Discussion Papers In Economics And Business

Patent Acquisitions under Uncertainty: The Case of Requests for Examination

Masayo Kani

Discussion Paper 07-06

Graduate School of Economics and
Osaka School of International Public Policy (OSIPP)
Osaka University, Toyonaka, Osaka 560-0043, JAPAN

Patent Acquisitions under Uncertainty: The Case of Requests for Examination

Masayo Kani

Discussion Paper 07-06

February 2007

この研究は「大学院経済学研究科・経済学部記念事業」
基金より援助を受けた、記して感謝する。

Graduate School of Economics and
Osaka School of International Public Policy (OSIPP)
Osaka University, Toyonaka, Osaka 560-0043, JAPAN

Patent Acquisitions under Uncertainty: The Case of Requests for Examination*

Masayo Kani†

Graduate School of Economics, Osaka University

February, 2007

Abstract

Under the Japanese patent system, an applicant has to request examination within a given period of time after application. This paper studies the timing of a request for examination when return on patent is uncertain. When a firm files a patent application, it acquires a timing option limited for a fixed period and can exercise it at anytime. After modeling a real options model of the request for examination, we estimate it based on micro patent application data. The paper finds that the request for examination is deferred when uncertainty increases. We also find that the probability of requesting examination rises as the time limit approaches since the option value declines with time and falls down to zero at the time limit.

JEL classification numbers: C41, L21, and O34

Keywords: patent, request for examination, real options, and duration analysis

*I would like to thank Kazuo Ogawa for the valuable comments and encouragement. I am also grateful to Sadao Nagaoka, and other participants in the 2006 Autumn Meeting of Japanese Economic Association for the helpful comments. I also thank Hitoshi Inoue, Yusuke Kinari, Masahiko Shibamoto, Takanori Tanaka, and Junmin Wan for their valuable comments. All remaining errors are naturally my own.

†Graduate School of Economics, Osaka University, 1-7, Machikaneyama, Toyonaka, Osaka 560-0043, Japan. E-mail: mkani@iser.osaka-u.ac.jp

1. Introduction

Much attention has been paid to the importance of Intellectual Property Rights in economic activity. Patent rights are the representing one, and also in Japan patents has been emphasized. Even if statistically, the number of Japanese patent applications is highest in the world according to World Intellectual Property Organization Patent Report 2006. Such a case of the high number of Japanese patent applications is a frequent issue in the field of patent management. As one opinion, Pitkethly (1997) suggests a deferred examination system in Japan; "the system must act at least as a potential incentive to file patents which in a less flexible system might not be filed because they would be less valuable. "

Before describing the system, we illustrate the procedures for obtaining a patent right in Figure 1. To put it briefly, we can whether to file a patent application for new invention, and then we request examination if we hope the patented invention. A patent will be granted only after examination as to patentability which may be requested by the applicant or by a third party.

Therefore, provide further details of the patent system, especially a request for examination. Under the system, an applicant has to request examination within a given period of time after filing. Otherwise the patent is deemed to be withdrawn[1]. With respect to a given period of time, for the patent applications filed on or before September 30, 2001, the time limit of seven years from the filing date is to be applied, and the above revised time limit is to be applied for patent applications filed on or after October 1, 2001. It is the most unique point that Japanese Patent Law allows examination to be deferred for up to certain fixed period while most other countries do not. That is, under

[1] An applicant does not expect patenting all applications. In fact the proportion of requests for examination to all applications is half.

the other patent systems an applicant must decide to continue applications with continued cost of applications, but under Japanese patent system a continuance procedure is not needed.

We discuss how firms accounting for 95% of the patent applications perform under the unique system. As shown in Figure 1, the Japan Patent Office publish the content of an application in the Official Gazette after 18 months have elapsed from the date of filing[2]. Therefore, as the firms defend patenting the invention by the rival firms, they take time and select the profitable patent applications slowly and carefully. At the time of invention, firms can not assess precisely return on patenting because the return is uncertain. Under the Japanese patent system the firms can decide the timing of a request for examination with no deferral charge. That is, when the firms file patents, they acquire timing options limited for a fixed period and can exercise in at anytime, or finite American call option. This paper studies the timing of a request for examination when return on patent is uncertain using real options approach.

Provided that the concept of viewing patents as options is expressed, Pakes (1986) presents the value of patents in Europe derived from renewal from data in aspects of theoretical and empirical study. Pakes (1986) shows that the view of the options represented by holding a patent is that payment of a renewal fee for a granted patent not only buys the coming years monopoly profits but also buys in all but the final year an option on renewing the patent at the end of the year, exercise price for which is the renewal fee then payable. The patent renewal model contribute to our study on a request for examination, but it has the different points, for example whether an owner has to pay fee every year is different. We seek a more suitable model to represent the Japanese system.

Meanwhile, in Japan the empirical studies have been difficult due to the problem of utilizing statistical data. However, recently the patent-affiliated organizations are

[2] After the publication of unexamined application, an applicant obtains the right to demand (payment of) compensation. Note that the compensation is claimed after a patent right is established.

promoting the data, for example "Results of the Survey of Intellectual Property-Related Activities" conducted by Japan Patent Office, and "The Institute of Intellectual Property (IIP) patent Database " provided by the IIP. The research reports (published in 2004, 2005) examine the Japanese patent activity empirically using individual data of "Results of the Survey of Intellectual Property-Related Activities". As mentioned the studies, in Japan it is expected that empirical study on patent activity will accumulate. In this paper, after modeling a real options model of request for examination, we estimate it based on micro patent application data collected from "The IIP patent Database ".

Section 2 provides an overview of the request for examination model used in this paper. In Section 3, we explain estimation method, or duration analysis. Section 4 describes the data and the descriptive statistics, and then Section 5 shows the results of both nonparametric estimation and the regression model. Section 6 contains concluding remarks.

2. Theoretical Model

When we consider requests for examination under the uncertain returns, especially in Japan, the real options model by Paddock, Siegel and Smith (1988) is useful. The model is the most popular (or mentioned) model for petroleum real options applications, and has practical advantages (when compared with others options models) due to its simplicity and few parameters estimation. It is suitable for the case of the requests for examination since the option to develop the reserve is not a perpetual one[3].That is, the method is to exploit the power of the analogy with a financial American call option on a stock paying a continuously compound dividend yield[4]. Following Paddock, Siegel and

[3] Offshore leases are usually subject to relinquishment requirements, which limit the time that the firm can hold the tract before developing it.

[4] An American call option is an asset that gives the holder the right (not the obligation) to buy one stock for a fixed exercise price, until a certain date (expiration τ).

Smith (1988), the close connection between the value of the request for examination and the call option on stock is illustrated in Table 1.

Moreover, Paddock, Siegel and Smith (1988) consider the valuation and exploitation of an offshore oil tract as a multistage problem: exploration, development, and extraction. Similarly, in the case of patents, applicants and patentees confront the following decision types: whether to file a patent application, whether to request examination, whether to keep any patent granted in force or let it lapse, and how to exploit the patent one granted (direct commercialization, licensing, a combination or outright sale)[5]. Dixit and Pindyck (1994) describe that the solution to the multistage investment problem has exactly the same form as the solution to the single stage problem, and the only thing that changes is the amount of the investment; the solution for the first stage uses the total investment cost and the solution for the second stage uses the second-stage cost. Therefore, when we consider the firm's decision on requesting examination after filing of patent applications, the cost includes not only the fee of requesting examination but also the cost of patenting and the commercialization cost. That is, consider that the first stage is a request for examination, and second stage is a patent commercialization. In particular, we focus on the valuation of waiting the request for examination.

The firm's problem is to decide on whether to request examination in consideration of the following situation. Filing a patent application provides the timing option to request examination, which is the right to decision-making for patenting the invention due to acquiring the monopoly profit from the invention in the future. At any time t up to a given expiration date τ, the firm can pay I including the cost of patenting and the commercialization cost, for which the expected future net cash flows conditional on undertaking the request have a present value V_t; it represents the appropriately discounted expected cash flows, given the information available at time t. For the firm,

[5] Lambrecht (2000) analyzes the sleeping patent phenomenon, which involves the consideration of the optimal timing of two sequential investment decisions: patenting and commercialization of the product innovation.

V_t represents the market value of a claim on the stream of net cash flows that arise from patenting the inventory. Typically, V_t is stochastic. We assume that V_t follows a geometric Brownian motion of the form,

$$dV = \alpha V dt + \sigma V dz, \tag{1}$$

where α is the drift (or growth rate) parameter, σ the proportional variance parameter, and dz the increment of the standard Wiener process.

Given equation (1) for the value of a patent , we can now determine the value of waiting a request for examination. Let $F(V, t)$ denote the value of waiting the request for examination. Using equation (1) and going through the usual steps, we can verify that $F(V, t)$ must satisfy

$$\frac{1}{2}\sigma^2 V^2 F_{VV} + (r - \delta)V F_V + F_t - rF = 0, \tag{2}$$

where r is the riskless interest rate, and $\delta = \mu - \alpha$ is the dividend rate[6]. Note that we do not need to know μ or α, but only the difference between them, δ. Equation (2) is a partial differential equation; since the option to request examination expires at time τ, the value of the option depends on the current time t.

[6] We can write equation (2) down immediately by noticing the formal analogy between this partial differential equation and the one obtained using the dynamic programing approach,

$$\frac{1}{2}\sigma^2 V^2 F_{VV} + \alpha V F_V + F_t - \rho F = 0,$$

where ρ is a discount rate. In equation (2), the exogenously specified discount rate ρ is replaced by the riskless rate r, and the growth rate α of the geometric Brownian motion of V is replaced by $(r - \delta)$. In other words, we can evaluate the future payoff by discounting it at the riskless rate r, provided we are willing to pretend that V follows a process with a different growth rate parameter $\alpha' = r - \delta$. We have here an instance of "equivalent risk-neutral valuation," a procedure with much wider applicability and interest in financial economics; See Dixit and Pindyck (1994, Chapter 4 and 5) for the relationship between dynamic programing and contingent claims valuation.

Equation (2) must be solved subject to boundary conditions as following.

$$F(0,t) = 0, \tag{3}$$

$$F(V,\tau) = \max\left[V_\tau - I, 0\right], \tag{4}$$

$$F(V^*,t) = V^* - I, \tag{5}$$

$$F_V(V^*,t) = 1. \tag{6}$$

Condition (4) just says that at expiration, the option will be exercised if $V_\tau > I$.

Equation (2) cannot be solved analytically, but it is not difficult to obtain a solution numerically using finite difference methods. The numerical solution will help to illustrate the results and show how they depend on the values of the various parameters. As we will see, these results are qualitatively the same as those that come out of standard option pricing models. Table 2 reports the solutions of numerical analysis by case, and Figure 2.1 to 2.4 show the threshold values.

The Basic Model

The basic model showed by the column 1 in Table 2 and Figure 2.1 is based on the following parameter values: the total cost $I = 1$, the profit volatility (or uncertainty) $\sigma = 0.2$, the time to expiration $\tau = 7$, the riskless interest rate $r = 0.04$, the dividend rate $\delta = 0.04$. In Table 2, the value of the threshold is higher than the cost, $V^* > I = 1$. That is, the value is higher than the threshold value in the standard NPV rule, $V^* = I = 1$. Figure 2.1 shows the threshold value V^* as a function of the number as years to expiration. Note that at expiration, $V^* = I = 1$ which follows from boundary condition (4), so that the standard NPV rule applies. The threshold declines toward unity as the expiration approaches since the option value declines with time and falls down to zero at the time to expiration. In particular, it declines drastically close to the expiration.

The Case of Larger Uncertainty

The column 2 in Table 2 and Figure 2.2 report the case of lager uncertainty, for $\sigma = 0.4$. The uncertainty increases the threshold value V^* and the option value F in Table 2. Therefore, it is difficult for a firm to request examination. Along with these value, the threshold curve showed by Figure 2.2 is upper than Figure 2.1. Thus, it is known that the uncertainty increases the value of a firm's investment opportunity, but decreases the amount of actual investing that the firm will do.

The Case of Larger Opportunity Cost

The parameter δ plays an important role. If V were the price of a share of common stock, δ would be the dividend rate on the stock. The total expected return on the stock would be $\mu = \delta + \alpha$, that is, the dividend rate plus the expected rate of capital gain. If the dividend rate δ were zero, a call option on the stock would always be held to maturity, and never exercised prematurely. The reason is that the entire return on the stock is captured in its price movements, and hence by the call option, so there is no cost to keeping the option alive. However, if the dividend rate is positive, there is an opportunity cost to keeping the option alive rather than exercising it. That opportunity cost is the dividend stream that one forgoes by holding the option rather than the stock. Since δ is a proportional dividend rate, the higher is the price of the stock, the greater is the flow of dividends. At some high enough to make it worthwhile to exercise the option. If $\delta > 0$, the expected rate of capital gain on the project α is less than the expected rate of return from owning the completed project μ. Hence δ is an opportunity cost of delaying construction of the project, and instead keeping the option to invest alive. If δ were zero, there would be no opportunity cost to keeping the option alive, and one would never invest, no matter how high the NPV of the project. That is why we assume $\delta > 0$. On the other hand, if δ is very large, the value of the option will be very small, because the opportunity cost of waiting is large. As $\delta \to \infty$, the value of the option goes to zero; in effect, the only choices are to invest now or never, and the standard NPV rule again applies. In the case of a request for examination, there could be an opportunity cost to delay the request. Since the deferred request for examination leads to take a long time to grant a patent from the filing date, in the meantime a firm might let the opportunity of profits go to waste and also period of patent right is shorter[7]. Thus, the patent applications with the large opportunity cost, including the shorter life cycle of a technology, should be requested immediately, while others with small opportunity cost, including the defensive patent applications, should be held until close to the time limit for requesting examination.

The column 3 in Table 2 and Figure 2.3 show the case of a larger opportunity cost, for $\delta = 0.08$. When the opportunity cost is large, the threshold value and the option value are lower than the basic model, that is, a firm requests examination at an earlier date.

The Case of Shorter Expiration Date

As we saw in section 1, the time limit for submitting a request for examination for a patent application is to be changed as of October 1, 2001 from "within seven years" from the filing date to "within three years" from the filing date. In response to this, the patent applications waiting the examination at Patent Office jump. We can examine such a revision using our model, and show in column 4 in Table 2 and Figure 2.4, for $\tau = 3$. As compared with seven years, or the basic model, the threshold value and the option value slightly decrease. It is implied that such revision promotes requesting examination, therefore, raises the number of requests for examination.

[7] The term of patent is 20 years from the filing date. Note that there is no case of patenting by the third party after filing.

3. Estimation Method

In the previous section, we capture requesting examination as exercising the call option, and show how to decide the timing of it under uncertainty when a firm is allowed examination to be deferred for up to certain fixed period. In this section, we briefly describe duration analysis ,which use models of the length of time spent in a given state before transition to another state, such as duration unemployed or alive or without health insurance. Considering such econometric models, the problem is that the distributions for time to an event might be quite dissimilar from the normal. Then, we should use the methods substituting a more reasonable distributional assumption, called parametric models, or relaxing the specification of the model, called semiparametric models.

We begin with explaining the basic concepts. Now consider that a patent application has not yet requested examination for T periods. Duration T is nonnegative random variable and has the cumulative distribution function $F(t)$ and the density function $f(t) = dF(t)/dt$. Then, the probability that the duration is less than t is

$$F(t) = \Pr[T \leq t] = \int_0^t f(s)ds. \tag{7}$$

A complementary concept to the cdf is the probability that the duration exceeds t, called the survivor function, which is defined by $S(t) = \Pr[T > t] = 1 - F(t)$. A key concept is the hazard rate (or function), which is the instantaneous probability of leaving a state conditional on survival to time t. This is defined as

$$\lambda(t) = \lim_{\Delta t \to 0} \frac{\Pr[t \leq T < t + \Delta t | T \geq t]}{\Delta t} = \frac{f(t)}{S(t)}. \tag{8}$$

We can obtain estimators of the survivor and the hazard function by using nonparametric analysis. Let $t_1 < t_2 < \cdots < t_j < \cdots t_J$ denote the observed discrete failure times of the spells in a sample of size N, $N \geq J$. We define it as follows,

$$
\begin{aligned}
d_j &= \text{the number of spells ending at time } t_j, \\
m_j &= \text{the number of spells censored in } [t_j, t_{j+1}), \\
r_j &= \text{the number of spells at risk at time } t_{j-} \ = \sum_{l|l\geq j} (d_l + m_l) \,,
\end{aligned} \tag{9}
$$

where "at time t_{j-}" means "just before time t_j ." In this paper, t_j is a period from a filing date to a requesting date or a censoring date, N is the number of patent applications, d_j is the number of patent application requesting examination at time t_j, r_j is the number of patent applications which still have deferred requests for examination at time t_{j-} .

Since $\lambda_j = \Pr[T = t_j | T \geq t_j]$, an estimator of the hazard function is the number of spells ending at time t_j divided by the number of spells at risk at time t_{j-}, or $\widehat{\lambda} = d_j/r_j$. The Kaplan-Meier estimator or product limit estimator of the survivor function is the sample analogue,

$$
\widehat{S} = \prod_{j|t_j \leq t} \left(1 - \widehat{\lambda}_j\right) = \prod_{j|t_j \leq t} \frac{r_j - d_j}{r_j}. \tag{10}
$$

In section5.1, we report this estimator based on our data set.

On the other hand, usually in econometric models we are interested in hazard functions conditional on a set of covariates or regressors. Perhaps the most widely used formulation used in regression analysis of durations is the proportional hazard model. A proportional hazard can be written as

$$
\lambda(t|\mathbf{x}) = \lambda_0(t, \boldsymbol{\alpha})\phi(\mathbf{x}, \boldsymbol{\beta}) \tag{11}
$$

where $\phi(\mathbf{x}, \boldsymbol{\beta}) > 0$ is a nonnegative function of $\mathbf{x}$, which is a vector of covariates, and $\lambda_0(t, \boldsymbol{\alpha}) > 0$ is called the baseline hazard. In addition, $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are vectors of parameters. The baseline hazard is common to all individuals in the population and is a function of t alone. The individual hazard function differs proportionately based on a function

$\phi(\mathbf{x}, \boldsymbol{\beta})$ of the observed covariates.

Furthermore, we can classify the methods of duration analysis into two groups. In parametric models an appropriate hazard function is specified, such as the exponential or Weibull distribution. We should use the distribution with due consideration for characteristics of our duration data.

Such fully parametric models are relatively simple to estimate but produce inconsistent parameter estimates if any part of the parametric model is misspecified. Fortunately, there is a semiparametric method that requires less than complete distributional specification because the baseline hazard is no particular parametrization and, in fact, is left unestimated. The model makes no assumptions about the shape of the hazard over time. This is called the Cox proportional hazards model. To keep the distribution of duration data flexible, we adopt the Cox proportional hazards model.

Following Cameron and Trivedi(2005, Chapter 20), we mention the Cox proportional hazards model along the analysis in this paper. The proportional hazard denotes

$$\lambda(t|\mathbf{x}) = \lambda_0(t)\exp(\mathbf{x}'\boldsymbol{\beta}). \tag{12}$$

This replaces $\phi(\mathbf{x}, \boldsymbol{\beta})$ with $\exp(\mathbf{x}'\boldsymbol{\beta})$ in the general form (5). That is, This model is considered, with the functional form for $\lambda_0(t, \alpha)$ unspecified and the functional form for $\phi(\mathbf{x}, \boldsymbol{\beta})$ fully specified. Suppose the kth regressor x_k increases by one unit and other regressors are unchanged. The change in the hazard is $1 - \exp(\beta_k)$ times the original hazard then.

To estimate $\boldsymbol{\beta}$ in the proportional hazard model, we set up a partial likelihood function. Let $t_1 < t_2 < \cdots < t_j < \cdots < t_J$ denote the observed discrete failure times of the spells in a sample of size N, $N \geq J$. Additionally, we define to be the set as follow.

$$\begin{aligned}
R(t_j) &= \{l : t_l \geq t_j\} = \text{set of spells at risk at } t_j \qquad (13)\\
D(t_j) &= \{l : t_l = t_j\} = \text{set of spells completed at } t_j\\
d_j &= \sum_l \mathbf{1}(t_l = t_j) = \text{number of spells completed at } t_j.
\end{aligned}$$

Now consider the probability of requesting examination at time t_j. Then

$$\begin{aligned}
\Pr[T_j = t_j | R(t_j)] &= \frac{\Pr[T_j = t_j | T_j \geq t_j]}{\sum_{l \in R(t_j)} \Pr[T_l = t_l | T_l \geq t_j]} \qquad (14)\\
&= \frac{\lambda_j (t_j | \mathbf{x}_j)}{\sum_{l \in R(t_j)} \lambda_l (t_j | \mathbf{x}_l)}\\
&= \frac{\phi(\mathbf{x}_j, \boldsymbol{\beta})}{\sum_{l \in R(t_j)} \phi(\mathbf{x}_l, \boldsymbol{\beta})}
\end{aligned}$$

where in the last line the baseline hazard factor $\lambda_0(t_j)$ has dropped out, as a consequence of the proportional hazard assumption, $\beta(t) = \beta$.

Furthermore, we should modify a partial likelihood function on the basis of equation (14) so that it adapts to three characteristics of our data described in next section. First, we should control for tied durations. If there is more than one failure at a given time, an adjustment is needed. It is possible that multiple patent applications request examinations at the same time. Then, the partial log-likelihood function denote

$$\ln L(\boldsymbol{\beta}) = \sum_{j=1}^{k} \left[\sum_{m \in D(t_j)} \ln \phi(\mathbf{x}_m, \boldsymbol{\beta}) - d_j \ln \left(\sum_{l \in R(t_j)} \phi(\mathbf{x}_l, \boldsymbol{\beta}) \right) \right]. \qquad (15)$$

Second, our data have right censoring data described in detail in next section, and until they are censored affect the size of the risk set, or the second in (15). Then, we should rewrite it as

$$\ln L(\boldsymbol{\beta}) = \sum_{i=1}^{N} \delta_i \left[\ln \phi(\mathbf{x}_i, \boldsymbol{\beta}) - \ln \left(\sum_{l \in R(t_j)} \phi(\mathbf{x}_l, \boldsymbol{\beta}) \right) \right] \tag{16}$$

where the indicator variables $\delta_i = 1$ for uncensored observation and equal zero otherwise.

Third, this paper focuses on the point what kind of technology is. We therefore allow the baseline hazards to differ by technical classification, but the coefficients $\boldsymbol{\beta}$ are constrained to be the same[8]. This method is called stratified estimation. The hazard function for technical classification gth denotes $\lambda_g(t) \exp(\mathbf{x}'\boldsymbol{\beta})$, $g = 1, \ldots, 8$. Then, the partial log-likelihood function is

$$\ln L(\boldsymbol{\beta}) = \sum_{g=1}^{8} \ln L_g(\boldsymbol{\beta}). \tag{17}$$

Using the equation (17), we perform maximum likelihood estimation.

4. Data

We use rich data set to study the timing of the request for examination under unique Japanese patent system. The data set link Japanese firm-level data to patent data, that is, each observation has not only the information about a patent application but also the applicant's, or firm's characteristics. We collect patent data from the Institute of Intellectual Property (IIP) Patent Database (DB) provided by Institute of Intellectual Property, and firm-level data from NEEDS financial database. We describe a making method of our data set as follows.

To begin with, we describe a outline of IIP patent DB. The DB is developed for patent statistics analysis based on arrangement standardization data, and covers the

[8] We classify the pantent applications according to International Patent Classification. 1.Human Necessities, 2.Performing Operations; Transporting, 3.Chemistry; Metallurgy, 4.Textiles; Paper, 5.Fixed Constructions, 6.Mechanical Engineering ;Lighting; Heating; Weapons; Blasting, 7.Physics, 8.Electricity.

observations which have been published the contents of applications or registered by January, 2004 from January, 1964. It consists of the following five data files; Application File, Registration File, Applicant File, Patent Holder File, and Citation File[9]. In this paper, we use Application File and Applicant File, which are connected with the applicant number. Then, we obtain the information about the date of filing and requesting, the International Patent Classification, and the applicant's name.

From NEEDS financial database, we extract the manufacturing firms which published the financial data from 1990 to 2005. By matching the firm's name including NEEDS database and the applicant's name recorded on IIP patent DB, we can make the rich data set including the patent data and the firm-level data[10].

Here we consider a revision of the time limit for submitting a request for examination. The time limit, which represents the time to expiration in section 2, is to be changed as of October 1, 2001 from "within seven years" from the filing date to "within three years" from the filing date. To avoid a problem with having two limits, we use the data which were filed from April 1, 1990 to September 30, 2001.

In this study, dependent variables are the durations which are the days from the filing date to requesting date. As described in the previous section, we should identify the two kinds of right censored data. One is the data of the application which has not been requested within a period of seven years from filing date. That is, it is the withdrawn one. The following reasons are thought; the business or right hopeless, or a defensive application. The other is the data which are right censored at a data collection time before the time limit for submitting a request for examination. In this study, we set the data collection time of November 20, 2003, on which we can observe the latest sample. As discussed in the previous section, the empirical model is appropriate for censored data.

[9] Goto and Motohashi (2005) gives a complete description of IIP patent DB.

[10] In matching of an applicant' name and a firm's name, we are careful to the following points. We accommodate a difference of firm's name notation and a change of a firm's name. However, a merger and holding company are removed from our sample.

Using our data set, Figure 3 provides the number of applications and the rate of requests for examination, which denotes the number of requests for examination divided by the number of applications[11]. Electrical Machinery and Precision Instruments have the large number of applications, but lower value in terms of the rate of requests for examination. Due to constantly advancing technology fields in such high-tech industries, they might not make a former application a patent if a more valuable technology invent after filing. Thus, the performance of applications and requests for examination is implied technical characteristics by industry.

In this paper, we suggest one explanation for the timing of a request for examination when returns on patents are uncertain. In section 2 we present the theoretical model, and show that the higher uncertainty of returns is, the more difficult it is to request examination. To analyze evidence empirically, we use the standard deviation of the growth rate of real sales within the duration as the uncertainty measure[12]. In terms of predictions in the theoretical model, it has the negative effect on the hazard rate which denotes the probability of requesting examination.

Besides the implications from our model, we investigate the effect of the average of the real sales growth rate within the duration. We consider that in the growth stage a firm requests examination actively because of making the patent strategy with an eye to the future. Therefore, it is expected that the higher growth rate firms perform, the shorter the duration is, that is positive effect of the hazard rate.

In addition, we show whether the number of employees has the effect on the hazard

[11] We calculate the rate of requesting examination in Figure 3 using the observation having expired by the collection date, or before November 20,1996. If we use the total observations, the rate is underestimated because of including the observations before the time limit.

[12] As discussed even by Pitkehly (1997), it is difficlut to assess the value of individual patents. For example, Pakes (1986) estimates the value of patents in Europe using the patent renewal model. Therefore, we face the problem of measuring the uncertainty of patent value. However, we cannot use the information after requesting because the feedback from the duration to the future value of the covariate violates strictly exogenous. In this paper, we asssume that a firm calculates the profit flow from a patent technology based on the performance of itself when decides a request for examination. Then, leaving it as a subject of future investigation, we use tthe standard deviation of the growth rate of real sales as the proxy of the uncertainty. The measure basically follows that of Ogawa and Suzuki (2000), except that the empirical study shows capital investment under uncertainty.

rate. This hypothesis is basically followed by Nagaoka and Nishimura (2005), who estimate the patent acquisition function and the patent use function using Japanese patent data. Although the size of complementary assets increases the number of application, the rate of requesting examination decreases, because of including the lower quality or unpatentable applications. We predict the negative effect on the hazard rate. As for the rest, some kind of dummy variables are provided. One is the technical dummy due to controlling the technical characteristics of applications. We take in 527 dummy variables based on International Patent Classification. The others are industrial dummy variables and filing year dummy variables which control the situation associated with economic and patents.

In duration analysis, the regressors contain the time-invariant covariates which denote the vector of regressors at time t and the time-varying covariates which denote the covariate path up through time t[13]. In this study, all dummy variables are clearly time-invariant covariates because they do not take different values over the duration. On the other hand, sales and the number of employments are observed each fiscal period, but we can consider them as time-variant covariates by transforming into the average and the standard deviation, that is, we look on their measures as the constant performance of the firm over the duration. In fact Cameron and Trivedi (2005) describe using the average over the duration as the easy method to deal with time-varying covariates by some software.

Table 3 and Table 4 show descriptive statistics and correlation coefficients, respectively.

[13]We can obtain the data after a request for examination from Registration File in IIP patent DB. However, they may exihibit feedback so that patent registration is involved in whether it requests examination or not. Lancaster (1990) provideds a definition that rules out feedback from the duration to future values of the covariates. Therefore the information on registration is not appropriate as covariates.

5. Results

5.1. Fact Finding

Figure 4 shows the rate of requests for examination by filing year, which denotes the number of requests for examination divided by the number of applications. Although in the first year it is little high 8%, after that decreases, just before time limit rises again. That is, the rate of request for examination draws the U-curve[14]. Such a unique situation might imply the Japanese system of request for examination.

The rise in the latter half is corresponding to the discussion in section 2; the number of requesting examination increases as the time limit approaches since the option value declines with time and falls down to zero at the time limit.

Furthermore, the high rate in the first year suggests the two factors. One is the value of the valuable patent is requested immediately. Pakes (1986) shows that there are a few highly valuable patents and many relatively worthless ones since the distribution of the potential returns skews towards as the patent ages. The other is that the high opportunity cost leads to request examination at once. Since we cannot identify the two factors, we need to undertake an additional analysis forward[15].

5.2. Nonparametric Estimation

Using the data of duration including censoring data, in Figure 5 we present the Kaplan-Meier estimator of survival function by industry. As the definition is showed in section 3, it provides the probability not requesting examination at the time. No regressors

[14] Note that such a curve is the finding by data of the Japan Patent Office Annual Report. Our data set cannot capture the curve, although the rate rises as time passes.

[15] We make table of it.

Value of patent	Opportunity cost	Request for examination
High	High	Immediate
High	Low	Immediate
Low	High	Immediate
Low	Low	Deferred

are included. The estimator is often insightful to know the shape of the raw hazard or survival function before considering introducing regressors. In addition, it is not corresponding to the rate of requesting examination in Figure 4, because denominators are different. The denominator of the rate is total number of applications, on the other hand, the estimator uses survival number of application at the time. That is, the rate is unconditional probability, and the estimator is conditional probability. Then, we should be careful to interpret the estimator.

Figure 4 shows that the estimator of the survivor decreases drastically over 7 years, or from 2191 days to 2557 days. To defend entry of other firms, a firm gets a large number of complement patents to encircle core patents. In such a case, representing the low opportunity cost, the firm is not always have to patent immediately, therefore requests for examination have been deferred until the time limit for requesting examination, that is, until the option value lowers enough.

5.3. Decision of timing to request examination

We report estimation results based on the Cox proportional hazard model described in section 3, using a 5% random sample of total population of our data set. Table 5 shows two estimation results. First, in the non-stratified estimation we assume that all patent applications have the same baseline hazard. Uncertainty, growth rate, and number of employees coefficients are significant at 5%, which are consistent with our view. However, we cannot pass the specification tests of the proportional hazards assumption that the coefficients are constant over time, $H_0 : \beta(t) = \beta$. The test statistic using Schoenfeld residuals by Grambsch and Terneau (1994) is reported in the last row of Table 5. As a result of it, we find the specification problem, and it suggests that the proportional hazard assumption is violated for some covariate. In such cases, it may be possible to stratify on that variable and employ the proportional hazard model within each group (or called stratum) for the other covariates. Figure 5 represents the baseline cumulative hazard function under the assumption that all observations face the same baseline hazard[16]. It is very restricted.

As discussed in section 3, in the stratified estimation the individuals in the gth group have an arbitrary baseline hazard function. And so, the baseline hazards are allowed to differ by technical classification based on International Patent Classification; $g = 1, \cdots, 8$. The coefficients are constrained to be the same. The estimation results reported by Table 5 are significant at 5%. Moreover, the coefficient estimators do not change as such non stratified estimation results. Cleves et al. (2004) recommend that the proportional hazards assumption be checked separately for each group. In Table 6 the specification tests of the proportional hazards assumption are passed except for "Physics".

In the result for the stratified estimation, we interpret the effects on the probability of requesting examination. The uncertainty increases the probability, then it is implied that a firm with larger uncertainty for project returns delays a request for examination, and it is consistent with the theoretical implication. For example, in the firm that the uncertainty is 0.1 points larger, the probability of requesting examination falls by 16.7% at any given point in time. The growth rate coefficient is positive, meaning that growing firms tend to promote requesting examination, and also as for the number of employee, we find that in the firm with larger complementary assets the probability of requesting examination is lower.

As another meaningful point described in section 2, we want to examine that the hazard, that is, the probability of the requesting examination is increasing over time since the threshold declines as the expiration approaches, especially close to the expiration. The cumulative hazard does appear to be increasing and at an increasing rate, meaning that the hazard itself is increasing (recall that the hazards is the derivative of

[16] Although the Cox model produces no direct estimate of the baseline hazard, estimates of functions related to $\lambda_0(t)$ can be obtained after the fact, conditional on the estimates of $\boldsymbol{\beta}$ from the Cox model. One of them is the estimates of the baseline cumulative hazard.

the cumulative hazard). Then, we should examine the estimate of the baseline cumulative hazard because the baseline hazard is a function of time alone, that is corresponds to the overall hazard when $\mathbf{x} = \mathbf{0}$. Figure 6 represents the estimates of the baseline cumulative hazard by technical classification. Unlike the rate of requesting examination in Figure 4 and the estimator of Kaplan-Meier in Figure 5, calculating the functions by technical classification, we can show the results taking into accounts the difference of the opportunity cost to some extent. We find that the probability of the requesting examination is increasing over time since the curves appear that they have the convex functions. In particular, the estimates explode cross over 2000 days, and then it should be showed that the option value declines with time and option value falls down to zero at the time limit. Between technical classification the order of the estimator differs vastly, In Electricity, Human necessities and Textiles; Paper, we can consider that the probability of requesting examination depend on time largely because the baseline hazard is a function of time alone.

6. Conclusion

In this paper, we have examined the timing of a request for examination under Japanese unique patent system both theoretically and empirically. We can explain the firm's decision taking into account a deferred examination system in Japan by the timing option with the dividend and the time to expiration. Our model shows that 1) the number of requests for examination increases as the expiration approaches since the option value declines with time and falls down to zero at the time to expiration, 2) the large uncertainty leads to defer requesting examination, 3) with the high opportunity cost a firm request examination immediately.

Using the rich data matching patents and firm-level data, we find empirical evidence supportive of predictions in respect of declining the option value over time and the uncertainty. Note that as far as the opportunity cost concerned, we cannot identify the effect on requesting examination empirically.

As the results of this study, it is implied that a firm decides to request examination in consideration of the timing option. Therefore, we should provide the evidence that the unique system of requesting examination in Japan causes the high number of Japanese patent applications, "file a patent application in the meantime", since it generates a valuable option.

There are several future directions to take this study. First, we must find the measure of uncertainty of individual patent value. Second, we show the effect of opportunity cost empirically.

References

[1] Cameron, A.Colin and Trivedi, Pravin K. (2005), *Microeconometrics: Methods and Applications.*

[2] Cleves, Mario A., Gould, William W. and Gutierrez, Roberto G. (2004), *An Introduction to Survival Analysis Using STATA,* STATA Press.

[3] Dixit, Avinash K. and Robert S. Pindyck (1994), *Investment and under Uncertainty*, Princeton, New Jersey: Princeton University Press.

[4] Goto, Akira and Motohashi, Kazuyuki (2005), "Tokkyo Database no Kaihatu to Innovation Kenkyu," *Chizaiken Forum*, Vol.63.

[5] Grambsch, P. M. and Therneau, T.M. (1994), "Proportional Hazards Tests and Diagnostics Based on Weighted Residuals," *Biometrica*, Vol.81, No.3, pp.515-526.

[6] Lambrecht, Bart (2000), "Strategic Sequential Investments and Sleeping Patents," in *Project Flexibility, Agency, and Competition*, ed.by Brennan,Michael J. and Trigeorgis, Lenos, pp.297-323. Oxford University Press, Oxford.

[7] Lancaster, Tony (1990), *The Econometric Analysis of Transition Data*, Cambrigdge University Press.

[8] Nagaoka, Sadao and Nishimura, Yoichiro (2005), "Acquisitions and Use of Patents: A Theory and New Evidence from the Japanese Firm Level Data," *IIR Working Paper* WP#05-14.

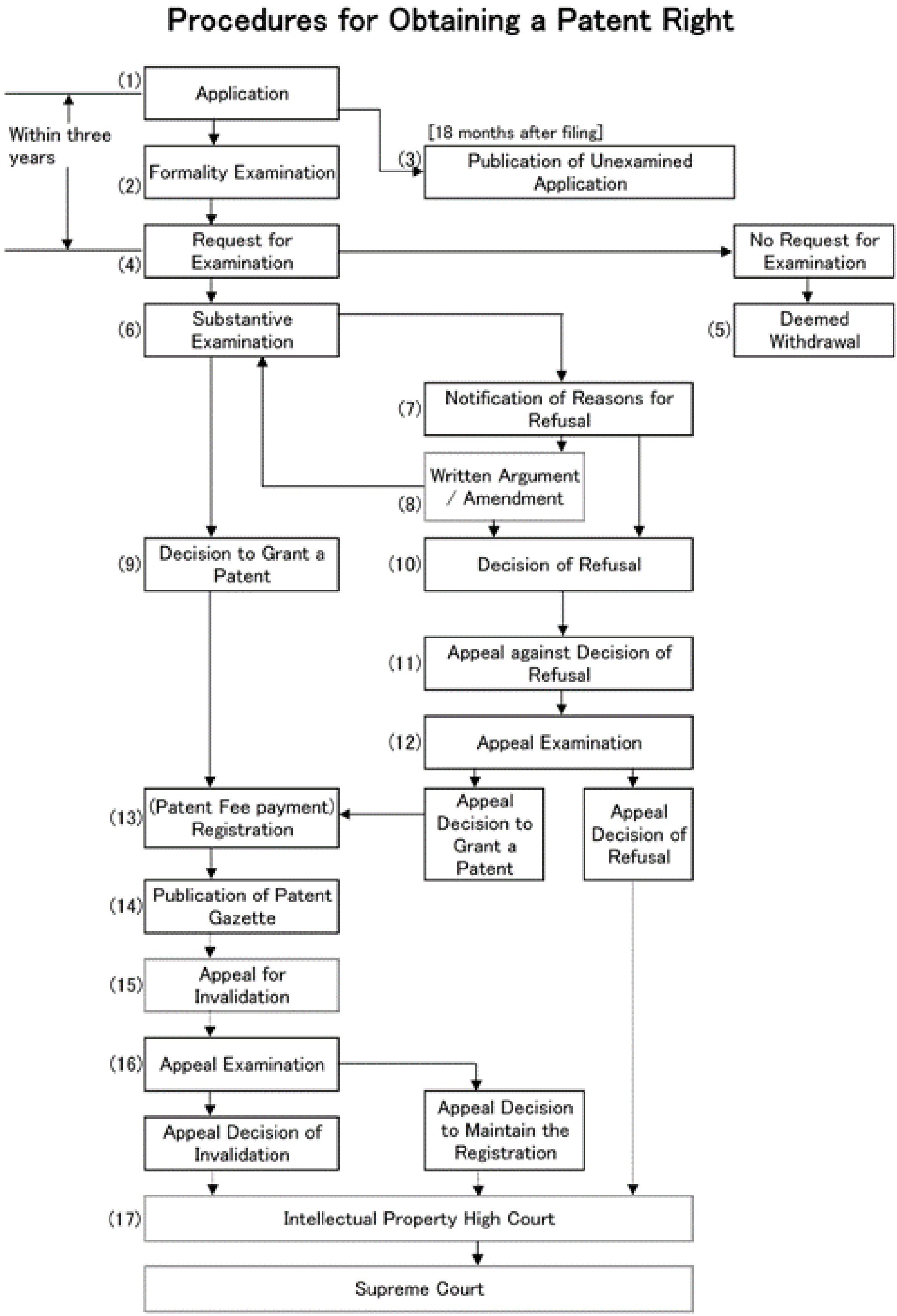
[9] Ogawa, Kazuo and Suzuki, Kazuyuki (2000), "Uncertainty and Investment: Some Evidence from the Panel Data of Japanese Manufacturing Firms," *Japanese Economic Review*, Vol.51, No.2, pp.170-192.

[10] Paddock, James L., Siegel, Daniel R., Smith, James L. (1988), "Option Valuation of Claims on Real Assets: The Case of Offshore Petroleum Leases," *The Quarterly Journal of Economics*, Vol. 103, No. 3, pp. 479-508

[11] Pakes,A. "Patents as options: some estimates of value of holding European patent stocks," *Econometrica*, Vol.54, No.4, pp.755-784.

[12] Pitkethly, Robert (1997), "The VALUATION OF PATENTS: Areview of patent valuation methods with consideration of option based methods and the potential for further research," *Judge Institute Working Paper* WP 21/97.

FIGURE 1



Source: "Procedures for Obtaining a Patent Right," by Japan Patent Office.
http://www.jpo.go.jp/tetuzuki_e/index.htm

Note: To the patent applications filed before September 30, 2001, the time limit of seven years from the filing date is to be applied.

TABLE 1

Comparison of a call option with a delayed request for examination

Call option on stock	Delayed request for examination
Current value of stock	(Gross) PV of expected cash flow creating patent
Exercise price	Cost, including fee for requesting examination
Time to expiration	Time limit for requesting examination
Stock value uncertainty	Patent value uncertainty
Dividend on stock	Net production revenue from patent less depreciation

TABLE 2

Parameters and Numerical Solutions for Four Cases

Column No.		1	2	3	4
		Basic	Larger uncertainty	Larger dividend rate, or opportunity cost	Shorter expiration date
1.Parameter					
The present value (at current date) of the operating project	V	1.2			
The present value (at current date) of the investment cost (net of tax credits)	I	1			
The volatility of the project V ' or a market variable as a proxy of the	σ	0.2	0.4		
The time to expiration of the rights of investment	τ	7			3
The riskless interest rate (real and after-tax)	r	0.04			
The dividend yield of V (or convenience yield from the commodity)	δ	0.04		0.08	
2.Numerical solution					
The value of the threshold (level of optimal immediate investment)	V*	1.653	2.473	1.337	1.5
The value of the option to invest (or the value of the investment	F	0.292	0.462	0.223	0.252
Threshold value × Time		Figure 2.1	Figure 2.2	Figure 2.3	Figure 2.4

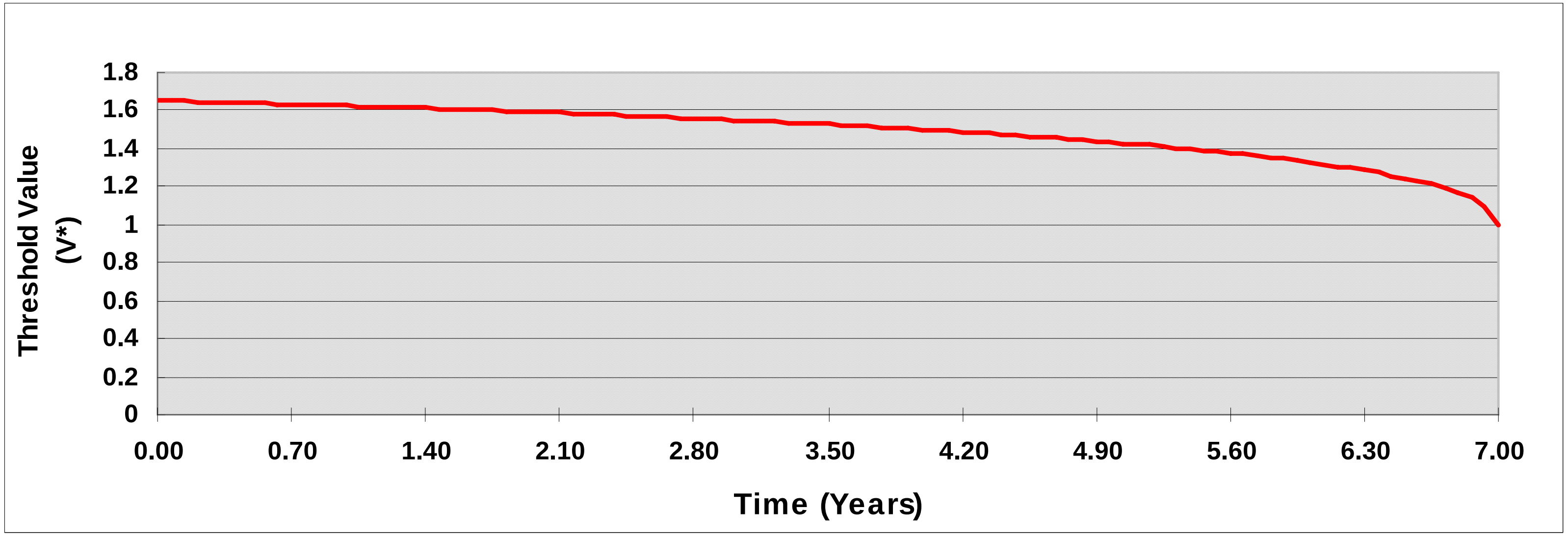
Note: We find the solutions using the shareware file for real options analysis provided by Marco A.G. Dias.

See http://www.puc-rio.br/marco.ind/main.html#contents

.

FIGURE 2.1

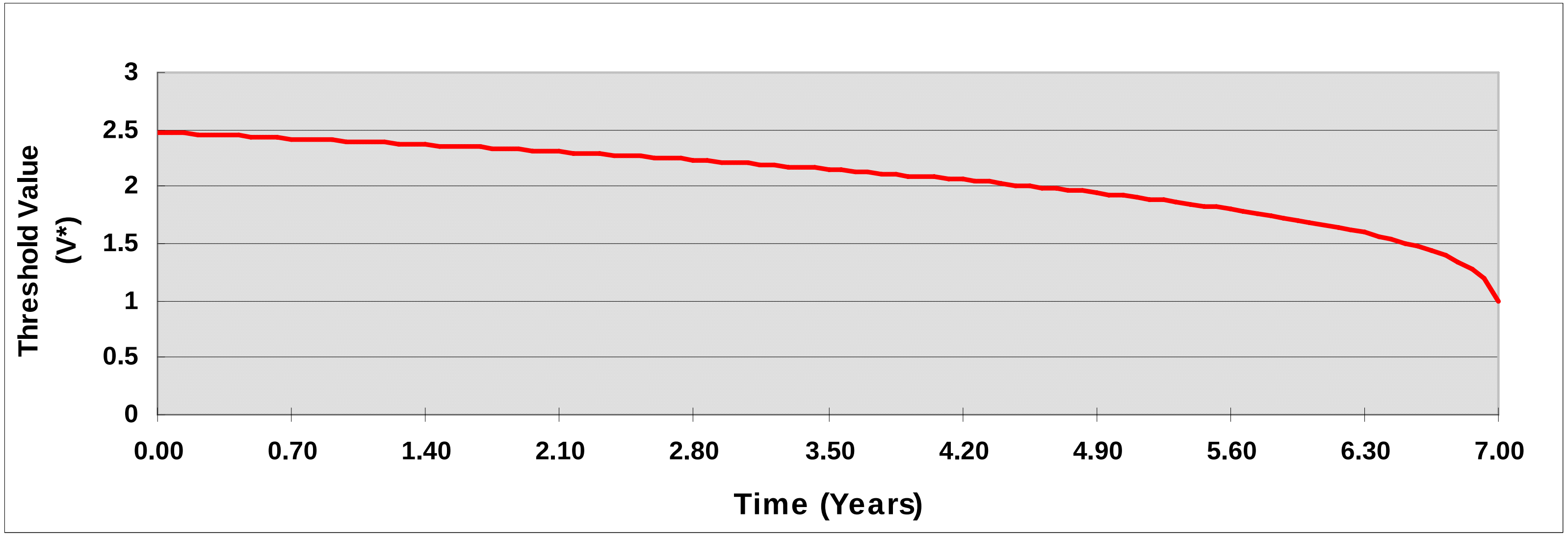
Threshold Value over Time: part 1



Note: The value is based on the basic case, Column 1 in Table 2.

FIGURE 2.2

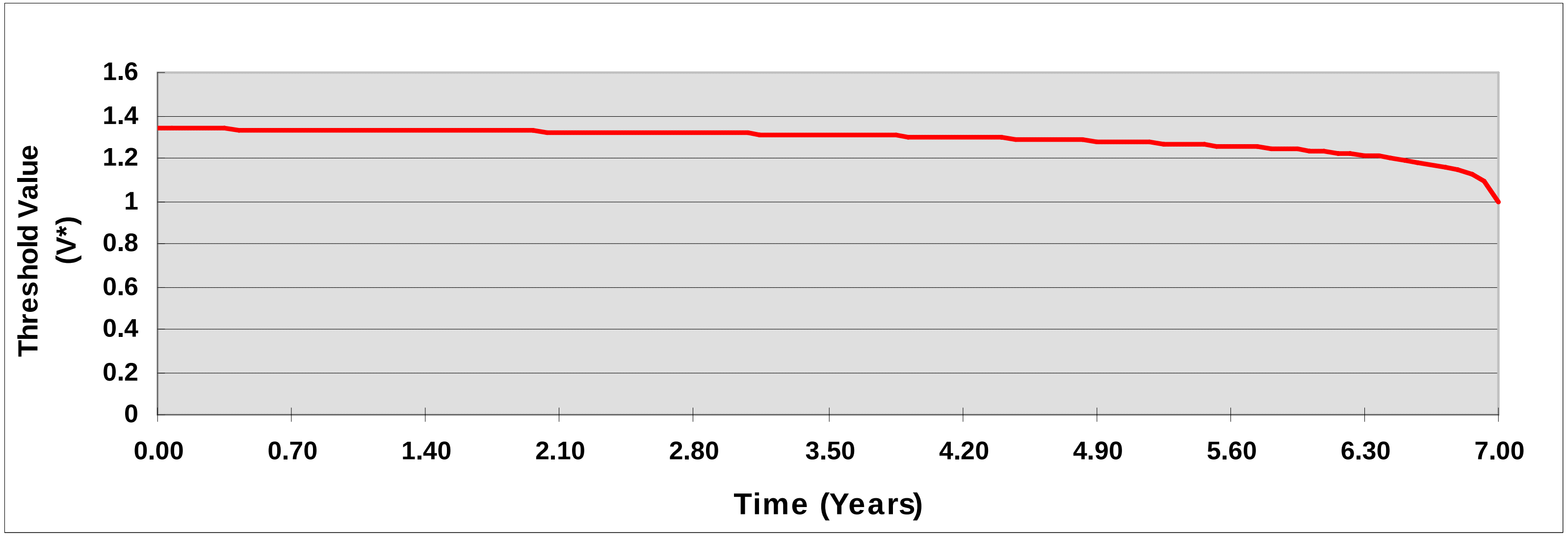
Threshold Value over Time: part 2



Note: The value is based on the larger uncertainty case, Column 2 in Table 2.

FIGURE 2.3

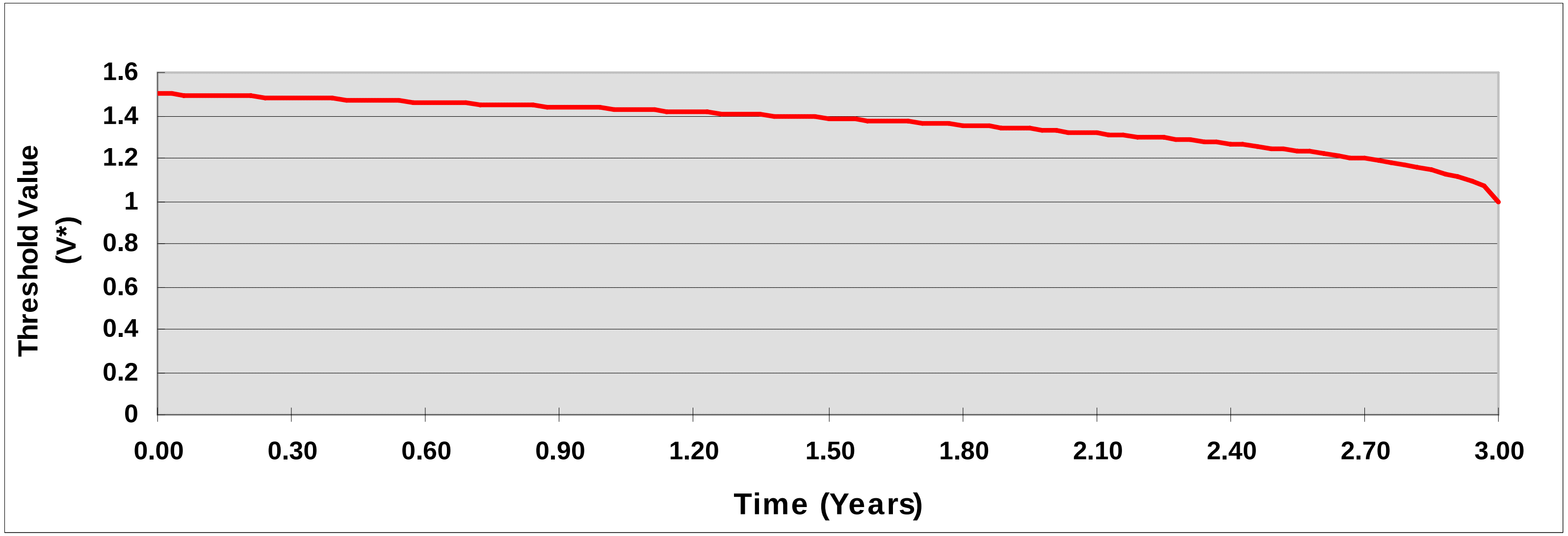
Threshold Value over Time: part 3



Note: The value is based on the larger dividend rate case, Column 3 in Table 2.

FIGURE 2.4

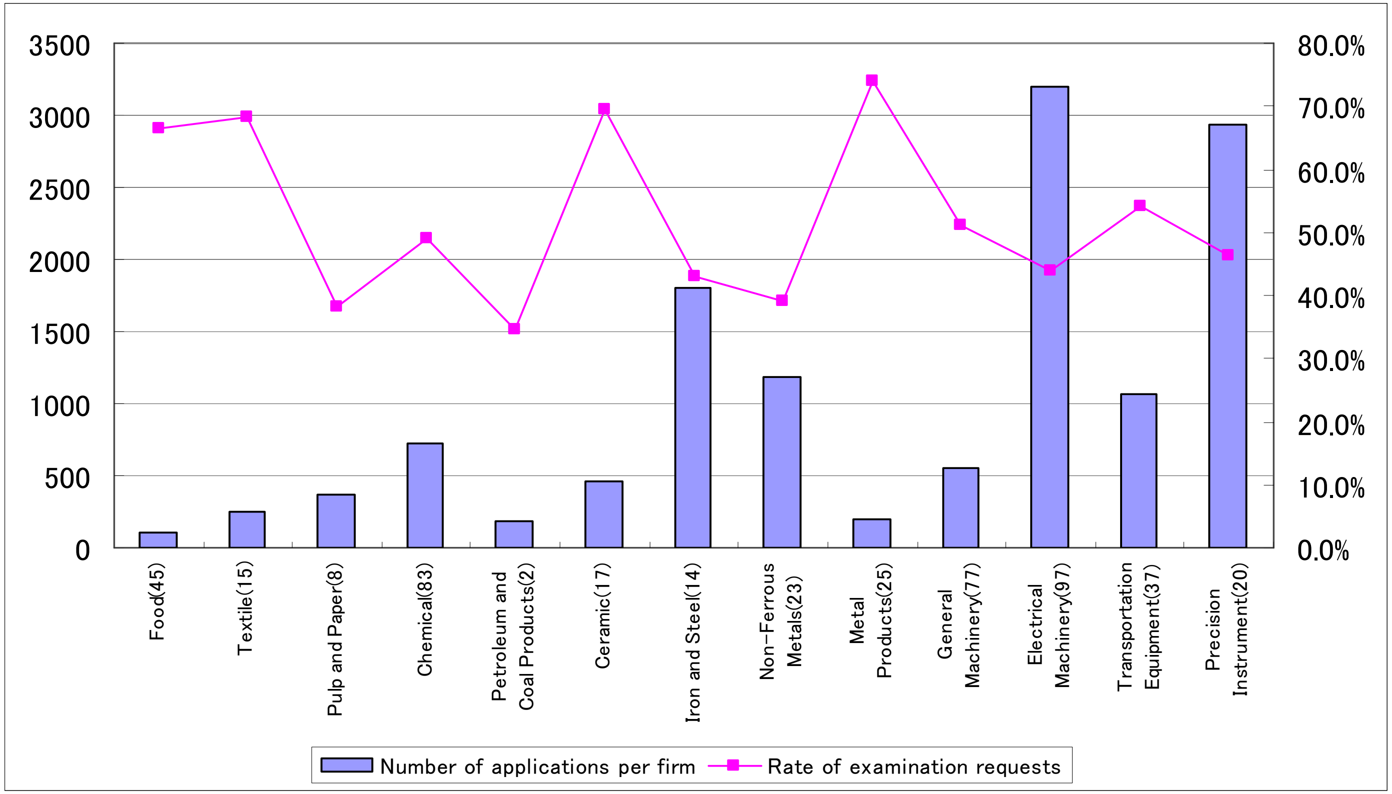
Threshold Value over Time: part 4



Note: The value is based on the shorter expiration date case, Column 4 in Table 2.

FIGURE 3

Number of applications (per Firm) and Rate of Examination Requests



Note: The figure is based on a part of data set in this paper, specifically having expired by the collection date; the observations of before November 20, 1996. The rate of examination requests is the number of examination requests divided by the total number of applications. The values in parentheses are number of the firms. Total number of application, examination requests, and firms is 588,496 and 273,471, and 463. Then average of application and rate is 1271, and 46.5%.

TABLE 3

Descriptive Statistics

Variable	Mean	Standard deviation	Minimum	Maximum
Duration	1918.193	663.330	1	2557
Uncertainty	0.084	0.053	0.000	1.090
Growth Rate	0.035	0.055	−1.517	0.608
No. Employees (log)	9.288	1.238	1.989	11.222

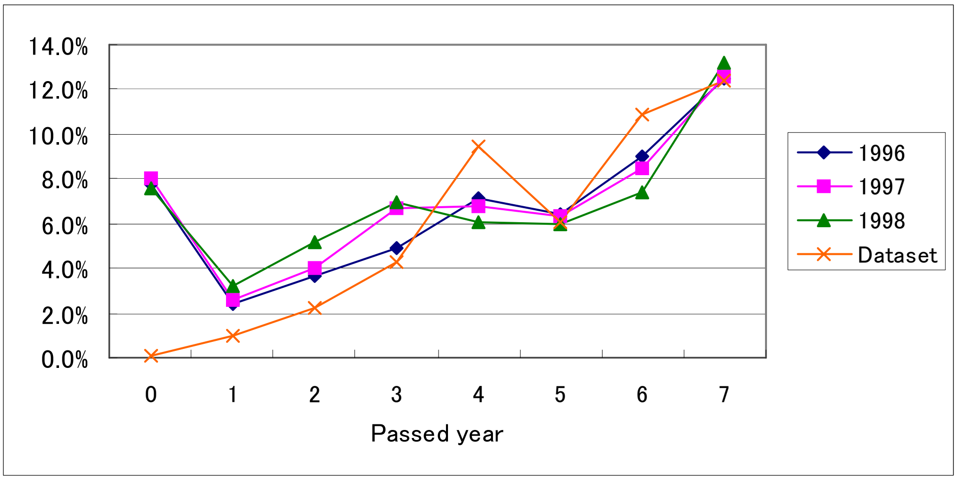
TABLE 4

Coefficient Correlation

Variable	Uncertainty	Growth Rate	No. Employees (log)
Uncertainty	1		
Growth Rate	0.024	1	
No. Employees (log)	−0.269	0.235	1

FIGURE 4

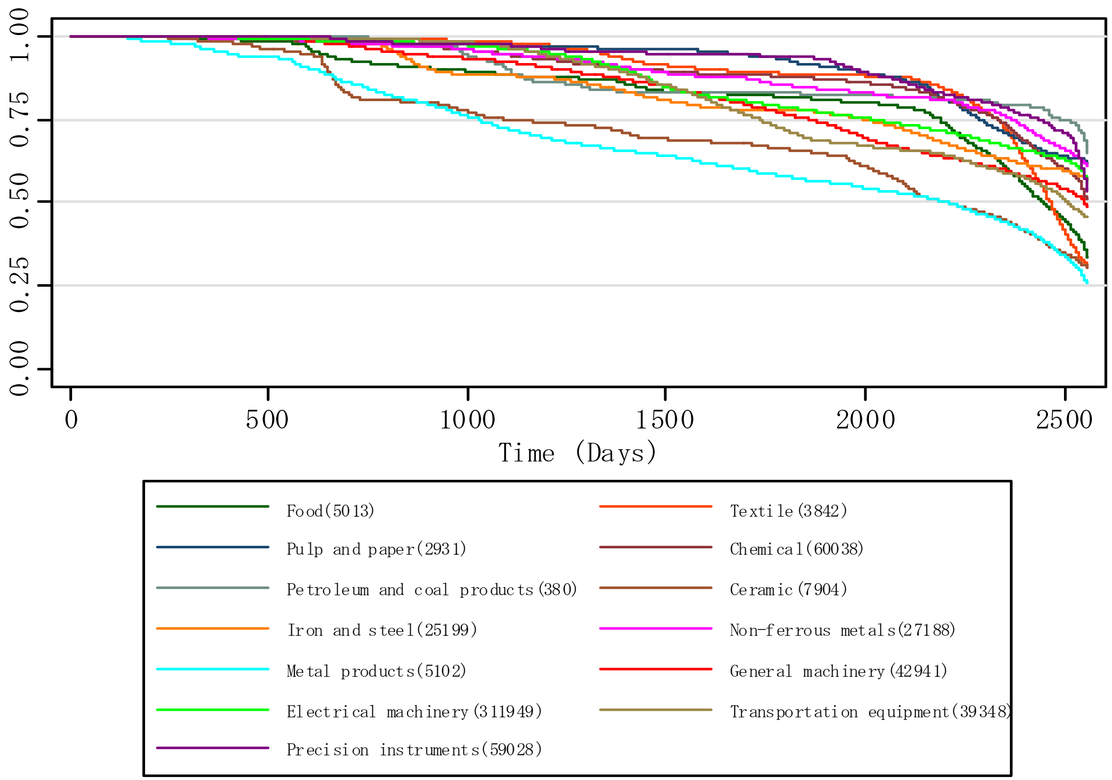
Rate of Examination Requests



Note: “1996”, ”1997” and ”1998” show the rates of requesting examination by application year, respectively. These data are obtained from the Japan Patent Office Annual Report 2006 (Statistical data). On the other hand, “Dataset” is calculated using a part of data set in this paper, specifically having expired by the collection date; the observations of before November 20, 1996. The rate of requesting examination is the number of requesting examination divided by the total number of applications.

FIGURE 5

Kaplan-Meier Survival Estimates by Industry



Note: Number of observations is 588,496 , with 273,471 of requesting examinations. Note that we limit the sample period until November 20, 1997 in consideration of censoring at the collection date, as in Figure 3 and 4. Values in parentheses are number of observations.

TABLE 5

Determinants of Requesting Examination

	Non stratified estimation			Stratified estimation		
Variable	Coefficient	Standard error	exp(0.1*β)−1	Coefficient	Standard error	exp(0.1*β)−1
Uncertainty	−1.747***	0.205	−0.160	−1.831***	0.207	−0.167
Growth rate	0.595**	0.231	0.061	0.541**	0.232	0.056
No. Employees	−0.052***	0.008	−0.005	−0.053***	0.008	−0.005
Observations (Exits)	49755(19637)			49755(19637)		
Log likelihood	−200727.05			−167015.41		
Global test of proportionality over all covariates: X^2	3023.75***			Table 6		

Note: Hetroskedasticitic-consistent standard errors. *, **, *** denote significant at the 10%, 5%,and 1% levels, respectively. The dummy of industry, application year, and technology are dropped. The degree of freedom for the specification test is 552.

TABLE 6

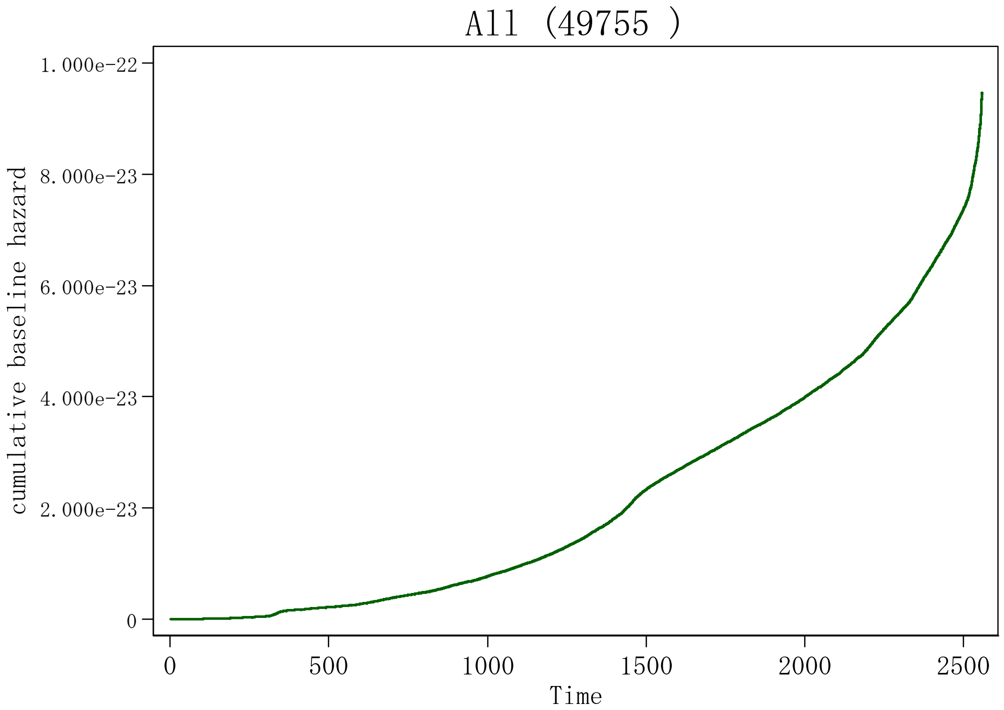
Specification Test; in Stratified Estimation

	Human necessities	Performing operations; Transporting	Chemistry; Metallurgy	Textiles; Paper	Fixed Constructions	Mechanical; et al.	Physics	Electricity
Global test of proportionality over all covariates: χ^2	139.99	273.39	216.2	35.22	43.37	144.71	671.95***	391.23

Note: *, **, *** denote significant at the 10%, 5%, and 1% levels, respectively. The dummy of industry, application year, and technology are dropped. The degree of freedom for the specification test is 552.

FIGURE 6

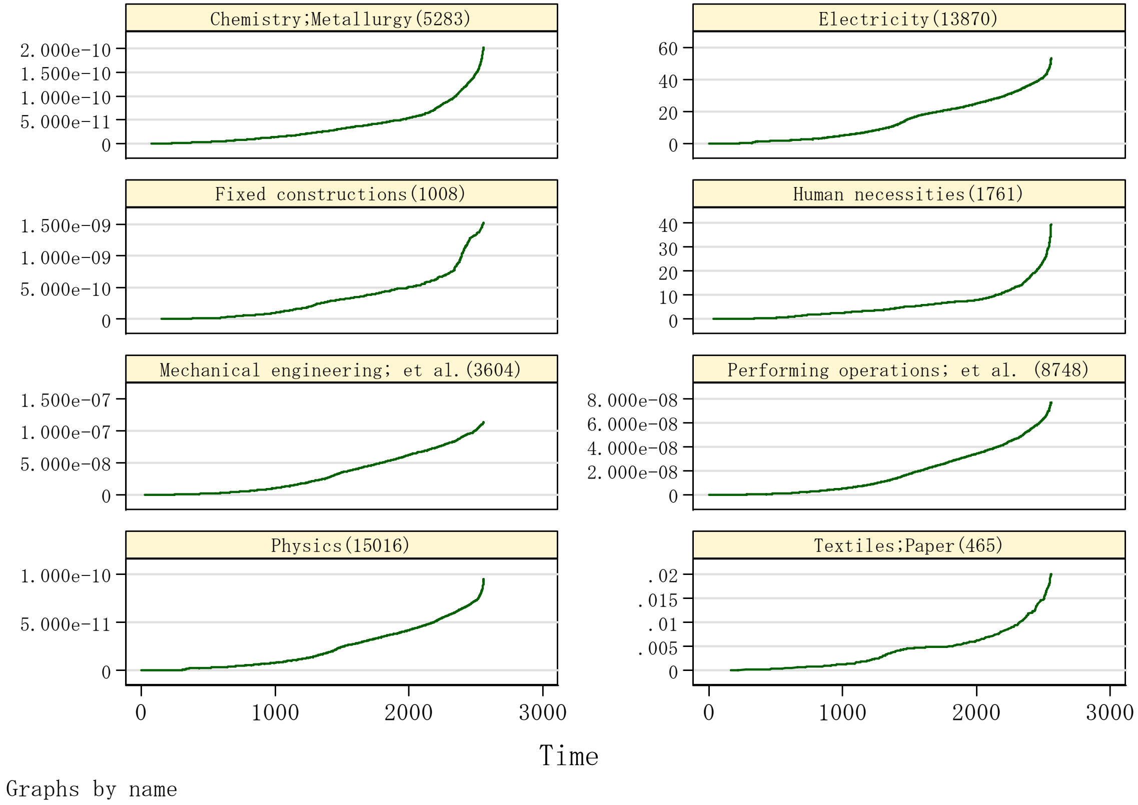
Estimated baseline cumulative hazard: Non-stratified estimation



Note: Values in parentheses are number of observations.

FIGURE 7

Estimated baseline cumulative hazard: Stratified estimation



Note: Values in parentheses are number of observations.