does not under the "deferral of domestic patent filing view."

4. Data and estimation strategy

4.1 Data

We constructed our dataset of the patent applications filed from 1992 to 2008, matched with three sources of database: (1) the data on the individual use of the grace period as reported to the JPO, (2) the bibliographic data such as non-patent literature reference data, and (3) the applicants data. The comprehensive data on the individual use of the grace period as reported to the JPO were made available from the JPO for this research. We have collected the bibliographic data from the IIP patent database compiled by IIP[6] and the databases developed by Jinko Seimei Kenkyuujo. In particular, we used the non-patent inventor references data extracted by Jinko Seimei Kenkyuujo from the patent documents to measure the science linkage of a patent. Lastly, both Japanese company name dictionary data developed by NISTEP and SIPRA data provided by JPO were used as applicants data and were merged with the above individual patent data.

To measure the timing of the knowledge flow accurately, the divisional applications and the applications based on domestic priorities were removed from our dataset of the econometric analysis for knowledge flow. As a consequence, our sampled patents have covered roughly 77% of the entire domestic patent applications.

[6] See Goto, A., Motohashi, K., 2007. Construction of a Japanese Patent Database and a first look at Japanese patenting activities. Research Policy 36, 1431-1442.

4.2 Descriptive statistics

Figure 2 shows the variation over time of the use of grace period and of the PCT application propensity by the applicants in Japan. As we have anticipated, there was a major surge of the use of the grace period exceptions since 2000, driven by the reform of grace period rule in 2000 (see the Appendix for details). Furthermore, the use of the grace period showed a decline and became flat since 2004 (the year when the designation-of-state rule for PCT filing was abolished). On the other hand, there have been a continued rise of the share of PCT applications.

(Figure 2, around here)

Figure 3 shows the variation over time of the use of the grace period on the basis of academic disclosure in science intensive sectors and that on the basis of exhibition in exhibition intensive sector, together with the aggregate use in the overall sectors. The level of the use of the grace period in science intensive sectors is significantly higher than that in the overall sectors. The former level (3-5.5%) is ten times larger than the latter one (0.3-0.55%). At the same time, the variation over time of the use of the grace period in science intensive sectors is very similar to that in the overall sectors. The variation of the use of the grace period on the basis of exhibition shows no strong changes as those for that on the basis of academic disclosure. This is what we would

expect, since the grace period on the basis of exhibition has been widely accepted globally. These patterns are consistent with Hypotheses H1-1 and H1-2.

(Figure 3, around here)

Figure 4 provides the variation over time of the incidence of the use of the grace period by four types of applicants. As is shown in figure 4, academia depends on grace period exception the greatest (7%~16%). In contrast, corporations use much less frequently, as we would expect (0.2%~0.32%).

(Figure 4, around here)

Figure 5 shows the level and variation over time of the use of the grace period by intensity of the use of PCT applications across sectors. As is shown in this figure, if a technology field is highly globalized, the inventions in those fields use more the grace period. Moreover, the sharp decline of the use of the grace period occurred in the sectors with high PCT propensity after the reform of a PCT filing rule in 2004. When we focus on technology sectors categorized by the level of science linkage, higher science linkage is associated with more use of grace period exception as shown in Figure 6.

(Figure 5 and Figure 6, around here)

4.3 Estimation strategy

(1) Determinants of the use of the grace period

We use the panel data covering the period from 1992-2008 and 33 technology fields. The estimation is at an individual patent level, using the decision on the use of the grace period as the dependent variable and the invention characteristics as independent variables. We estimate the following basic equation for the use of the grace period.

$$\mathrm{GRACE}_i = \beta_0 + \beta_1 \cdot \ln(\mathrm{SCIENCE}_i + 1) + \beta_2 \cdot \ln(\mathrm{INV}_i) + \beta_3 \cdot \ln(\mathrm{CLAIM}_i) +$$

$$\beta_4 \cdot \mathrm{PCT}_{k-f,t-1} + \beta_5 \cdot \mathrm{PCT}_{k-f,t-1} \times \mathrm{REFORM\_PCT}_i + \sum_j \beta_j \mathrm{APPLICANT}_{i,j} +$$

$$\sum_k \beta_k \mathrm{TECHNOLOGY}_{i,k} + \sum_t \beta_t \mathrm{YEAR}_{i,t} + \epsilon_i \qquad (5)$$

A patent is denoted by *i*, firm by *f*, applicant by *j*, technology sector by *k* and year by *t* respectively. The dependent variable, GRACE, is a binary variable that takes a value equal to 1 if the applicant files a patent application with a grace period exception and a value of zero otherwise.

As for the explanatory variables, SCIENCE is the number of backward citations to non-patent literature, and INV is the number of inventors who made the patented inventions. CLAIM, which is the number of claims, measures the commercial value from patenting. For the purpose of measuring the globalization of domestic patent filing, we do not use the international patent filing data of the focal patent unlike the previous study (Franzoni and Scellato, 2010), since the latter is clearly an

endogenous variable (if a particular patent uses the grace period exception, its foreign extension is constrained). Thus, we use a sector level variable, PCT, which is the ratio of the count of PCT patent applications (excluding the number of PCT applications made by the focal institution) relative to domestic patent (JP) applications (excluding the number of JP applications made by the focal institution) in each technology *k* in each year *t*-1. This variable measures the globalization of patent filings by domestic residents (excluding the focal institution) for each sector in each year. Since we introduce fixed effects for technology sectors, the PCT variable essentially measures the effect of the time variation of the globalization of patent filings, lagged by one year.

REFORM_PCT is set to 1 after 1st January 2004 and to a value of zero before this date. From 1st January 2004, all PCT contracting states are automatically designated for a national or regional patent if the applicant files the PCT patent application afterward. As a result, a single PCT application gives its applicant a bundle of options to apply for a patent in any number of countries if it is done within 30 months from the priority date. We use this variable as an exogenous policy shock enhancing the benefit of preserving the option of making foreign patent applications to those countries with no grace period. We use the interaction term between PCT and REFORM_PCT as the explanatory variable.

Other important explanatory variables are dummy variables: APPLICANT, by which we classify applicant types into 7 categories (Academic Institutions, Other Academic Institutions, Technology Licensing Organizations (TLOs), Public Research Organizations (PROs), Other Research Organizations, Individuals and Commercial Companies; the base type is commercial companies) and TECHNOLOGY, which are sets of technology dummy variables based on WIPO statistical reports (33 technology fields) . We also introduce YEARs, which are application years when the applicant filed the patent document, as control variables.

In order to assess the monotonicity between the level of the science linkage of the invention and the use of the grace period, as describes in Hypothesis 1-2, we introduce SCI_P95, which is a dummy variable for the inventions at the top 5% level of science linkage. We add the interaction term between $\ln(\mathrm{SCIENCE}_i + 1)$ and SCI_P95 as additional explanatory variable to basic equation (5).

(2) Effect of grace period on knowledge flow

Earlier academic disclosure will accelerate knowledge spillover to an invention as well as to scientific research. We focus on the first channel (non-self inventor forward citations), since the spillover to science is more difficult to assess, partly because a

significant part of the disclosures occur in the conference and the other academic meetings, and the disclosures through journal papers is a minor part. We use the sample of corporate inventors for this estimation, given that the spillover to invention is more important for those inventors and the incentive for using the grace period exception for the purpose of deferring the domestic patent filing would be stronger for a corporative inventor, if it is important.

There is an endogeneity issue: a more science intensive project has high spillover and simultaneously more likely to use the grace period. We control such endogeneity by the combination of taking the difference between the non-self forward citations and the self forward citations (difference in logarithmic terms to control for unobserved heterogeneity) and by introducing the level of science linkage as a control.

We will estimate the following equation for examining the impact of a grace period system on the knowledge flow. We use the logarithm of inventor non-self forward citation flows ($\mathrm{OTHER\_FORWARD}_i$) in order to assess the effects of early disclosure of the invention in academic conferences or through publications. Given that it is likely that there is a unobserved selection effect (that is, those inventions using the grace period are likely to be higher spillover inventions (μ_i), embodying scientific discoveries, but cannot be observed by bibliographic indicators), we adopt a “difference

in differences" approach, with the logarithm of self -citation flows (SELF_FORWARD_i) as a control, given that self-citation flow would not be affected by the early disclosure of its own patented invention, whereas citation flow made by other parties would be affected by the early disclosure of the invention:

$$\text{SELF\_FORWARD}_i = \beta_{SELF,0} + \beta_{SELF} \cdot \text{X}_i + \mu_i + \epsilon_{SELF,i}, \quad (6)$$

$$\text{OTHER\_FORWARD}_i = \beta_{OTHER,0} + \beta_{OTHER} \cdot \text{X}_i + \mu_i + \alpha \cdot gd_i + \epsilon_{OTHER,i}, \quad (7)$$

When we subtract the first equation from the second equation, we will gain the following equation to be estimated.

$$\text{OTHER\_FORWARD}_i - \text{SELF\_FORWARD}_i = \left(\beta_{OTHER,0} - \beta_{SELF,0}\right) + (\beta_{OTHER} - \beta_{SELF}) \cdot \text{X}_i + \alpha \cdot d_i + (\epsilon_{OTHER,i} - \epsilon_{SELF,i}), \quad (8)$$

In the above equations, OTHER_FORWARD_i represents the logarithm of citation flow by the third parties and $\alpha \cdot gd_i$ denotes the effect of early disclosure for the third parties, where gd_i is a dummy representing whether the grace period is used or not. $\varepsilon_{*,i}$ represents exogenous stochastic term. We control for the nature of invention

(CLAIM, SCIENCE and INV), technology area, applicant type, application year and etc:

$$\text{OTHER\_FORWARD}_i - \text{SELF\_FORWARD}_i = \gamma_0 + \gamma_1 \cdot \text{GRACE} + \gamma_2 \cdot \text{GRACE} \cdot \ln(\text{SCIENCE}_i + 1) + \beta_1 \cdot \ln(\text{CLAIM}_i + 1) + \beta_2 \cdot \ln(\text{SCIENCE}_i + 1) + \beta_3 \cdot \ln(\text{INV}_i) + + \sum_j \beta_j \text{APPLICANT}_{i,j} + \sum_k \beta_k \text{TECHNOLOGY}_{i,k} + \sum_t \beta_t \text{YEAR}_{i,t} + \epsilon_i. \quad (9)$$

We use the sample of corporate inventors for this estimation, given that the incentive for using the grace period exception for the purpose of deferring the domestic patent filing would be stronger for a corporative inventor, if it is important[7]. The above equations would be estimated by an ordinary least square regression (OLS).

5. Estimation Results

5.1 The determinants of using grace period exception

The following Table 2 (a,b) provides the estimation results on the determinants of applying for a grace period exception, using an OLS model and a probit model.

(Table 2 (a,b), around here)

[7] We intend to undertake the analysis based on this framework for academic inventors in the future.

Model 1 to 4 pool the grace period exceptions based on academic disclosure as well as that based on exhibition by both corporate and academic inventors. In model 1, we include the attributes of the patent (SCIENCE, CLAIM, INV), application year dummies of the patent (YEAR), technology field dummies of the patent (TECHNOLOGY), and applicant type dummies of the patent (APPLICANT). Model 2 adds the following variables to those in model 1: the cross term between PCT ratio (PCT) and the time dummy of PCT reform (REFORM_PCT) to examine the impact of the PCT reform on the use of grace period under un-harmonized patent system. In order to assess whether the use of the grace period increases with science linkage even at very high science linkage, a dummy variable for the top 5% level of science linkage (SCI_P95) is introduced in model 3. Since the dependent variable (GRACE) is a binary variable regarding whether an applicant applies for a grace period exception upon filing a patent application or not, not only an OLS model but also the Probit model are used for our estimation (model 4). However, the finding based on probit model is qualitatively the same as the estimation result from OLS model.

Before we present the main results, we would like to show how the propensity that applicants use grace period exception varies significantly across technology sectors and

across applicant types. The probability that grace period exception was employed by applicants in Japan ranges from 2.95% (genetic engineering) to 0.16% (dyes, petroleum products) across technologies (Appendix Figure 1), controlling for invention characteristics. With regard to the applicant type dummies, the average use of the grace period per application varies significantly across applicant types (see Appendix Figure 2): Academic institutions (universities) (14.6%), Technology Licensing Organizations (14.1%), Public Research Organizations (9.6%) and commercial firms (0.1%), after controlling for technology sectors. At the same time, the commercial firms account for around a half of the patent application using the grace period, due to their large number of patent applications (see Appendix Figure 3). These findings support the applicant type hypothesis (H1-2) we described in section 3.

As for the effects of globalization, we have obtained the evidence strongly supporting our first hypothesis (H1-1): More chances of using global applications reduces the use of grace period exception more in those technology fields with more global patent applications. The coefficient of the cross term of PCT ratio with PCT reform dummy (REFORM_PCT) is negative and statistically significant at 1% level. This tendency holds even after we control for science linkage in model 3. Namely, the negative impact of PCT reform on the use of the grace period is higher for the sectors

with extensive use of PCT applications, which shows that the relationship as observed in Figure 5 is robust to statistical testing. The estimated effect is very large: one standard deviation increase of the PCT share (7.7 %) results in the decrease of the use of the grace period by 0.21 % points, which is roughly a half of the average probability of the use of the grace period (0.40 %).

Model (5) and (6) uses the grace period exception on the basis of academic disclosure and that on the basis of exhibition separately as dependent variables. The samples are also different: the sectors with high science linkage (Drugs (5), Organic chemistry, Pesticides (13), Biotechnology, Beer, Fermentation (16) and Genetic Engineering (17)) for science intensive sectors and Personal and Domestic Articles (3) and Packing, Lifting (11) for the exhibition intensive sectors. Consistent with our hypothesis, the cross term of PCT ratio with PCT reform dummy (REFORM_PCT) is negative and statistically significant only in Model (5).

Another major finding is that SCIENCE has a positive and highly significant effect on the use of the grace period, with no sign of the diminishing effect, supporting our hypothesis (H1-2) Considering that the average probability of using grace period is 0.40%, the estimated impact of this variable for SCIENCE=2 references is very strong (2.94%). As shown in Model (3), the cross-term between the science linkage and top 5%

patent status in terms of science linkage has significantly positive coefficient.

The third major finding is that CLAIM has a significantly negative coefficient, while INV (inventor team size) has a significantly positive coefficient, in addition to SCIENCE. In our estimation model, CLAIM is an indicator of patenting value. The negative coefficient suggests that the invention with high patenting value uses less the grace period exception, consistent with disclosure acceleration view (see Hypothesis H1-3).

Finally, Model (7) and (8) separates the sample into academic inventors and corporate inventors. Although the size of the estimated coefficients is generally much larger for academic inventors than for corporate inventors, the signs of the estimated coefficients are highly consistent with each other, and both supporting the three hypotheses. The only exception is PCT variable. For corporative inventors, more globalization of applications has a negative effect on the use of the grace period and the PCT reform in 2004 strengthened that effect. On the other hand, for academic inventors, more globalization of applications at the level of a sector has a positive effect on the use of the grace period, although the PCT reform in 2004 reduced that effect. Even if we introduce SCI_P95 in our estimation, similar results are obtained in model 9.

5.2 Impacts of grace period exception in Japan on knowledge flow

Our dependent variable is the difference between a logarithm of citations made by third parties (other than the applicant and the examiner) and a logarithm of self-forward citations, as explained in section 4. All the models introduce the same set of explanatory and control variables: grace period dummy (GRACE), the number of claims (CLAIM), the number of science linkages (SCIENCE), the number of inventors (INV), application year dummy (YEAR), technology class dummy (TECHNOLOGY) and applicant type dummy (APPLICANT). We separately estimate three models (Model 1a to Model 3b in Table 3a) employing the following three types of dependent variables in terms of the scope of the parties citing the focal patent: (a) the count of citations received from all applicants, (b) the count of citations received from publicly traded Japanese firms, and (c) the count of citations received from non-publicly traded Japanese firms, which are mostly small firms

(Table 3 (a,b), around here)

The estimated coefficient for the variable, GRACE, is positive and statistically significant in all models as we expect in the hypothesis 2. This implies a positive knowledge spillover effect: the estimated coefficient for GRACE is 5.5%, 2.7% and 6.1%, respectively and the spillover effect is stronger for small firms. These

findings indicate that earlier academic disclosure before the domestic patent filing enhances the knowledge flow to the other firm, especially for S&M firms.

Model 4a/4b and 5a/5b in Table 3b show the estimation results for self-forward citations and forward citations by the others separately (the corresponding models are model 1a and 1b). The results show that the number of non self-citations increases significantly with the use of the grace period (2.7%), but that of self-citations declines significantly (-2.9%). This asymmetric result for the coefficient of the grace period may imply that the invention using a grace period is often an invention from basic research, so that the internal follow-up inventions are slow to increase, while there are a large spillover to the other firms. Furthermore, the results show that both self-citations and non-self-citations increase significantly and similarly (the estimated coefficients are close) with the measure of science linkage, which provides support to our strategy of using the difference of the two citation flows.

6. Conclusions and discussions

One of the most important differences among the national patent systems lies in the grace period system: in the US it is automatic for one year while there is almost none in Europe, and Japan in between. This paper has examined what determines the use of the

grace period, in particular, how significantly the globalization of the patent applications can account for the reduction of the use of the grace period in Japan in recent years, as well as its effect on knowledge flow. Japan allows 6 months grace period upon the notification of the specific earlier disclosure. Knowledge flow effect is critical for us to discriminate which of the three views (acceleration of disclosure, deferral of domestic patent filing and promotion of domestic patenting) best explains the economic effect of the grace period.

Our first major finding is that the globalization of the applications, especially, the PCT reform in January 2004, had a significantly negative impact on the use of the grace period. The PCT reform in 2004 has enabled a single PCT application to give its applicant a bundle of options to apply for a patent in any number of countries if it is done within 30 months from the priority date. Significantly due to this reform, the use of the grace period has significantly declined since the middle part of 2000s, especially in those sectors with more share of PCT applications, despite the jump of its use in early 2000s, following the significant liberalization of the use of the grace period, including the mode of the disclosure (the use of internet) in 2000. On the other hand, the use of the grace period on the basis of exhibitions has not declined significantly since 2004. These results show that an increasing globalization of the patent applications has made

the search for the best system and the harmonization of the patent systems toward that goal more urgent.

Secondly, we find significant evidence that the acceleration of disclosure view significantly explains the effect of the grace period used by corporate inventors. Although academic institutions use the grace period more intensively, the private companies account for a large share of the use of the grace period (around a half) in Japan, due to its large number of applications. The direct evidence we have found for the acceleration of disclosure view is the evidence of significant knowledge flow as measured by patent citations to the third parties: the level of non-self forward citations of the invention using the grace period is significantly higher than that of the invention without the grace period, relative to the corresponding difference of the level of self-forward citations. This knowledge flow effect to the third parties is larger for those to small and medium size firms: the average is 5.5%, with 2.7% for large firms (listed firms) and 6.1 % for SMEs. If a deferral of domestic patent filing view holds, the grace period has no knowledge flow effect to the third parties. Our additional finding is that the grace period is monotonically more used for the invention with higher science linkage, but it is less used for the invention with more claims (high commercial value). This finding provides support to the acceleration of disclosure view of the grace period

system, instead of deferral of domestic patent filing view or promotion of domestic patenting view.

Given that the applicant has the choice of using the grace period, these results suggest that the grace period system is likely to enhance innovation and welfare. It could significantly enhance the knowledge diffusion, without harming the interest of the inventors. At the same time, the global introduction of the grace period system has become more important, given that the increasing globalization of the patent applications make policy spillover across countries significantly more important.

There are a number of issues to be addressed for improving the design of the grace period system, with respect to transparency, although our study does not directly address them. The system of notification of the earlier disclosure does provide important information to the third parties, that such disclosure will be associated with patent applications in the future. In addition, an early publication of the patent application reliant on the grace period (for an example, in 18 months from the date of academic disclosure) would be desirable, if significant differences between the disclosure and patent application are allowed. .

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Table 1 Implications of three views of the grace period

Several Views on the effect of grace period	Effects on the Use of the grace period		
	More chance to make global applications	High science linkage	High private value of a patent
Acceleration of disclosure view	Minus	Plus	Minus
Deferral of domestic patent filing view	Minus	Plus but may turn to becoming flat	Can be plus
Promotion of domestic patenting view	None	Plus (+) but may turn to negative	Plus

Table 2a The determinants of the use of grace period exception

GRACE is a binary variable that takes a value equal to 1 if the applicant files a patent application with grace period exception on the basis of exhibition for model (6), on the basis of the other disclosure for the rent and a value of zero otherwise.

	(1) OLS					(2) OLS				
dependent variable=GRACE	Coef.	Std. Err.	t	P>|t|	signi ficance	Coef.	Std. Err.	t	P>|t|	signi ficance
ln(SCIENCE+1)	2.9309	0.0088	331.94	0	***	2.9412	0.0088	332.87	0	***
ln(INV)	0.2050	0.0051	39.94	0	***	0.2022	0.0051	39.39	0	***
ln(CLAIM)	-0.1424	0.0054	-26.23	0	***	-0.1424	0.0054	-26.25	0	***
PCT						-0.2531	0.1816	-1.39	0.163	
REFORM_PCT*PCT						-2.5586	0.1095	-23.37	0	***
CONSTANT	0.1961	0.0329	5.96	0	***	0.1419	0.0330	4.31	0	***
TECHNOLOGY sector dummies		YES						YES		
APPLICANT type dummies		YES						YES		
application YEAR dummies		YES						YES		
Number of observations		4,207,325					4,207,325			
Adj R-squared		0.0729					0.0731			

	(3) OLS					(4) Probit				
dependent variable=GRACE	Coef.	Std. Err.	t	P>|t|	signi ficance	Coef.	Std. Err.	t	P>|t|	signi ficance
ln(SCIENCE+1)	0.3308	0.0211	15.69	0	***	75.2319	0.4263	176.49	0	***
ln(SCIENCE+1)*SCI_P95	3.0417	0.0223	136.29	0	***					
ln(INV)	0.2176	0.0051	42.46	0	***	28.8174	0.5565	51.78	0	***
ln(CLAIM)	-0.1318	0.0054	-24.33	0	***	-11.4406	0.5866	-19.5	0	***
PCT	-0.3235	0.1812	-1.79	0.07	*	-93.1890	10.6963	-8.71	0	***
REFORM_PCT*PCT	-2.7200	0.1092	-24.9	0	***	-62.2317	5.6905	-10.94	0	***
CONSTANT	0.1281	0.0329	3.89	0	***	-321.1757	3.6149	-88.85	0	***
TECHNOLOGY sector dummies		YES						YES		
APPLICANT type dummies		YES						YES		
application YEAR dummies		YES						YES		
Number of observations		4,207,325					4,207,325			
Adj R-squared		0.0772				Pseudo R2	0.3315			

Note: * significance at 10%; ** significance at 5%;*** significance at 1%.

All of the coefficients and standard errors are multiplied by 100.

The explanatory variables are SCIENCE, which is the number of patent backward citations, SCI_P95, which is a dummy variable for the top 5% level of science linkage and INV, which is the number of inventors for the patent. The variable PCT is the ratio of the count of PCT patent applications to domestic patent (JP) applications in each technology *k* in each year *t*-1, REFORM_PCT which takes 1 after 1st January 2004 and a value of zero before this date, when all PCT contracting states are automatically designated for a national or regional patent if the applicant files the PCT patent application afterward and the interaction term of both variables. Dummy variables, APPLICANT, where we classify applicant types into 7 categories (Academic Institutions, Other Academic Institutions, Technology Licensing Organizations(TLOs), Public Research Organizations (PROs), Other Research Organizations, Individuals and Commercial Companies; its reference type is commercial companies), TECHNOLOGY, which are sets of technology dummy variables based on WIPO statistical reports (33 technologies) and YEAR, which are sets of application year when the applicant filed the patent document (its reference year is 1992). Science intensive technology sectors include Drugs (5), Organic chemistry, Pesticides (13), Biotechnology, Beer, Fermentation (16) and Genetic Engineering (17). Exhibition technology sectors comprise Personal and Domestic Articles (3) and Packing, Lifting (11). Those patented inventions which were solely disclosed by exhibition have been dropped from the sample in equation (5), (7) to (9). The sample of equation (6) is only limited to the patented inventions which were solely disclosed by exhibition when an inventor used grace period.

Table 2b The determinants of the use of grace period exception

GRACE is a binary variable that takes a value equal to 1 if the applicant files a patent application with grace period exception on the basis of exhibition for model (6), on the basis of the other disclosure for the rent and a value of zero otherwise.

	(5)	OLS	Science intensive sectors			(6)	OLS	Exhibition intensitve sectors		
dependent variable=GRACE	Coef.	Std. Err.	t	P>|t|	signi ficance	Coef.	Std. Err.	t	P>|t|	signi ficance
ln(SCIENCE+1)	3.6863	0.0759	48.54	0	***	0.3218	0.0570	5.65	0	***
ln(INV)	0.5606	0.1149	4.88	0	***	-0.0099	0.0104	-0.95	0.343	
ln(CLAIM)	-0.7045	0.1107	-6.36	0	***	-0.0350	0.0118	-2.98	0.003	***
PCT	5.1606	1.8600	2.77	0.01	***	-6.4497	2.1608	-2.98	0.003	***
REFORM_PCT*PCT	-6.6293	2.3003	-2.88	0	***	3.9738	4.7157	0.84	0.399	
CONSTANT	0.2052	0.8198	0.25	0.8		0.2527	0.0772	3.27	0.001	***
TECHNOLOGY sector dummies	YES					YES				
APPLICANT type dummies	YES					YES				
application YEAR dummies	YES					YES				
Number of observations		86,731					202,197			
Adj R-squared		0.0783					0.0007			

	(7)	OLS	Academia			(8)	OLS	Corporations		
dependent variable=GRACE	Coef.	Std. Err.	t	P>|t|	signi ficance	Coef.	Std. Err.	t	P>|t|	signi ficance
ln(SCIENCE+1)	13.9520	0.2013	69.3	0	***	2.2058	0.0073	300.89	0	***
ln(INV)	0.6905	0.2728	2.53	0.01	**	0.2076	0.0041	50.11	0	***
ln(CLAIM)	-1.6470	0.2773	-5.94	0	***	-0.0990	0.0044	-22.6	0	***
PCT	11.6672	5.7038	2.05	0.04	**	-1.7183	0.1509	-11.38	0	***
REFORM_PCT*PCT	-4.7202	1.8905	-2.5	0.01	**	-1.1179	0.0943	-11.86	0	***
CONSTANT	2.5697	1.8953	1.36	0.18		0.1515	0.0279	5.43	0	***
TECHNOLOGY sector dummies		YES					YES			
Large firm dummy		NO				-0.04421	0.01001	-4.42	0	***
application YEAR dummies		YES					YES			
Number of observations		41,349					4,135,183			
Adj R-squared		0.1146					0.0273			

	(9)	OLS	Science intensive sectors		
dependent variable=GRACE	Coef.	Std. Err.	t	P>|t|	signi ficance
ln(SCIENCE+1)	0.4487	0.2642	1.7	0.09	*
ln(SCIENCE+1)*SCI_P95	3.2375	0.2530	12.79	0	***
ln(INV)	0.5823	0.1148	5.07	0	***
ln(CLAIM)	-0.7319	0.1106	-6.62	0	***
PCT	5.1602	1.8582	2.78	0.01	***
REFORM_PCT*PCT	-6.5119	2.2981	-2.83	0.01	***
CONSTANT	0.4055	0.8191	0.5	0.62	
TECHNOLOGY sector dummies		YES			
APPLICANT type dummies		YES			
application YEAR dummies		YES			
Number of observations		86,731			
Adj R-squared		0.08			

Table 3a Grace period and knowledge flow (forward citations)

dependent variable is based on forward citations received from all firms

	(1a) OLS					(1b) OLS				
	Coef.	Std. Err.	t	P>|t|	significance	Coef.	Std. Err.	t	P>|t|	significance
GRACE	5.5392	0.6768	8.18	0	***	5.6935	1.2859	4.43	0	***
GRACE*ln(SCIENCE+1)						-0.1289	0.9132	-0.14	0.888	
ln(CLAIM)	4.0906	0.0578	70.8	0	***	4.0905	0.0578	70.8	0	***
ln(SCIENCE+1)	-0.0623	0.0949	-0.66	0.512		-0.0611	0.0953	-0.64	0.521	
ln(INV)	1.7050	0.0555	30.73	0	***	1.7049	0.0555	30.73	0	***
CONSTANT	4.7378	0.4086	11.6	0	***	4.7380	0.4086	11.6	0	***
TECHNOLOGY sector dummies	YES					YES				
APPLICANT type dummies	YES					YES				
application YEAR dummies	YES					YES				
Number of observations	3,476,151					3,476,151				
Adj R-squared	0.0249					0.0249				

dependent variable is based on forward citations received from large firms

	(2a) OLS					(2b) OLS				
	Coef.	Std. Err.	t	P>|t|	significance	Coef.	Std. Err.	t	P>|t|	significance
GRACE	2.6753	0.6275	4.26	0	***	2.0905	1.1923	1.75	0.08	*
GRACE*ln(SCIENCE+1)						0.4884	0.8468	0.58	0.564	
ln(CLAIM)	2.9445	0.0536	54.96	0	***	2.9447	0.0536	54.97	0	***
ln(SCIENCE+1)	-0.7208	0.0880	-8.19	0	***	-0.7253	0.0884	-8.21	0	***
ln(INV)	0.8879	0.0514	17.26	0	***	0.8881	0.0514	17.26	0	***
CONSTANT	-3.8502	0.3789	-10.16	0	***	-3.8508	0.3789	-10.16	0	***
TECHNOLOGY sector dummies	YES					YES				
APPLICANT type dummies	YES					YES				
application YEAR dummies	YES					YES				
Number of observations	3,476,151					3,476,151				
Adj R-squared	0.0202					0.0202				

dependent variable is based on forward citations received from SMEs

	(3a) OLS					(3b) OLS				
	Coef.	Std. Err.	t	P>|t|	significance	Coef.	Std. Err.	t	P>|t|	significance
GRACE	6.1097	0.4997	12.23	0	***	3.5126	0.9495	3.7	0	***
GRACE*ln(SCIENCE+1)						2.1692	0.6743	3.22	0.001	***
ln(CLAIM)	-0.3838	0.0427	-9	0	***	-0.3832	0.0427	-8.98	0	***
ln(SCIENCE+1)	-2.1641	0.0701	-30.87	0	***	-2.1841	0.0704	-31.04	0	***
ln(INV)	-1.0808	0.0410	-26.38	0	***	-1.0799	0.0410	-26.36	0	***
CONSTANT	-1.6675	0.3017	-5.53	0	***	-1.6698	0.3017	-5.53	0	***
TECHNOLOGY sector dummies	YES					YES				
APPLICANT type dummies	YES					YES				
application YEAR dummies	YES					YES				
Number of observations	3,476,151					3,476,151				
Adj R-squared	0.0061					0.0061				

Note: * significance at 10%; ** significance at 5%;*** significance at 1%.
All of the coefficients and standard errors are multiplied by 100.
The patented inventions which were disclosed at exhibition are dropped from the sample.

Table 3b Grace period and knowledge flow (forward citations)

	(4a) OLS					(4b) OLS				
dependent variable is self-forward citations	Coef.	Std. Err.	t	P>|t|	significance	Coef.	Std. Err.	t	P>|t|	significance
GRACE	-2.864	0.402	-7.13	0	***	1.557	0.763	2.04	0.041	**
GRACE*ln(SCIENCE+1)						-3.693	0.542	-6.81	0	***
ln(CLAIM)	2.503	0.034	72.98	0	***	2.501	0.034	72.95	0	***
ln(SCIENCE+1)	3.696	0.056	65.59	0	***	3.730	0.057	65.93	0	***
ln(INV)	2.574	0.033	78.16	0	***	2.572	0.033	78.11	0	***
CONSTANT	10.390	0.243	42.84	0	***	10.394	0.243	42.86	0	***
TECHNOLOGY sector dummies		YES						YES		
APPLICANT type dummies		YES						YES		
application YEAR dummies		YES						YES		
Number of observations		3,476,151					3,476,151			
Adj R-squared		0.0189					0.0189			

	(5a) OLS					(5b) OLS				
dependent variable is non self-forward citations	Coef.	Std. Err.	t	P>|t|	significance	Coef.	Std. Err.	t	P>|t|	significance
GRACE	2.675	0.619	4.32	0	***	7.251	1.177	6.16	0	***
GRACE*ln(SCIENCE+1)						-3.821	0.836	-4.57	0	***
ln(CLAIM)	6.593	0.053	124.67	0	***	6.592	0.053	124.65	0	***
ln(SCIENCE+1)	3.633	0.087	41.81	0	***	3.668	0.087	42.05	0	***
ln(INV)	4.279	0.051	84.25	0	***	4.277	0.051	84.22	0	***
CONSTANT	15.128	0.374	40.45	0	***	15.132	0.374	40.46	0	***
TECHNOLOGY sector dummies		YES						YES		
APPLICANT type dummies		YES						YES		
application YEAR dummies		YES						YES		
Number of observations		3,476,151					3,476,151			
Adj R-squared		0.0565					0.0565			

Note: * significance at 10%; ** significance at 5%;*** significance at 1%.
All of the coefficients and standard errors are multiplied by 100.
The patented inventions which were disclosed at exhibition are dropped from the sample.

Figure 1　Three views on the effects of grace period

Several Views on the effect of grace period	Choice on the use of grace period	Timing	Knowledge diffusion to the third party begins at	Effect of grace period on knowledge spillover
Acceleration of disclosure view	Yes	A ○ – – – → ● B, 6 months	A	YES
	No	A △ – – – – → ● ○ B	B	
Deferral of domestic patent filing view	Yes	A ○ – – – → ● B, 6 months	A	NO
	No	A △ ● ○ B	A	
Promotion of domestic patenting view	Yes	A ○ – – – → ● B, 6 months	A	NO
	No	A △ ○ B	A	

△: Invention Completed, ○: Academic disclosure, ●: patent filing

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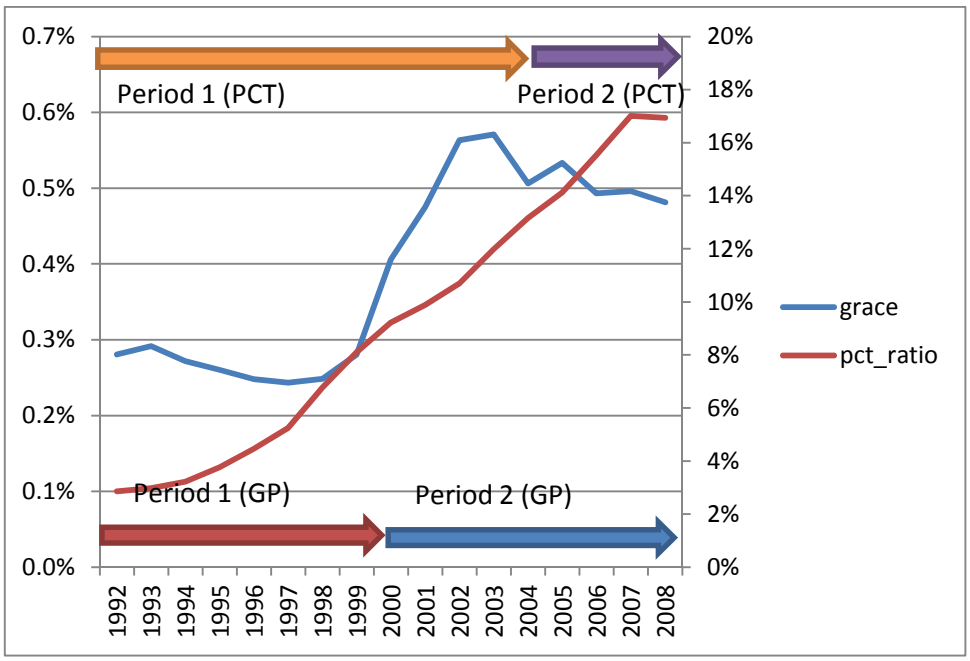
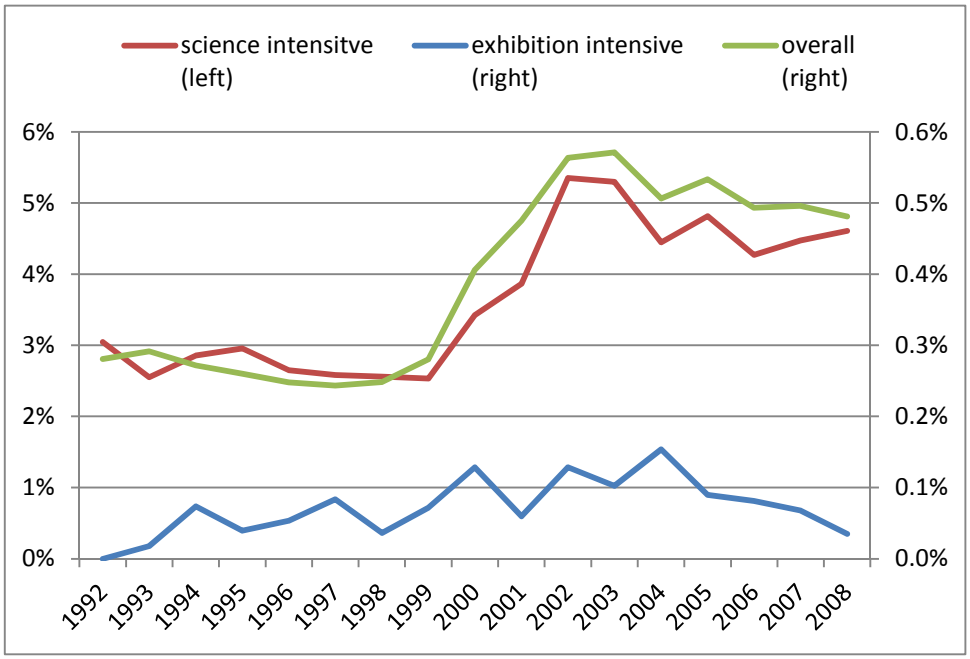
Figure 2　Use of grace period and the share of PCT applications in Japanese patent applications



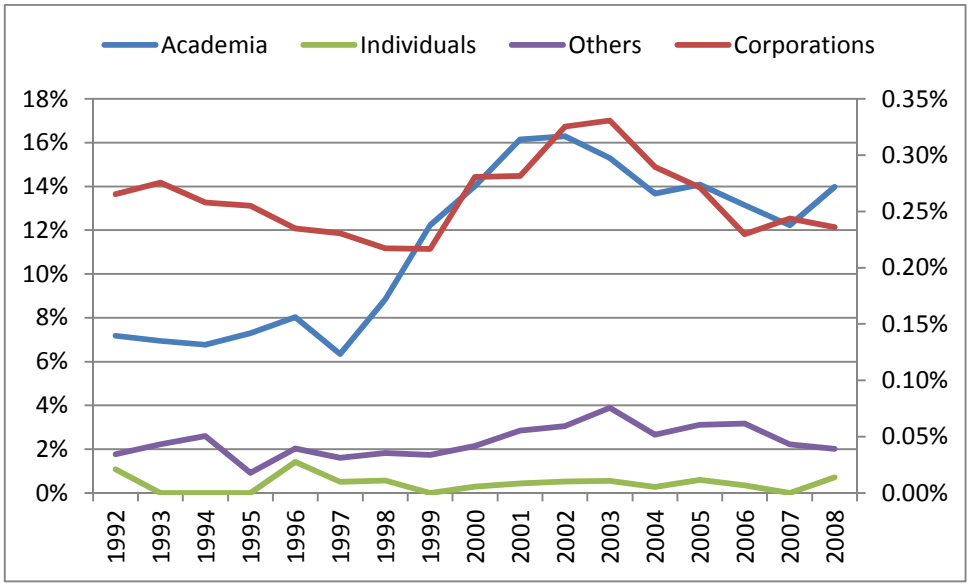
Note: Designation-of-states rule for PCT filing system was abolished in 2004. Internet form of disclosure for grace period exception in Japan was permitted in 2000.

Figure 3 Grace period on the basis of academic disclosures and that on the basis of exhibitions



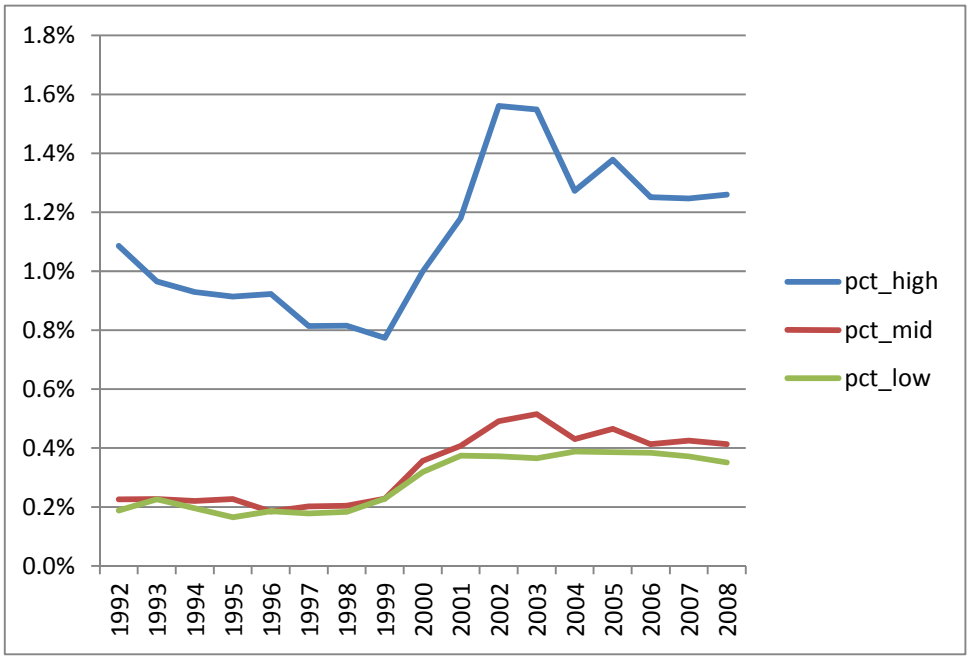
Note: Science intensive technology sectors include Drugs (5), Organic chemistry, Pesticides (13), Biotechnology, Beer, Fermentation (16) and Genetic Engineering (17). Exhibition intensive technology sectors comprise Personal and Domestic Articles (3) and Packing, Lifting (11). Figures in the blanket are sectorial ID.

Figure 4 Applicant type and the frequency of reliance on grace period



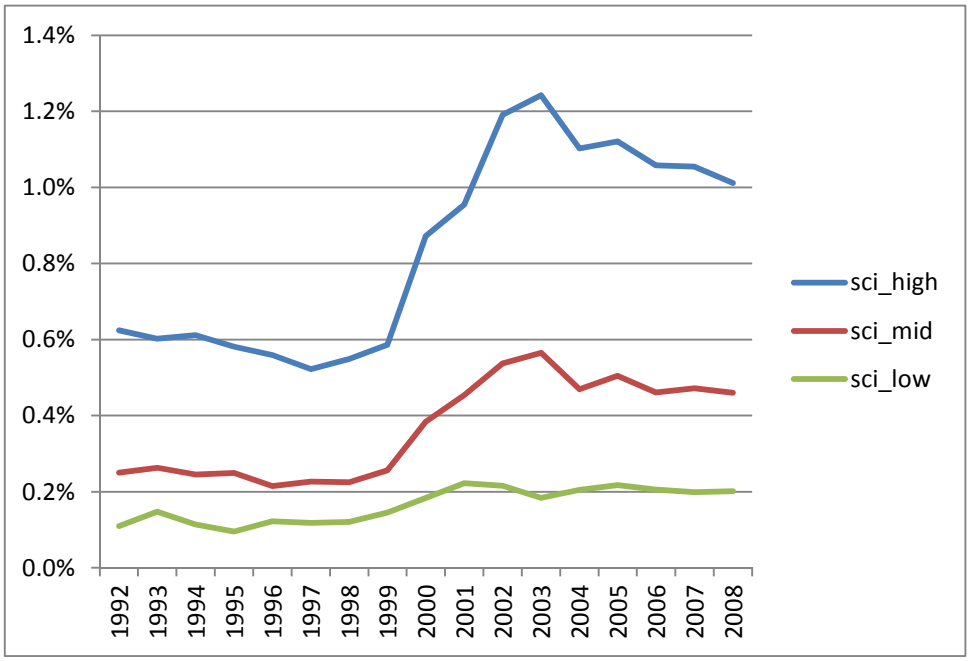
Note: “Academia” denotes Academic Institutions, TLOs and PROs, “Corporations” denotes Commercial Companies, “Individuals” for Individuals and Others for “Other Academic Institutions and Other ROs. Graphs with a right Y-axis are Academia, individuals and others and Graph with a left Y-axis is Corporations.

Figure 5 Use of the grace period by intensity of the use of PCT



Note: Classification of sectors by the intensity of PCT applications is as follows: PCT high intensive technology sectors are Health&Amusement, Drugs, Organic chemistry&Pesticides, Organic molecule compounds, Dyes&Petroleum, Biotechnology&Beer&Fermentation, Genetic Engineering, Paper, Weapons&Blasting, and Others; PCT middle intensive sectors are Food Stuffs, Separating&Mixing, Casting&Grinding&Layered Product, Non organic chemistry&Fertilizer, Metallurgy&Coating metals, Textile, Engine&Pump, Clock&Controlling&Computer, Display&Information Storage&Instruments, Electronics components&semiconductor, and Electronics circuit&communication tech; PCT low intensive sectors are Agriculture, Personal and Domestic Articles, Machine tools&Metal working, Printing, Transporting, Packing&Lifting, Construction, Mining&Drilling, Engineering elements, Lighting&Steam generation&Heating, Measurement&Optics&Photography, and Nuclear physics.

Figure 6 Science linkage and grace period



Note: Classification of the extent of science linkage is listed as follows: high science linkage technology sectors are Drugs, Organic chemistry&Pesticides, Organic molecule compounds, Dyes&Petroleum, Biotechnology&Beer&Fermentation, Genetic Engineering, Measurement&Optics&Photography, and Others; middle science linkage technology sectors are Agriculture, Food Stuffs, Health and Amusement, Separating&Mixing, Non organic chemistry&Fertilizer, Metallurgy&Coating metals, Paper, Clock&Controlling&Computer, Display&Information Storage&Instruments, Nuclear physics, Electronics components&semiconductor, and Electronics circuit&communication tech; low science linkage technology sectors are Personal and Domestic Articles, Machine tools&Metal working, Casting&Grinding&Layered Product, Printing, Transporting, Packing&Lifting, Textile, Construction, Mining&Drilling, Engine&Pump, Engineering elements, Lighting&Steam generation&Heating, and Weapons&Blasting.

Appendix Table 1 Descriptive Statistics of the determinants of using grace period

all sample

Variable	Obs	Mean	Std. Dev.	Min	Max
grace	4207325	0.0040484	0.0634982	0	1
ln_sci_link	4207325	0.1016994	0.3635663	0	5.075174
sci_p95	4207325	0.0463423	0.2102253	0	1
ln_inv	4207325	0.5870804	0.5982	0	3.433987
ln_claim	4207325	1.624024	0.6057491	0	6.907755
pct	4207325	0.0902783	0.0774708	0.0113496	0.7549719
reform_pct	4207325	0.2774062	0.4477187	0	1

science intensive sectors

Variable	Obs	Mean	Std. Dev.	Min	Max
grace	86731	0.0363768	0.1872271	0	1
ln_sci_link	86731	0.744339	0.9117674	0	5.075174
sci_p95	86731	0.3603441	0.480103	0	1
ln_inv	86731	0.9388933	0.5430752	0	2.890372
ln_claim	86731	1.62171	0.6164243	0	4.727388
pct	86731	0.4250335	0.1638467	0.1604137	0.7549719
reform_pct	86731	0.2655337	0.4416195	0	1

exhibition intensive sectors

Variable	Obs	Mean	Std. Dev.	Min	Max
grace	202197	0.000727	0.0269535	0	1
ln_sci_link	202197	0.0100448	0.1054785	0	4.442651
ln_claim	202197	1.493434	0.5397425	0	4.553877
ln_inv	202197	0.5246039	0.578539	0	3.091043
pct	202197	0.0605729	0.0300317	0.0225225	0.1334586
reform_pct	202197	0.245063	0.4301256	0	1

academia

Variable	Obs	Mean	Std. Dev.	Min	Max
grace	41349	0.1343684	0.3410518	0	1
ln_sci_link	41349	0.7718258	0.9085188	0	4.820282
sci_p95	41349	0.3882077	0.4873482	0	1
ln_inv	41349	0.9725793	0.5893799	0	3.332205
ln_claim	41349	1.856591	0.6084074	0	4.59512
pct	41349	0.2043925	0.1839357	0.0116112	0.7539729
reform_pct	41349	0.5338944	0.4988559	0	1

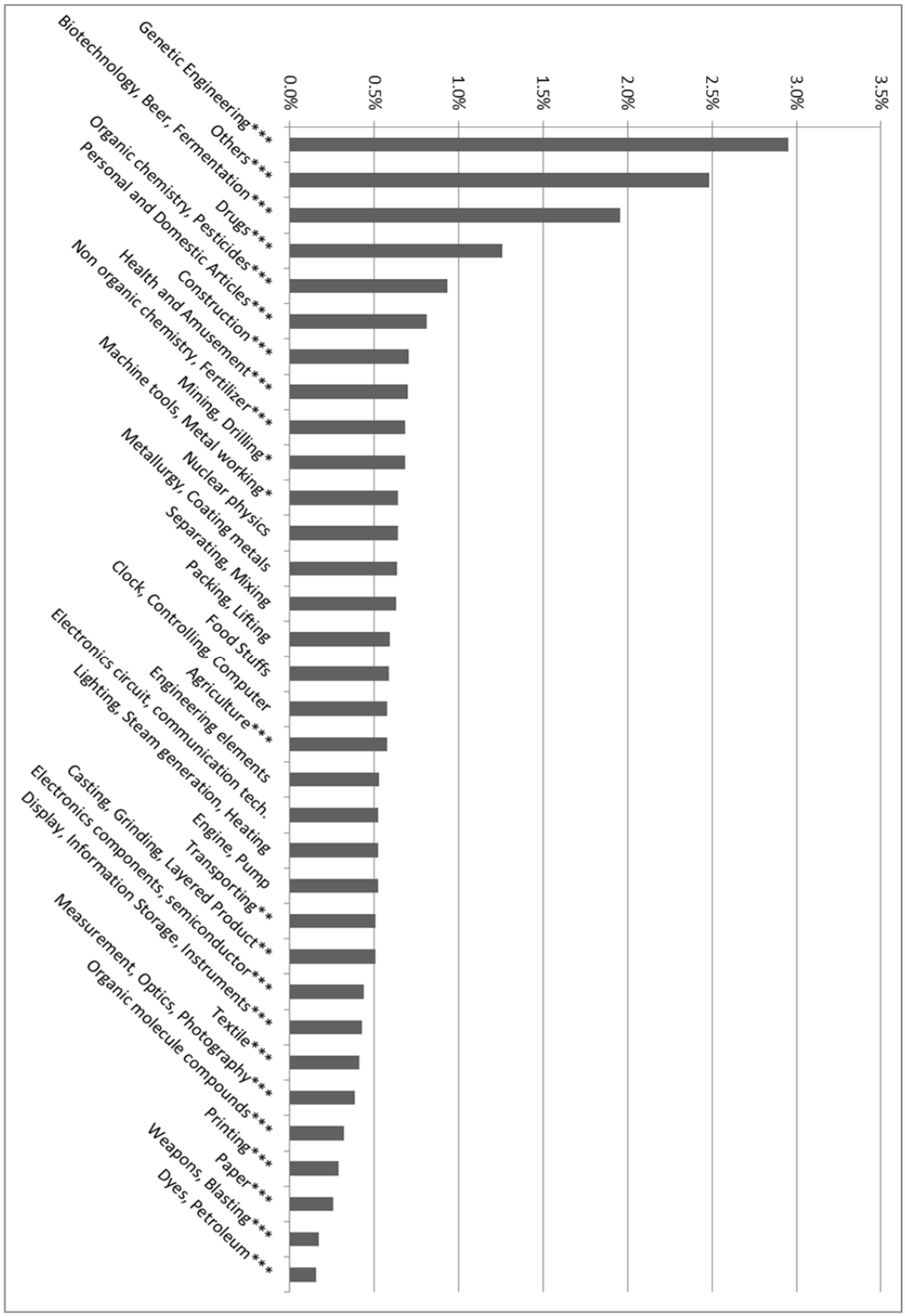
corporations

Variable	Obs	Mean	Std. Dev.	Min	Max
grace	4135183	0.0024611	0.0495482	0	1
ln_sci_link	4135183	0.0940601	0.3455029	0	5.075174
sci_p95	4135183	0.0424373	0.2015847	0	1
ln_inv	4135183	0.5821925	0.5965279	0	3.433987
selfcit	3463664	0.1155336	0.3560927	0	7.013016
ln_claim	4135183	1.621436	0.6052515	0	6.907755
pct	4135183	0.0890082	0.074558	0.0113496	0.7549719
reform_pct	4135183	0.2742401	0.4461306	0	1

Descriptive Statistics of the effects of using grace period

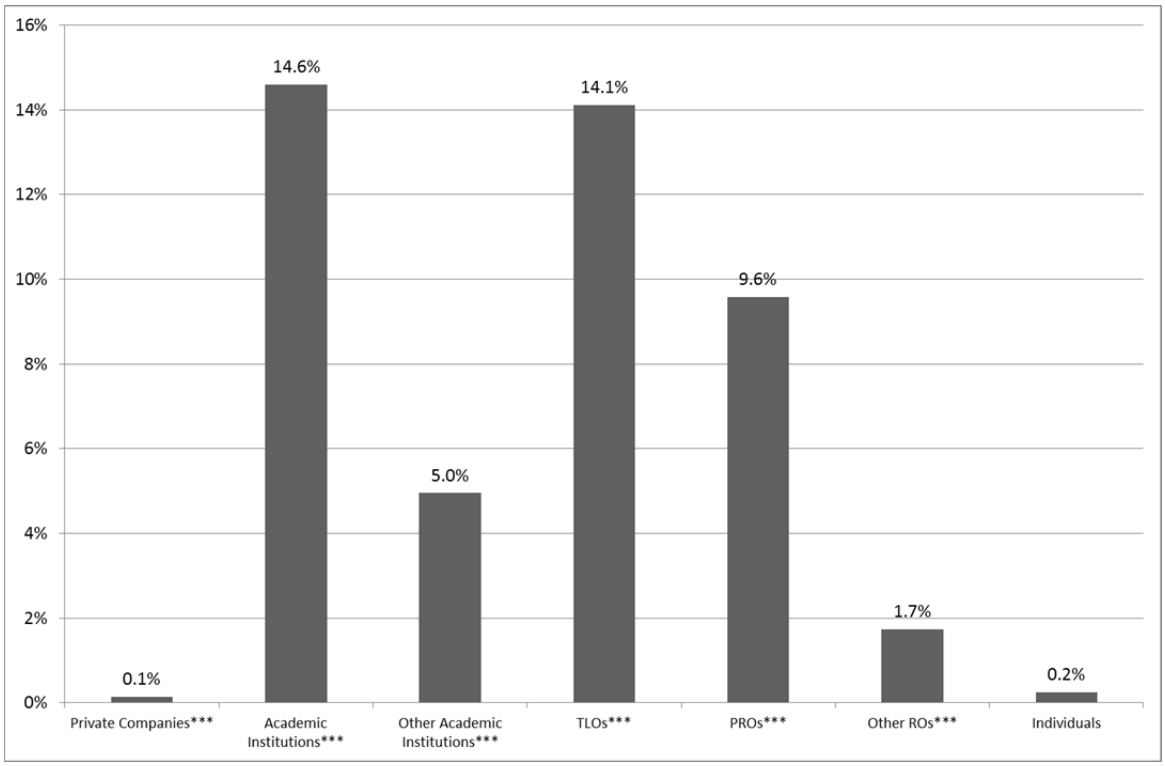
Variable	Obs	Mean	Std. Dev.	Min	Max
ln(non-self_forward+1) -ln(self_forward+1)	3476151	0.2026941	0.6018994	-5.587249	6.579251
ln(non-self_forward received from large firms+1) -ln(self_forward received from large firms+1)	3476151	0.1241837	0.5567711	-5.587249	6.499787
ln(non-self_forward received from SMEs+1) -ln(self_forward received from SMEs+1)	3476151	-0.009527	0.4402209	-6.322565	5.556828
ln(self_forward received from SMEs+1)	3476151	0.1155858	0.3561677	0	7.013016
ln(non-self_forward received from SMEs+1)	3476151	0.31828	0.5600877	0	7.096721
grace	3476151	0.0022859	0.047756	0	1
ln_claim	3476151	1.635435	0.6103858	0	6.907755
ln_sci_link	3476151	0.1003128	0.356469	0	5.075174
ln_invs	3476151	0.577757	0.5920078	0	3.332205

Appendix Figure 1 Technology field and use of grace period exception



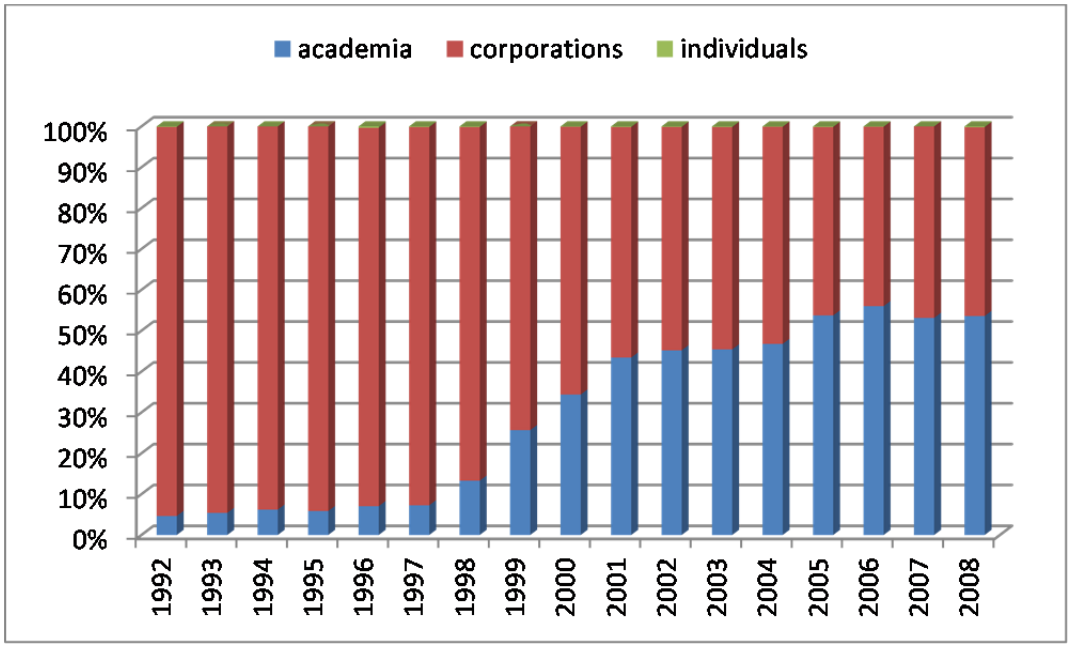
Note: * significance at 10%; ** significance at 5%;*** significance at 1%.

Appendix Figure 2 Applicant type and the intensity of the use of grace period exception



Note: * significance at 10%; ** significance at 5%;*** significance at 1%.

Appendix Figure 3 Share of the patent applications using grace period across the type of institutions



Appendix **Grace period in Japan**

1. Overview of the grace period system in Japan

As of the beginning of 2012, just before the most recent patent reform enforced in April 2012, Japanese Patent Act (hereafter we call it "Japan patent law"), Article 30, stipulates the conditions for granting the inventor a so-called "Exception to lack of novelty of invention" (hereafter called "grace period exception") as follows: "In the case of an invention which has fallen under any of the items of Article 29(1) by reason of the fact that the person having the right to obtain a patent has conducted a test, has made a presentation in a printed publication, has made a presentation through electric telecommunication lines, or has made a presentation in writing at a research meeting held by an academic group, designated by the Commissioner of the Patent Office, such invention shall be deemed not have fallen under any of the items of Article 29(1) (conditions of patentability in terms of the novelty of invention) for the purposes of Article 29(1) and (2) (conditions of patentability in terms of the inventive step of invention) for the invention claimed in a patent application which has been filed by the said person within six months from the date on which the invention first fell under any of those items." Article 29(4) explains the procedure of adopting a grace period exception: "Any person seeking the application of paragraph (1) or (3) shall submit to

the Commissioner of the Patent Office, at the time of filing of the patent application, a document stating thereof and, within thirty days from the date of filing of the patent application, a document proving the fact that the invention which has otherwise fallen under any of the items of Article 29(1) is an invention to which paragraph (1) or (3) of this Article may be applicable." From these paragraphs, three steps needs to be taken to obtain a grace period exception: An applicant needs to (1) file a patent application within 6 months from the date of disclosing, (2) submit a document declaring that he/she wants to receive the application of grace period at the time of filing, and (3) submit a proof document to represent that the invention was made public by the act of the person having the right to obtain a patent, within 30 days from the date of filing.

The grace period system in the Japanese patent law was amended most substantially in 2000 during the period between 1992 and 2008. By this reform, the channel to disclose the invention was considerably liberalized to include an internet form of disclosure by inventors. Moreover, the scope of grace period exception was extended to the case where there exists a slight gap between the invention described in patent document and the one revealed by inventor. Hence it became possible for an academic researcher to disclose his/her invention at conferences, meetings or journals, and fairs or exhibitions from the perspective of its academic importance which is

different from its patent eligibility on filing a patent application. As a consequence, it was expected that academic researcher heavily uses the grace period exception under the new rule.

In April 2012 as of the date of 1 April, Japan broadened its grace period to cover essentially any form of disclosure by the inventor, including sales. This was the second major reform with respect to a grace period in Japan. Since this legal change was very recent, we do not analyze it in this present study.

2. International Comparison

There exist major differences across the US, Europe and Japan in grace period system. The rule of grace period in the Unites States (35 U.S.Code 102(b)) is the most generous to inventors in the world. In the United States, the grace period up to one year is triggered automatically. There is no restriction for the scope of grace period exception. An inventor does not need to submit a document to declare or describe that he/she would like to adopt grace period for his/her invention.

On the other hand, the scope of grace period exception is very limited in European countries (for example, EPC Article 55(1)). They only admit disclosure though approved exhibitions as an exception (plus disclosures resulting from an evident

abuse of the other applicant). Similar to Japan, their grace period is 6 month and an inventor is required to submit the document which describes that he/she would like to receive the application of grace period, at the time of filing. Furthermore in case of EPC, it is necessary for an inventor to submit a proof document to show that the invention was made public by the act of the person having the right to obtain a patent, within 4 months from the date of filing.

Japan's exception is different from the US in the following three respects. The first difference is that in the US, the priority to claim the patented invention (which work is considered to be a prior art) is established at the time of the first disclosure of the inventor, not at the filing date. Conversely, in Japan, the priority is decided at the filing date because of the first-to-file regime. Hence, the inventor who reveals his/her invention prior to domestic patent filing cannot obtain a patent in Japan if the third party files a patent application alternatively for the similar invention based on his or her early disclosure before the true inventor files the patent application. Secondly, unlike the procedure in the US, an inventor needs to take an action to use the grace period exception in Japan. As is the same in Europe, an inventor is asked to (1) file a document to report that he/she would like to receive grace period at the date of filing, (2) submit a proof document to represent that the invention was made public by the act of the person

having the right to obtain a patent, within 30 days from the date of filing. The last difference is the length of the grace period. It is 6 months in Japan.