Determinants of Patent Survival in Emerging Economies: Evidences from Residential Patents in India

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Abstract

The purpose of this paper is to use patent level characteristics to estimate the survival of resident patents (filed at Indian Patent Office (IPO) and assigned to firms' in India). Firms are classified into two categories: Department of Scientific and Industrial Research (DSIR) - tax incentive appropriating firms- and non-DSIR firms. We use the renewal information of firm level patents applied during 1st January1995 and 31st December 2005, which were eventually granted. The data provided by IPO consists of 2025 resident patents assigned to 266 firms (foreign subsidiary firms and domestic firms). The survival analysis is carried out via Kaplan-Meier estimation and Cox proportional hazard regression. The outcomes of this study suggest that the survival length of patents significantly depends on their technological scope and inventor size. Moreover, the patents of the firms taking tax credit benefits exhibit lower survival rate as compared to patents of remaining firms. The study also finds that the patents filed by the foreign firms with DSIR affiliation are getting more benefit from the R&D tax incentive policy.

Keyword: survival analysis, patent life, tax credit policy, residential patent, technology scope
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1. Introduction

Several governments promote inventors to have exclusive rights on their invention for a certain period of time, which in turn encourages R&D and innovation. The effect of technological innovation on the firms' performance has been widely discussed in the literature; however, the literature on patent valuation is scarce. The valuation, quality assessment and survival length of patent reveals important information regarding firms' R&D quality, strategy towards intellectual property and government policies. Note that a shorter survival length reveals poor quality of the patent and hence considered to have a lower value. The lower value of the patent reveals the poor performance of innovation. There are several factors that possibly influence a patent performing poorly, for example, lack of infrastructure and skilled scientists, lack of funding and inadequate government policy leads to lower quality of invention. However, in survival literature, we often ignore the inclusion of the policy variable such as R&D tax credit variable (see Barney, 2002; Han and Shon, 2015). In an attempt to bridge this literature gap, we conducted a thorough analysis of survival length of firm-level patents filed at IPO. The rise of patenting activities coupled with efficient IP management becomes an important source of competitive advantage at the micro-level in many industries. Therefore, understanding the patent survival rate and its various determinants reveals potential information about the technological stability in the firms and industry.

Patent life is divided into two phases: pre-grant period called 'provisional' life, and post-grant period called 'active' life. The present study is based on the active life of the patent (Maurseth 2005, Svensson 2007). The length of the active life of a patent depends upon the various factors like the quality of the invention, marketability of the invented product, license or sale of the invention, and the technology group. In order to keep a patent in-forced (i.e., active), the patent owners have to renew it every year by paying the renewal fee. If the renewal fee is not paid, then the patent expires and is no longer protected from infringement. That is, anyone who desires to use such patent information to copy or imitate the product is free to do so. Thus, the scheduled payment of renewal fee separates the valuable patent from not so valuable patents, and the patent owners will never allow it to lapse due to non-payment of maintenance fee (renewal) (Schankerman and Pakes, 1985).

Most of the empirical literature on the patent survival have focused on the simulation of patent value distribution using the cost of patent renewal (Pakes and Schankerman, 1985; Griliches et al., 1986; Lanjouw et al., 1998) and cost of patent filing (Putnam, 1996), However, there are only a few studies that have used patent renewal/survival length (Zeebroeck and Pottelsberghe, 2007).

The motivation of this study is to understand firms' decision about the patent renewal in India. Svensson (2012) suggested that high-quality patents (measured by a higher number of citations, litigated patents, boarder technology scope) would have a higher probability of being both renewed and commercialized. Scholars working in this area have identified a number of factors that could influence the renewal decision (see Pakes and Simpson, 1989; Tong and Frame, 1994). Schankerman and Pakes (1985) assume that the renewal decision of patent is purely based on economic criterion. In many countries including India, patent holders are required to pay an annual renewal fee to keep their patents active, which makes sense only if the renewal cost is lower than the value generated by those patents.

We investigate several observable and measurable (quantitative and qualitative) factors that may influence the patent survival length. The objective of this study is to contribute to the literature on patent survival in two main aspects. First, many government policies such as R&D tax credit policy help firms to develop strong R&D base in the country. Therefore, it is believed that the firms affiliated with Department of Scientific and Industrial Research (DSIR) – a tax credit policy – has the advantageous position as compared to non-DSIR firms. The tax credit on R&D investment provide financial freedom to the firms to focus on the cutting-edge technology and therefore such patents are assumed to be less vulnerable relative to non-DSIR affiliated firms' patents, and hence should lead to a longer patent survival.

Based on the literature, the determinants of patent survival are clustered into three groups. First, the *complexity of the inventions* measured by patent technology class (4-digit IPC class), number of inventors, and grant lag. Second, the *filing strategy* includes the structure and quality of the drafted document (number of claims) and protecting the same patent in different jurisdiction (family size). Third, *ownership characteristic* that is firms' country affiliation are included in the study. This study proposes a systematic approach to estimate how different explanatory variables influence the firms' decision on patent renewal. Earlier studies on patent survival have used patent level information to see their impact on patent life however no study to best of our knowledge has focused on the firms' level information along with R&D tax credit policy to observe the patent survival differences.

There are number of methodologies proposed to analyze survival data. The Kaplan-Meier curves and Cox proportional hazards (Cox-PH) regression is popular among others used frequently by scholars across different application areas. Kaplan-Meier curve estimation is a non-parametric statistical tool whereas Cox-PH model is semi parametric model. This study focuses on the survival function estimates for patents based on their affiliation with DSIR vs. non-DSIR firms. in order to have in-depth impact analysis of patent characteristics on the survival length, the Cox-PH model is applied. The number of patent and ownership characteristics such as number of claims (NC), number of inventors (NI), family size (FS), technology scope (TS), DSIR dummy, and ownership dummy (OW) is applied in the Cox-PH model.

The econometric model is used on the data set of all granted patents (resident) that were filed at IPO between 1st January 1995 and 31st December 2005. We have sample of 2025 resident out of 4343 patent assigned to 266 firms (domestic and foreign subsidiary) with complete information. The patents are classified in five categories (electrical, mechanical, instruments, chemistry and other fields) on the basis of international patent classification (IPC). Applying both Kaplan-Meier and the Cox proportional hazard model to the data, this study finds that overall non-DSIR firms' patents are more likely to survive for a longer time. As per the hypothesis patents of DSIR affiliated firms survive longer however the results suggest otherwise. The finding of ownership category shows that patents of foreign affiliates in India are less likely to survive however interaction between ownership and DSIR (ownership*DSIR) in our Cox-PH model finds positive impact on the survival length of the patent. Thus, the overall domestic firms produce low quality patent in-comparison to foreign subsidiaries in India. Electrical and mechanical patents are more likely to survive as compared to chemistry and instruments. The impact of technology class on survival length suggests that if a patent belongs to more than one technology class, it is more likely to survive longer. Whereas, geographical scope (family size) and drafting style (number of claims) have no significant impact on the firms' patent survival rate.

The rest of the manuscript is organized as follows. Section 2 presents and overview of the study on the determinants of patent survival and brings the necessary discussion on the contradictory results reported by various studies. Section 3 presents the data and descriptive statistics. In

Section 4 we propose the empirical model. The estimated results are presented in Section 5. We conclude our results in Section 6.

2. Literature

A brief review of different literature related to survival analysis from the valuation perspective is presented in section 2.1. The survival studies find that a longer patent life is an indicator of higher value patent. Section 2.2 presents number of quality an indicators that influence the survival length of the patents. The section 2.3 briefly discusses the R&D tax credit policy in India's context.

2.1 Patent survival

Patents count considered to be the weak proxy of innovation (Trajtenberg, 1990). The simple patent count does not consider the heterogeneity among the patents. Therefore, we often end up making wrong judgment about the quality and value of innovation. However, disaggregated information revealed in the patent documents brings richness in the patent data. Over the period renewal length of a patent is studied by many scholars to estimate the value of patents (see Pakes and Schankerman, 1984; Schankerman, 1998, Lanjouw et al., 1998). To keep a patent alive/inforce after issuance, the patentee must pay the renewal fee. The renewal fee varies with the age of a patent and the patent offices in which it is sought for protection. In return, patent generates implicit profit to the patent owner during the coming year. However, if the patent renewal fee is not paid, the patent expires permanently and therefore after the return on that patent becomes zero (Lanjouw et al., 1998).

Most of the previous studies have used patent renewal information to estimate the value distribution of patents (Schankerman and Pakes, 1986; Griliches, 1990; Bessen, 2008). The literature on patent valuation finds that patents who survive longer have higher value compared to patents lapsed in the early age (Bessen, 2008). It is assumed that owners' are well aware of the usability and quality of the patent and the decision about the renewal of patent is based on the economic principle (Svensson, 2012). Having said that, the patent renewal decisions of owners' are influenced by many other uncontrolled factors such as future marketability of the patented products, the invention of new improved product around the earlier invention and so on. Schankerman and Pakes (1986) estimate the distribution of patent value where they find that about half of the European patents continue to be renewed after 10 years and only 10 percent of patent lives up to statuary term. Griliches (1990) finds that the patent with lower value depreciates rapidly and only a few patents qualify to high value.

There are other strands of literature that focus on the determinants of patent renewal. Harhoff et al. (1999) find that patents renewed to statuary period are cited more often than patent ceased/expired in early age. Serrano (2008) finds that the acquired patent is more likely to be renewed than non-acquired ones. Maurseth (2005) uses a survival model to estimate the determinants of patent renewal. The result suggests that patent cited across the technological field survive longer than patent cited within the technological field.

2.2 Determinants of patent survival

The selection of the explanatory variables and the sampling methodology varies widely across the studies. To start with some of the explanatory variables- patent citation, number of claims, family size, and technology scope- that is proven reliable when patent value distribution or patent survival measured (value and survival is interchangeably used). The valuation studies have extensively used citation information along with legal disputes and renewal information to measure the value of patents (Moore, 2005; Allison, 2003). The patent value determinants are grouped into four different categories of variable in the equations: (1) different characteristics of patent application (PC), (2) ownership characteristics (OC) (3) some contextual information collected through survey, if any (4) and the filing strategy inventors (FS) (van Zeebroeck and van Pottelsberghe, 2011).

In many cases, explanatory variables have been used in both sides of the equation depending upon the underlying objective of the study. The forward citation counts are derived measure which indicates about the quality and value of the patent. The patent family size identifies as a measure of geographical scope, measure of the patent length (renewal years) and the litigation information are often used as dependent as well as an independent variable in valuation studies. van Zeebroeck and van Pottelsberghe, (2011) reviewed several studies on patent valuation that precisely used these four variables.

The backward citation (measure of existing technological background) (Reitzig, 2004), non-patent citation (basic research) (Narin et al., 1987), number of claims (legal breadth of the patent)

(Tong and Frame, 1994), number of technology class (technological scope) (Lerner, 1994) and the number of inventors (indicating the research efforts) (Brusoni et al., 2006) have been frequently used as a determinants of patent value. Brusoni et al., (2006) study show that the number of inventors is strongly associated with the size of the applicant firm. This indicates a difference in the scale of research activities among the organization and firm'. Thus, inventor size is often used as a proxy of firm size in the studies. Zeebroeck et al. (2011) used some of these characteristics as a complexity indicator in their study and found them positively associated with the patent value. The presence of multiple applicants denotes the joint research efforts (Duguet and Iung, 1997), cross-border ownership indicates international collaborations (Guellec et al., 2000), are expected to positively associate with the patent value.

Gambardella et al., (2008) find that independent inventors to large multinational firms have an ambiguous relationship with patent value. On the other hand, academic patents are related to more basic research, which may have higher scientific value (Harhoff et al., 2002) but have very limited takers in the market because it has a lot of uncertainty in the market. Allison et al. (2003) proposed inexperience patentee (new to the patent system) as one of the determinants of patent value. Shane (2011) uses the firms' patent portfolio as an indicator of the level of experience with the patent system as a determinant of patent value. The result suggests that the patent portfolio is positively related to the value of patents. The high patent portfolio also indicates the higher propensity to patent, possibly encouraging many patent filing of a lower value.

The present study is based on an event (survival duration) where survival analysis (Cox proportional hazard model) is used to estimate the function (Cox, 1972). The event refers to the year in which a patent expires. The censored patents are those patents which reach to 20 years or has not expired during the study period. Svensson (2011) studies the impact of the different explanatory variable (e.g. commercialization decision, patent quality, firm size, etc.) on the patent length. The study surveys Swedish patent granted to firms and individuals in 1998. The result shows that commercialization and defensive strategies increase the probability that patent to be renewed. Svensson (2011) study is based on the patents owned by small firms and individuals. Therefore, the results of this study cannot be generalized to all firms', country or region. However, the present study overcomes this issue by conducting a comprehensive study on both big and small firms' patents in India. To best of our knowledge, there is no literature available on the survival of Indian patents particularly using renewal information along with in-depth patent level information.

2.3 Tax credit policy

Government of India's department for scientific and industrial research (DSIR) provides tax credit to the firms on the R&D investment under Section 35(2AB) of the Income-tax Act, 1961. The Section 35(2AB) provides weighted tax deduction of 150 percent on in-house R&D[1]. The guideline specified that companies are allowed to claim deduction of capital investments on R&D center of more than Rs. 10 million (excluding expenditure on land and building). This initiative was started by the government in the year 2001 to attract innovation and technological advancement in its jurisdiction. This policy initiative has immensely influenced the R&D activities and witnessed some robust growth in the innovation activities. Many progressive steps have been taken by the government of India to promote newer R&D investment in India by Indians as well foreign potential investors. For example, increase in R&D support, improvement in the pool scientific manpower, providing good R&D infrastructure, Establishment of research facilities and centers of scientific excellence on par with some of the most globally renowned facilities (Worldwide R&D Incentives Reference Guide 2018)[2].

The stated goal of tax credit policy is to encourage local research and development (R&D), to incentivize businesses through IP, and to reduce the cost of R&D. Since we know that R&D funding is one of the crucial factors that influence innovation across the sectors, tax credit policy on R&D brings relief. Thus, we hypothesize that affiliation with the DSIR positively influences the quality of the patent. Hence the survival of the patents is higher. Jose et al., (2019) study finds that DSIR affiliation improves the R&D and patenting activities in India. However, the impact of DSIR affiliation on the quality and value of the patent has not been investigated yet. This study divides patents into two categories one owned DSIR companies and other non-DSIR companies. We want to see how survival length of patent varies between these two categories.

[1] 200% upto AY 2017-18

[2] https://www.ey.com/Publication/vwLUAssets/ey-worldwide-rd-incentives-reference-guide-2018/$FILE/ey-worldwide-rd-incentives-reference-guide-2018.pdf

3. Data and Variable Description

The data used in this study consist of all firm level resident patents (assignee country India) applied between 1st January 1995 and 31st December 2005 that were eventually granted by the Indian patent office (IPO). The total number of patents as per IPO is 4343. The granting period of these patents were between 1st January 1997 (minimum two years since the filing date) and 31st December 2018 (the data collection date). The patent level information was collected from the IPO website[3] and PatSeer[4]. Table 1 summarizes the patent level characteristics for this data. We only considered the patents with complete information on renewal length and these patent characteristics. Note that the restriction on completeness of the data further reduced our sample size to 2025. The dataset represents 266 firms and 5 technology groups (Chemistry, Electrical, Mechanical, Instruments and Others).

Table 1. Summary of patent characteristics based on 2025 patents filed at Indian Patent Office during 1st January 1995 and 31st December 2005.

Patent characteristics	Determinants [Acronym-Notation]	Mean
Life (survival / renewal length) of a patent	Difference between filing and expiry date	12.52
Geographical scope (Family size)	Number of countries (worldwide a patent is sought) [FS]	9.06
Drafting style	Number of claims made by the patent [NC]	10.21
Complexities	Number of inventors involved in the patent [NI]	2.79
Technology scope	Number of 4-digit IPC classes of a patent (five technology groups have been identified for this data: Chemistry, Electrical, Mechanical, Instruments and 'Other field') [TS]	3.68
Applicant profile	Whether a patent is assigned to Indian firms (0) or a foreign subsidiary (1) [OW]	1=94 0=1931
Tax credit policy/DSIR	Firms listed in the government tax credit policy DSIR is assigned 1, and zero otherwise.	1=1647 0=378

Several patent characteristics presented in Table 1 have also been discussed in the literature earlier, for instance, Xie and Giles (2011), and Zeebroeck and Pottelsberghe de la Potterie (2011). However, we have included additional features like ownership characteristics and grouped the patents into five different technology categories based on 4-digit IPC classification.

[3] https://ipindiaservices.gov.in/publicsearch
[4] A private data base company license owned by IIT Indore.

The dependent variable in this study is patent renewal duration (or survival length). From a survival analysis standpoint, if a patent has expired then it coded as 1 (and referred to as the occurrence of the "event"), whereas if the patent has either matured (completed 20 years of renewal life) or still in-force at the time of data collection (31st December 2018), then the patent is coded as 0 (and referred to the non-occurrence of the event).

4. Model Description

Survival analysis or failure time data analysis has been used in many disciplines and applications ranging from the actual lifetime of a patient (Lawless, 1982) to economic quantities (Kiefer et al., 1988, and Haurin and Sridhar, 2003), labour dispute (Kennan, 1985) and monetary policies (Yu, 2005). However, as per our knowledge, there is no survival study on the renewal length of patents with respect to different characteristics.

Here, the objective of survival analysis is to model the underlying distribution of the failure time, T, which is patent expiration event due to non-payment of renewal fee under 20 years of patent life from the date of filing. The dependent variable (renewal years) is assumed to have a continuous probability distribution $f(t)$ with

$$F(t) = Prob(T \leq t) = \int_0^t f(s)ds. \tag{1}$$

The corresponding survival function is $S(t) = 1 - F(t) = Prob(T \geq t)$, and the hazard rate (or hazard function) can be estimated via

$$h(t) = \frac{f(t)}{S(t)}. \tag{2}$$

As per the literature, a plethora of methodologies have been proposed to analyze survival data, and, Kaplan-Meier curves and Cox proportional hazards regression are very popular tools across different application areas.

Kaplan-Meier curve estimation is a non-parametric statistical method used for estimating the survival function. That is, S(t) can be approximated as

$$\hat{S}(t) = \prod_{\substack{j=1 \\ (t_j<t)}}^{N} \left(1 - \frac{d_j}{n_j}\right), \tag{3}$$

where t_j is the j-th event time (basically, year-end) when the patent expires, d_j is the number of patents expire at t_j and n_j is the number of patents known to have survived up to time t_j. Typically, the estimated survival curves are used to assess the impact of important grouping variables. In this paper, we focus on the comparison of survival function estimates for patents based on their affiliation with DSIR versus non-DSIR firms.

For a more in-depth impact analysis of patent characteristics on the survival length, we use Cox proportional hazard regression model (in short, referred to as Cox-PH model). The model is expressed by the hazard function denoted by $h(t)$, which measures the risk of getting a patent expired at time t. The hazard function is characterized by a set of time invariant covariate vector x_i, and a time dependent baseline hazard h_0 – which corresponds to the value of hazard rate if x_i is equal to zero. The model is written as follows:

$$\begin{aligned} h(t|x_i) &= h_0(t) \cdot \exp(x_i^T \boldsymbol{b}) \\ &= h_0(t) \\ &\quad * \exp(b_1 \cdot NC + b_2 \cdot NI + b_3 \cdot FS + b_4 \cdot TS + b_5 DSIR + b_6 \cdot OW + b_7 \cdot D_{chem} \\ &\quad + b_8 \cdot D_{elec} + b_9 \cdot D_{mech} + b_{10} \cdot D_{inst} + b_{11} \cdot D_{other} + b_{12} \cdot OW * DSIR), \end{aligned} \tag{4}$$

where x_i is a 12-tuple vector of covariate values that correspond to the patent characteristics: NC, NI, FS, TS, DSIR and OW, described in Table 1, and $D_{chem}, D_{elec}, D_{mech}, D_{inst}$ and D_{other} – the dummies for the five technology categories as per the 4-digit IPC classification.

A popular summary statistic of interest, called the hazard ratio, is defined by $\exp(b_i)$, which implies that if the i^{th} covariate value increases, the hazard (or the chance of patent expiring) increases and thus the length of survival decreases. More precisely if the value of hazard ratio is greater than 1 the covariate is positively associated with the event probability, and negatively associated with the length of survival.

One can use a variety of approaches to assess the validity of proportionality assumption of Cox-PH model, for instance, the graphical techniques based on Schoenfeld residuals, and tests built using hazard ratios. Even the Kaplan-Meier curves can indicate the violation of proportionality assumption. See Harrell and Lee (1986) for details on the assumption of Cox-PH model.

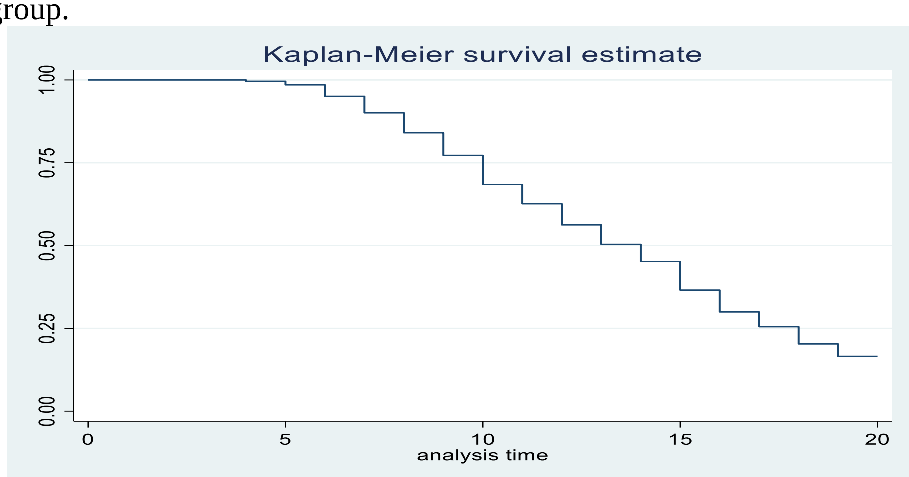
5. Results Discussion

In this section, we first present the Kaplan-Meier curve analysis of patent survival length data with respect to DSIR affiliation, and then discuss the impact analysis of different patent characteristics on survival length via Cox-PH model.

5.1 Kaplan-Meier Approach

Recall that the paper makes a patent policy level hypothesis: the patents filed by firms that are DSIR affiliated are more likely to be worthy as compared to firms not affiliated with DSIR, and it is intuitive to assume that a worthy patent has a longer survival/renewal life. We use all 2025 firm-level resident patent data obtained from IPO filed between 1st January 1995 and 31st December 2005 (and eventually granted) to estimate the Kaplan-Meier survival curves under the two categories (DSIR and non-DSIR). Figure 1 shows the estimated survival function of all patents. The plots are drawn using STATA software.

Figure 1. survival curves obtained through Kaplan-Meier estimator for 2025 patents for five technology group.



It is clear from Figure 1 that, on average, the patent expiration continues at each renewal year and therefore the survival curve declines with time, and approximately 18 percent of all patents survive at the end of the study.

Figure 2. Survival curve estimates obtained through Kaplan-Meier approach for 2025 firm-level resident patents filed at IPO during 1st January 1995 and 31st December 2005.

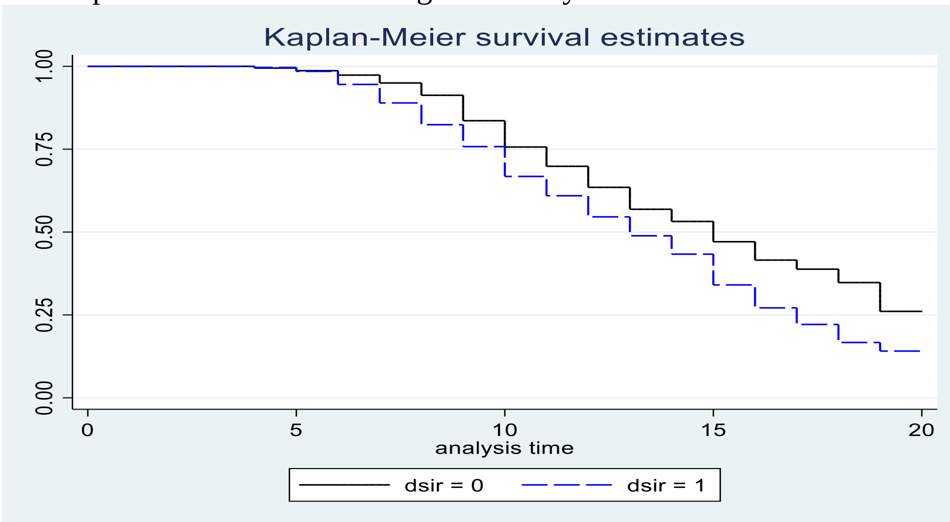


Figure 2 presents the comparison of survival function estimate for DSIR and non-DSIR categories. Note that the two survival curves are somewhat parallel which supports the proportionality assumption. The non-DSIR (coded as 0) curve is above the DSIR (coded as 1) curve. It is also clear from Figure 2 that the survival curve of DSIR firms is above the non-DSIR survival curve. This implies that the patent belonging to DSIR firms expire at a slightly faster rate as compared to non-DSIR firms. Also the divergence between DSIR and non-DSIR firms patents are smaller at the beginning which increases subsequently. This implies that after 12th year survival rate of the DSIR patents decreases faster. One possible interpretation could be that such firms file a lot of patents but many of them do not have very high quality, and hence tend to lapse a little early. Also big firms who involved in the higher R&D activities are possible to end up increasing patent portfolio to attract investment through initial public offering (IPO) then creating a quality patent. However, for the deeper understanding of DSIR impact on survival length in the Cox-PH model we interacted ownership with DSIR dummy. The result is presented below in Table 2.

We also conducted "log-rank test" to test the difference between DSIR $(n = 148)$ and non-DSIR firms $(n = 118)$ (Harrington, 2005). The results obtained show statistically significant difference between the survival rates for the two groups of patents $\chi^2(1) = 23.38,\ p \approx 0.00$.

5.2 Cox Proportional Hazard Model

The main objective of this section is to assess the impact of the following patent characteristics, number of claims (NC), number of inventors (NI), family size (FS), technology scope (TS), DSIR affiliation, ownership (OW), and the dummies for the five technology categories (Chemistry, Electrical, Mechanical, Instruments and 'Other field') as per the 4-digit IPC classification. The dependent variable represents the probability of a patent expiring at time (t). Table 2 summarizes the model fit under different scenarios. Model 1 corresponds to a simpler case with only DSIR as the independent variable, and Model 2 – Model 6 include all additional five patent characteristics (NC, NI, FS, TS and OW), but focus on only one technology at-a-time. Finally, Model 7 assumes all technologies (with Instruments as the reference category) and all patent characteristics.

Table 2. Cox proportional hazard regression model fitted to the firm level resident patent data filed at IPO during 1st January 1995 and 31st December 2005.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
Variable	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
DSIR	0.330*** (0.07)	0.310*** (0.08)	0.321*** (0.08)	0.266*** (0.08)	0.290*** (0.08)	0.318*** (0.08)	0.305*** (0.08)
Claims (NC)		0.003 (0.00)	0.003 (0.00)	0.001 (0.00)	0.002 (0.00)	0.003 (0.00)	0.001 (0.00)
Inventor size (NC)		0.026** (0.01)	0.026** (0.01)	0.018 (0.01)	0.021 (0.01)	0.025*** (0.01)	0.017 (0.01)
Family size (FS)		0.001 (0.00)	0.002 (0.00)	0.000 (0.00)	0.001 (0.00)	0.002 (0.00)	0.000 (0.00)
Technology scope (TS)		-0.009** (0.00)	-0.009* (0.00)	-0.013*** (0.01)	-0.011** (0.01)	-0.009* (0.00)	-0.014*** (0.01)
Ownership (OW)		0.036 (0.14)	-0.015 (0.14)	0.039 (0.14)	-0.036 (0.14)	-0.013 (0.14)	0.344** (0.19)
Electrical		-0.228** (0.11)					-0.348*** (0.16)
Instrument			0.096 (0.13)				
Chemistry				0.306*** (0.06)			0.044 (0.13)
Mechanical					-0.287*** (0.07)		-0.294** (0.14)
Other field						-0.198 (0.18)	-0.263 (0.22)
Ownership*DSIR							-0.633** (0.29)
LR $\chi^2(1)$	22.24***	34.9***	30.73***	56.38***	48.14***	31.42***	39.56
No. of observation	2,025	2,025	2,025	2,025	2,025	2,025	2,025
PH assumption $\chi^2(7)$	0.22	9.10	7.45	12.05	3.70	3.07	20.06

Notes: Standard errors are shown in parentheses. Parameters are significant at, *** $p < 0.001$, **$p < 0.05$, *$p < 0.01$

A few quick remarks as per Table 2 are as follows:

1. The coefficient of DSIR is consistently positive and statistically significant, which implies that DSIR affiliated firm patents (coded as 1) as compared to non-DSIR firm patents (coded as 0) have a greater hazard rate and hence lower survival rate. This inference is consistent with the Kaplan-Meier curve estimate comparison.
2. The following patent characteristics: number of claims (NC), family size (FS) and technology scope (TS), have the same sign of parameter estimates and are statistically significant across different models, except ownership (OW) and inventor size (NI).
3. The coefficient of inventor size is positive and significant, which implies that the larger the inventor size, the higher the hazard rate is. This appears to be counter intuitive as compared to some other studies, for example, Brusoni et al. (2006).
4. In technological category, electrical and mechanical patents are more likely to survive for longer time compared to chemistry, instruments and other field. This result corroborate with Danish et al., (2019) study on Indian patent valuation.
5. The negative coefficient of the interaction term between ownership and DSIR (in model 7) shows that foreign subsidiary firms with DSIR affiliation have positive impact on the survival length as compared to Indian firms with DSIR affiliation.

6. Conclusion

The main ingenuity of this study is to investigate the determinants of patent survival in a systematic way utilizing rich set of data on Indian patents assigned to both domestic and MNCs during 1995 to 2005. The first outcome of this study reveals that increase in the average patent length is not only influenced by the patent characteristics but the technological and ownership characteristics are equally important. The delays in the granting process of the patent not necessarily associated with the higher renewal rate.

Other finding reveals that patents owned by DSIR affiliated firms are more likely to lapse early and therefore the survival rate is lower and the hazard rate is found to be higher. Although tax credit policy (DSIR affiliation) is beneficial for the firms, the life of the patent is not improved relative to non-DSIR firms. Geographical scope (family size) and drafting style (number of claims) have no significant impact on the firms’ patent survival rate. However, if a patent belongs to more than one IPC (4-digit) technology group the survival rate is found to be higher and hazard ratio lower. This implies that broader technological patents in India are more likely to survive. In technological categories result suggests that electrical patents and mechanical patents have a lower hazard rate and higher survival rate relative to instrument patents while chemistry and ‘other field’ patents found insignificant. The longer survival of a patent can be understood as a high-value patent. Foreign subsidiary firms in India benefit more from the government tax credit policy. The result suggests that DSIR affiliated foreign subsidiary firms’ patent hazard ratio is smaller compared to non-DSIR firms and therefore the higher survival rate is observed for such patents. One could also investigate other more flexible models like survival trees and survival random forest. The future work can be extended to all patents (residential and non-residential) in India.

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