The Performance of Licensed and Acquired Patents with Different Payment Terms: Evidence from Patent Renewal Data

Roger Svensson *

November 2007

Key words: Patents, renewal, acquisition, licensing, payment structure, variable and fixed fees, survival model.

JEL Classification: L24, O31, O34.

Abstract

How should the payment be structured when external firms acquire or license patents from individual inventors or small firms? Variable fees, such as equity sharing or royalties, provide incentives for inventor effort during the commercialization. Fixed fees provide incentives to the external firm to make investments in the commercialization process. Excluding either variable or fixed fees from the contract leads to a moral hazard problem. By including both variable and fixed fees, the incentives of the inventor and the firm become more aligned. The performance of licensed and acquired patents with different payment structures has, however, seldom been analyzed empirically. Based on a detailed database on Swedish patents, I use a survival model to estimate how the commercialization decision and the payment structure influence the patent renewal decision. I find that that commercialization substantially increases the probability of renewal, but only for patents which are (i) commercialized by the original owner or (ii) licensed/acquired using both variable and fixed fees. If the contract relies uniquely on either fixed or variable fees, the probability of renewal is as low as for patents that are not commercialized at all. The results are inconclusive, however, since the difference in renewal between acquired/licensed patents with different terms is not statistically significant.

----

* Research Institute of Industrial Economics (IFN), P.O. Box 55665, SE-10215 Stockholm, Sweden; E-mail: roger.svensson@ifn.se ; Tel: + 46 – 8 – 665 45 49; Fax: + 46 – 8 – 665 45 99.

The author would like to thank Marie Thursby, William Greene, Johan Almenberg and Erik Mellander as well as the seminar participants at the EEA annual conference in Budapest, Uddevalla Symposium and the Vaxholm Entrepreneurship workshop for constructive comments, and Jakob Eliasson for excellent research assistance. Financial support from the Torsten and Ragnar Söderberg's Foundation is gratefully acknowledged. This paper was written within the Gustaf Douglas Research Program on Entrepreneurship.

1. Introduction

Many patents originate from individuals and small firms that may lack the resources required for commercialization. Instead they may choose to let an external firm commercialize the patent – either through a licensing or through an acquisition.

A problem for the external firm that acquires or licenses the patent is that further inventor cooperation might be needed during the commercialization. Most inventions need to be adapted to market conditions before commercialization and the necessary technical knowledge might be the inventor's private information. By engaging the inventors, *ex post*, the external firm also avoids follow-up inventions from the inventors. Jensen and Thursby (2001) analyze university licensing contracts and conclude that many licensed university inventions are so embryonic that further engagement by inventors is necessary for commercial success. They report that the technology transfer offices at American universities estimate that further inventor cooperation is required for 71 percent of the licensed inventions. Here, I argue that further cooperation by the inventors is not only valid for university inventions, but for inventions in general. This argument is in line with the findings in Braunerhjelm and Svensson (2007), where it is shown that inventors play an active role in the commercialization of 87 percent of all patents originating from small firms and individuals. The activity of inventors was one of the most important determinants of successful commercialization.

Based on the requirement of further inventor cooperation, Jensen and Thursby (2001) point out that there is a moral hazard problem with regard to inventor effort when licensing contracts rely uniquely on fixed fees. For the external firm, licensing with royalty payments is therefore preferable. Royalties link the inventor's license income to the external firm's output, and hence to inventor effort. Based on a survey, Jensen and Thursby (2001) report that a vast majority of the university licensing contracts include some form of royalty payments.

The moral hazard problem also applies to acquired patents. If a patent is acquired solely on a fixed fee basis, this generates a moral hazard problem with respect to further inventor effort during the commercialization. Therefore, acquisition terms that include variables fees and licensing terms that include royalty payments are preferable. Besides the moral hazard problem, I argue that there is also an adverse selection argument that favors variable fees in the contract. Suppose that patent quality is unobservable to outsiders. An inventor might know that his patent is not good enough for commercialization, but the external firm does not. The inventor then has an incentive to sell/license the patent for a fixed fee. By contrast he has no incentive to license the patent in exchange for royalty payments, since in this case his revenues will depend on the commercial potential of the patent.

There is another parallel moral hazard problem for acquisition and licensing contracts that rely uniquely on variable fees (Dechenaux, *et al*., 2007b). Commercialization requires investment by the external firm, but the firm's true intention is private information and cannot be observed by the inventor. The licensee may "shelve" the invention for strategic reasons, for example, in an attempt to block other firms from developing the invention. The shelving may also be unintentional if the firm during development realizes that the expected profits are lower than the firm's required rate of return. By including fixed fees (upfront or annual fees) in the contract, the external firm has an incentive to commercialize the invention, and hence signals its intentions to the inventor.

Based on the moral hazard problems discussed above, one would expect acquired/licensed patents with contracts that include both variable and fixed fees to perform better *ex post* than patents with contracts that rely uniquely on either variable or fixed fees. In the former case, both inventors and the external firm have incentives to make an effort during the commercialization. Until now, this hypothesis has not been tested empirically.

The main purpose of the present study is to assess empirically whether there is a difference in the performance of acquired and licensed patents whose contracts differ with regard to the terms of payment. In principle, if contracts could be complete there would be no difference between licensing and acquisition (Tirole, 1988). Therefore, this study focuses on different payment terms, rather than on the distinction between licensing and acquisition. The performance of patents with different payment terms will also be compared to other possible commercialization modes, i.e. patents that are commercialized by the original owner either (i) in his original (existing) firm or (ii) in a new start-up firm.[1] I also test the hypothesis that the commercialization decision influences patent renewal, bearing in mind that patents might also retained for strategic

[1] Commercialization here means that the original owner of the patent has either: 1) sold the patent; 2) licensed the patent; 3) introduced a new product based on the patent on the market in his own, existing firm; or 4) introduced a new product on the market in his own, new firm. Thus, a minimum requirement is that the patent has generated some income to the owner. However, commercialization does not need to be profitable for the original owner. This definition is similar to those made in the few previous studies on the commercialization of patents; see e.g. Griliches (1990) and Morgan *et al.* (2001).

reasons. For example, patents may deter competitors from using the invention or serve as shadow patents, i.e. protecting other patents of the owner.

I use a unique data set on Swedish patents, granted to small firms and individuals, based on a survey conducted in 2003 and 2004. The survey response rate was 80 percent. The dataset includes information on *if*, *when* and *how* the patent was commercialized as well as on the payment structure (variable and/or fixed fees) of acquired and licensed patents.

The commercialization performance for the original owner of the patent is captured in the data, but there is no information on how successful the external firm was during the commercialization, following the acquisition/licensing of the patent. Instead I use the patent renewal scheme as a proxy for the commercialization success of the external firm. The model and the statistical estimations are based on the assumption that more valuable patents are renewed for longer periods. This assumption has also been made in previous patent renewal studies.[2] Patents have a statutory period of 20 years and the owner must pay an annual renewal fee every year to keep their patents in force – otherwise the patent expires for ever. If licensed/acquired patents with particular payment terms are *not* renewed 1) to the same extent as other commercialized patents; and/or 2) to a higher degree than non-commercialized ones, it would suggest that contracts with these payment terms were associated with less successful commercialization.

I use a Cox survival model to analyze the determinants of the renewal, following the acquisition or licensing of a patent. This model tests how different explanatory variables affect the probability of patents being renewed and thereby indirectly the patent values. The renewal decision is here an option to keep the patent. A methodological variant of the Cox model is applied in the present study. I take account of the fact that a patent cannot expire until it has been granted. The Cox model is therefore left-truncated.

---

[2] Most previous studies analyzing renewal of patents have estimated the value distribution of patents (Griliches, 1990; Pakes, 1986; Schankerman and Pakes, 1986). All of these studies assume that more valuable patents are renewed for longer periods than less valuable ones. Owners are assumed to only renew patents if it is economically profitable to do so. The percentage of renewed patents indicates how large a share of the patents that have an economic value after a given number of years. Schankerman and Pakes (1986) estimate both the distribution of the patent values and their rate of depreciation. They show that about half of the European patents are still being renewed after 10 years, but only 10 percent are renewed during the whole statutory period. According to Griliches (1990), most patents have low value and depreciate rapidly. Only a few patents have a very high value.

A closely related study is Dechenaux *et al.* (2007a), who look at how different factors affect the commercialization decision of licensed university inventions, using a model based on optimal stopping. They use a Hazard model to estimate the determinants of whether the licensee decides to terminate the license, commercialize the invention or delay the commercialization. They conclude that the importance of lead times induces the licensee to delay the commercialization until the licensee has developed the product. On the other hand, patent scope and learning increase the probability of commercialization. The Hazard of terminating a license decreases in the effectiveness of patent strength and secrecy. However, Dechenaux *et al.* (2007a) have no information on the payment structure of the licensing contracts. My study complements their research by relating terms of payment to the renewal of patents.[3]

There has been little previous research relating the commercialization decision to the renewal scheme, mainly due to a lack of data. In general, there are few studies that analyze any of the determinants of patent renewal. Using American patent data, Serrano (2007) finds that acquired patents have a higher probability of being renewed than non-acquired patents. A limitation of Serrano (2007) is that there is no information on whether the other non-acquired patents have been commercialized or not. Harhoff *et al.* (1999) show that German and U.S. patents that were renewed during the whole statutory period were more often cited than expired patents. The authors conclude that patents with economic value get cited more often. In the only previous study that has used a survival model to estimate how different factors influence the renewal scheme, Maurseth (2005) makes an intuitive distinction between citations across and within technology fields. Maurseth (2007) finds that patents which receive citations across fields survive longer than average, whereas patents with citations within the same field expire earlier. The interpretation is that citations across technology fields indicate a scientific breakthrough, while citations within fields indicate many competing patents.

The paper is organized as follows. The data set is described in section 2, including summary statistics. The theoretical and statistical models are outlined in section 3. In section 4, the explanatory variables are described in detail. The results from the empirical estimations are presented in section 5, and the final section concludes.

---

[3] In the present study, I do not know whether the licensee/buyer commercializes, or delays the commercialization of, the invention. Instead, I focus on whether patents are renewed or not. An expired licensed patent differs from the terminated licenses in Dechenaux *et al.* (2007a), since a licensed patent that expires could first have been commercialized and thereafter the contract might terminate.

2. Database and descriptive statistics

I use a unique data set on patents granted to small firms (less than 1000 employees) and individual inventors.[4] The data set is based on a survey of Swedish patents granted in 1998. In that year, 1082 patents were granted to Swedish small firms and individuals.[5] The sample selection is not a problem, as long as the conclusions are drawn for small firms and individuals. Information about inventors, applying firms and their addresses as well as application dates and renewal dates for each patent was bought from the Swedish Patent and Registration Office (PRV). Thereafter, a questionnaire was sent out to the inventors of the patents.[6]

In the questionnaire, I asked the inventors about the work place where the invention was created, if and when the invention had been commercialized, which kind of commercialization mode was chosen, and whether the commercialization was profitable. As many as 867 of the inventors filled in and returned the questionnaire, i.e., the response rate was 80 percent (867 out of 1082). This response rate is satisfactorily high, if taking into account that such a database has seldom been collected before and that inventors or applying firms usually consider information about inventions and patents to be secret.

In Sweden, patent owners must pay an annual renewal fee to the national patent office to keep their patents in force. If the renewal fee is not paid in any single year, the patent expires. A patent can only expire at a fixed date every year, which coincides with the application date. In 1999, the size of the renewal fees was increasing annually ranging from 200 SEK in the first year to 4,300 SEK in the last year, adding up to total of around 35 000 SEK over 20 years.[7] The Swedish renewal fees are modest in size

---

[4] All inventions do not result in patents. However, since an invention that does not result in a patent, is not registered anywhere, there are two problems in empirically analyzing the invention rather than the patent. First, it is impossible to find these ne2w ideas, products and developments among all firms and individuals. On the other hand, all patents are registered. Second, even if the inventions are found, it is difficult to judge whether they are sufficient improvements to qualify as inventions. Only the national and international patent offices make such judgements. Therefore, focusing on patents rather than all inventions is the only alternative for an empirical study of the commercialization process.

[5] In 1998, 2760 patents were granted in Sweden. 776 of these were granted to foreign firms, 902 to large Swedish firms with more than 1000 employees, and 1082 to Swedish individuals or firms with less than 1000 employees. In a pilot survey carried out in 2002, it turned out that large Swedish firms refused to provide information on individual patents. Furthermore, it proved very difficult to persuade foreign firms to fill in questionnaires about patents. These firms are almost always large multinationals firms.

[6] Each patent always has at least one inventor and often also an applying firm. The inventors or the applying firm can be the owner of the patent, but the inventors can also own the patent indirectly, via the applying firm. Sometimes, the inventors are only employed in the applying firm, which owns the patent. If the patent had more than one inventor, the questionnaire was sent to one inventor only.

[7] In 1999, the annual fees for the 20 years in ascending order were: 200, 250, 350, 550, 700, 900, 1 100, 1350, 1 600, 1 900, 2 250, 2 500, 2 700, 2 850, 3 050, 3 300, 3 550, 3 800, 4 050 and 4 300 SEK.

compared to the fees for EPO and American patents (Van Pottelsberghe de la Potterie and Francois (2006).[8]

The commercialization and renewal rates of the 867 patents by firm size are described in Table 1. 408 patents (47 percent of the sample) were granted to individuals, and 116, 201 and 142 patents were granted to medium-sized firms (101-1000 employees), small firms (11-100 employees) and micro companies (2-10 employees), respectively.[9] The commercialization rate for the whole sample is 61 percent. This rate should be compared to the few available studies which have measured commercialization of patents in other contexts: 47 percent for American patents reported by Morgan *et al.* (2001) and 55 percent in the American studies surveyed by Griliches (1990).[10] The higher commercialization rate in the present study is most likely explained by the fact that only patents owned by small firms and individual inventors are included. Large (multinational) firms tend to have many more defensive patents. Griliches (1990) confirms this view and reports that the commercialization rate is 71 percent for small firms and inventors.

In our sample, the commercialization rate for the firms ranges from 66 to 74 percent as compared to the rate of 51 percent for individual patent holders. A contingent-table test indicates a statistically significant difference between the commercialization rates of firms and individuals. The chi-square value is 30.6 (with 3 d.f.), significant at the one percent level.

The renewal rate is increasing in the firm size, rising from 44 percent for individuals to 76 percent for medium-sized firms. A contingent table test indicates a statistically significant difference between firm size categories. The chi-square value is 46.7 (with 3 d.f.), significant at the one percent level.

---

[8] According to Van Pottelsberghe and Francois (2006), the total cost for a patent which is renewed for 20 years is EUR 120 000 (40 000) in 13 (3) EPO member states, EUR 14 500 in the U.S. and EUR 17 300 in Japan. High costs include procedural costs (official costs up to the grant date) and external services that the inventor/firm needs when filing the patent. EPO patents are much more expensive due to high translation costs – the granted patent must be translated and validated in each targeted national patent office. The other reason why EPO patents are more expensive is higher annual renewal fees (which vary with the duration of the protection). The authors show that renewal fees for 20 years in the EPO system are EUR 89 000 (22 000) in 13 (3) member states, whereas this cost is considerably lower in the U.S. and Japan. However, the renewal fees in a single European country like Sweden are of modest size.

[9] The group of individual inventors includes private persons, self-employed inventors as well as two-three inventors, who are organized in trading companies or private firms without employees.

[10] These studies use a definition of commercialization that is similar to mine, i.e. that the patent has been used commercially. In Morgan *et al.* (2001) commercialization means a commercialized product or process or a licensing contract, in Griliches (1990), it means that the patent is used commercially. The commercialization does not need to be profitable for the owner in either of these studies.

[Table 1]

Table 2 shows how the patents were commercialized across firm groups. Most patents were commercialized within the firm that created the invention, hereafter called the original firm. The inventor's ownership in original firms is clearly related to firm size. The larger is the firm, the higher is the probability that the inventor is only employed and not the owner, and vice versa. In 71 cases, a new firm based on the patent was set up, while 46 patents were licensed and 19 were sold. None of the medium-sized firms used external commercialization (licensing or selling) as their first choice. The smaller the firm size, the higher the probability that the patent was sold or licensed. This result is in line with Serrano (2007), who found that individual inventors and small firms sell their patents more often than large firms do. New firms are almost exclusively started by individual inventors.

However, the patent owner can later decide to change the mode of commercialization. As shown in the lower part of Table 2, this occurs for 47 patents – most of them commercialized in the original firm. But now the pattern is quite different and external commercialization dominates, especially through selling the patent. In total, 56 patents were sold and 52 were licensed. 75 patents were commercialized in new firms, which constitute 14 percent of all commercialized patents. This is somewhat higher than for American patents, for which around 10 percent of all patents are commercialized in new firms (AUTM, 1998).

[Table 2]

There is some basic information on the payment structure of acquired and licensed patents, as shown in Table 3. An overwhelming majority of the acquired patents included only a fixed fee: of 56 acquired patents, 48 included only fixed fees, while the remaining eight involved both fixed and variable fees.[11] By contrast, all licensing contracts included variable fees: of the 52 licensing contracts, 30 included both royalty payments linked to the turnover of the licensee and fixed fees (upfront or annual fees), while the remaining 22 licensing contracts included only royalty payments.

[11] Payment in the form of equity is only considered as a variable payment if the shares are locked in. If the inventor can sell the shares, immediately uupon acquisition, it is considered a fixed payment.

[Table 3]

Jensen and Thursby (2001) show that further inventor cooperation was needed for 71 percent of all licensed university patents in their sample. In our questionnaire, we did not ask the inventors if inventor cooperation was necessary during commercialization. We did ask, however, if the inventor played an active role during the commercialization. Among the 530 commercialized patents in our sample, 87 percent of the inventors had participated actively during the commercialization. This suggests that inventor collaboration is frequently required during the commercialization process of "industry" patents too.

Table 4 compares commercialized patents and renewed patents. As expected, renewed patents (71 percent) have been commercialized to a higher degree than expired ones (48 percent). The chi-square test statistic reported at the bottom of the table shows that we can clearly reject independence of commercialization and renewal. However, 35 percent of the patents have been commercialized, but have already expired. This is either due to the products having a short lifecycle or the commercialization having failed. 42 percent of the non-commercialized patents are still alive. Many of these patents might be defensive patents, with the purpose of defending other patents, but then the owner should have more similar granted patents. Among the commercialized patents in our database, 46 percent of the owners have at least one more similar patent. Among the non-commercialized patents, this percentage is only 33 percent. If the patent had not been commercialized, the inventor was also asked: why the patent had not been commercialized. Among the 341 non-commercialized patents, only 15 inventors listed shadow-patenting as one of the reasons for why the patent had not been commercialized.[12] Thus, I conclude that keeping patents for strategic reasons is not common among individuals and small firms. This strategy is more frequent among large multinational firms.

[Table 4]

[12] The most frequent reasons here were: 1) problems with financing (115 patents); 2) problems with marketing (75 patents); 3) problems in finding a manufacturing firm/licensor (74 patents); and 4) the product is not yet ready for commercialization (62 patents). Note that inventors may have mentioned more than one reason for why the patent was not commercialized.

Table 5 shows the renewal scheme across modes of commercialization. For each mode, the numbers of patents that were still alive in 2004, had expired or had changed mode are shown. As many as 43 percent of the acquired patents had expired compared to 35 percent for licensed patents and 30-34 percent for patents commercialized in original or new firms. By looking more closely at the *expired* patents, it turns out that acquired patents survive on average less than three years after they have been acquired. The other groups of patents survive around four years after they have been commercialized. Thus, acquired patents are renewed to a lower degree, and for a shorter time, than patents associated with other modes of commercialization. In the lower part of Table 5, acquired/licensed patents with contracts relying on both variable fees are compared to those relying on either variable or fixed fees. The latter group of patents expires to a much higher degree (48 percent) and survive for a shorter time (3.2 years), given that they expire, compared to those with both variable and fixed fees (28 percent and 3.7 years). This result is in line with the hypothesis that moral hazard problems with regard to commercialization effort arise if either variable or fixed fees are excluded from the acquisition/licensing contract.[13]

[Table 5]

3. Theoretical and statistical models

3.1 Theoretical model

The model described here follows Schankerman (1998). Since Swedish patents can only expire at fixed annual dates, I use discrete time.[14] The patent owner must pay an annual renewal fee, C_{aj}, to keep the patent in force. This fee varies with age a and cohort j of the patent.[15] The patent owner who pays the renewal fee earns the current implicit return to patent protection during the coming year, R_{aj}. It is assumed that the pattern of R_{aj} is known with certainty when the patent is applied for. If the owner does not pay the fee, the patent expires permanently and the return is equal to zero thereafter. The owner's decision problem is then to maximize the discounted value of net returns by choosing

[13] There are of course other factors influencing the renewal decision that are not accounting for in this analysis.
[14] Maurseth (2005) uses a model with continuous time, similar to that with discrete time.
[15] All patents applied for in the same year belong to the same cohort.

the age at which to stop paying the renewal fee. Therefore, the owner chooses a lifetime, T, in order to solve the problem:

$$V(T) = \max_{T \leq M} \sum_{a=1}^{T} r^{a} (R_{aj} - C_{aj}) \quad , \tag{1}$$

where V is the value of patent protection given the optimal renewal decision, r is the discount rate and M is the statutory limit of patent protection (20 years). Provided that the path of net revenues ($R_{aj} - C_{aj}$) is non-increasing in age, the optimal rule for the owner is to renew the patent as long as the revenues cover the renewal costs, i.e. as long as $R_{aj} \geq C_{aj}$.[16] When the net returns become negative, the owner should stop payment. If no such time point exists, the patent should be kept for the maximum life span (T=M). Thus, the renewal decision is an optimal stopping problem and the patents can be seen as options. The initial returns in a given cohort, R_{0j}, are allowed to vary across patents, but they decay by the same rate, δ_{aj}. If all patents in a cohort had the same initial returns and path of revenues, they would expire at the same age. If $R_{aj} = R_{0j}e^{x\beta}\prod^{a}_{t=1}d_{tj}$ and $d_{tj} = (1 - \delta_{tj})$, the condition for renewal of patent i at age a can be written:

$$R_{i0j} \geq C_{aj} \; e^{-x_i\beta} \prod_{t=1}^{a} d_{tj}^{-1} \quad , \tag{2}$$

where $\mathbf{x}$ is a vector of patent-specific explanatory variables and $\boldsymbol{\beta}$ is a vector of parameters. Let $g(R_{0j}; \boldsymbol{\theta})$ and $G(R_{0j}; \boldsymbol{\theta})$ be the density and cumulative distribution functions of initial returns, where $\boldsymbol{\theta}$ is a vector of parameters. The proportion of patents in cohort j renewed at age a is:

$$P_{aj} = \int_{z_{aj}}^{\infty} g(R_{0j};\theta)\, dg = 1 - G(z_{aj};\theta) \quad , \tag{3}$$

where $z_{aj} = C_{aj}e^{-x\beta}\prod^{a}_{t=1}d_{tj}^{-1}$. Given a functional form of R_0, equation 3 provides the basis for the relationship between patent renewal and the unknown parameters. Since P_{aj} is a function of t, equation (3) is in fact the survival function of patents, $S(t)$, which shows the probability of a patent surviving beyond time point t. The cumulative distribution function of patent duration is given by $F(t) = 1 - S(t)$.

[16] The renewal fees are non-decreasing in age. A sufficient condition for the net revenues to be non-increasing in age is that the path of revenues, R_{aj}, is non-increasing in age.

One objection against the model is that R_{aj}, the net return from a patent, is uncertain. There may also be an uncertainty about the market conditions, which might affect the renewal decision. These uncertainties are discussed by Maurseth (2005), but have neither been applied in the previous studies that rely on semi-parametric or parametric models nor in the present study.

3.2 Statistical model

Since the analysis focuses on an event to occur, survival (duration) analysis is used in the statistical estimations. The event in question is the decision to let the patent expire, and it is also measured when this occurs. Firstly, I estimate a survival distribution function and a hazard function. The survival function, *S(t)* in equation 1, shows how a large share of the patents survive beyond a time point, *t*. The hazard function, *h(t)* in equation 2, shows the conditional probability of a patent expiring in a specific time period Δt, given that it has been renewed until time point *t*. The hazard can also be expressed as a function of the probability density function, *f(t)*, and the survival function:

$$S(t) = \Pr(T > t) = 1 - F(t) \quad , \tag{4}$$

$$h(t) = \frac{f(t)}{S(t)} = \lim_{\Delta t \to 0} \frac{\Pr(t \le T < t + \Delta t \mid T \ge t)}{\Delta t} \quad . \tag{5}$$

In the main empirical analysis, I estimate how different explanatory factors affect the decision to let the patents expire. The dependent variable, t_i, is a random variable showing how many years it takes until patent *i* expires, measured from the time point of patent application.[17] Patents that have not yet expired in 2004 – the end point of observation – are "right-censored" (480 observations). The other 387 patents have expired in 2004 at the latest. Given this, the appropriate statistical model is the Cox (1972) proportional hazard model:

$$\log h_i(t) = \log \lambda_0(t) + x_{i1}\beta + x_{i2}(t)\gamma \quad , \tag{6}$$

[17] The application year is the standard starting time point to use. Information on the application year is directly available from the Swedish National Patent Office (PRV).

where log $\lambda_0(t)$ is a baseline hazard function, **β** and **γ** are vectors of parameters to be estimated, $\mathbf{x_1}$ is a vector of time independent explanatory variables, and $\mathbf{x_2(t)}$ is a vector of time dependent explanatory variables. The measurement of number of years is an exact measure, since the owner must pay a renewal fee the same date every year as the patent was applied for. Therefore, I use a discrete approximation of the Cox model, to account for the fact that two or more events may occur at the same point in time (Allison, 1995).

A patent cannot expire until it has been granted, and is therefore not in the risk set before this time point. If the owner had not paid the renewal fee for an applied patent before the patent was granted, the invention would neither have been granted a patent nor have been included in the data set. Therefore, I remove the patent from the risk set between the origin (application date) and the time point for granting patents. This procedure is called left truncation.[18] This is an important methodological extension over previous studies, which have not taken this into account.[19]

The largest advantage with the Cox model compared to the alternative statistical model, the accelerated failure time model, is that time dependent explanatory variables can be included in the estimations. In the present study, the time point of commercialization of the patent will be included. Another advantage of the Cox model is that there is no need to choose between different residual distributions. Thus, the baseline hazard function, log $\lambda_0(t)$, can be left unspecified. Finally, the Cox model makes it possible to interpret the quantitative effects in terms of how an increase in the explanatory variable affects the hazard.

Maurseth (2005) also estimates a log-likelihood model to test how the explanatory variables influence the expected survival time (see equations 12-13 and Table V in Maurseth, 2005).[20] This type of parametric model is not able, however, to handle time-dependent explanatory variables. Since time-dependent variables are

---

[18] This is accomplished by defining a time-dependent covariate whose values are missing at times when the patent is not in the risk set. In practice, this means that patents, which have a grant date before the renewal (application) date in 1998, will get a starting year of 1997 (the first possible year of expiration is then 1998). If the renewal date occurs before the grant date in 1998, the starting year is 1998 (the first possible year of expiration is then 1999).

[19] Using the grant year as the starting year in the model is not appropriate, since some of the time-dependent explanatory variables (in particular, those associated with the commercialization decision) change values between the application and the grant dates.

[20] First, Maurseth (2005) estimates the decay rate, as well as the mean and the standard deviation of patent returns, R_{aj} in order to estimate the distribution of patent values. This is similar to previous studies in this area (see, e.g. Schankerman, 1998). The estimated parameters are then used to estimate how explanatory variables influence the time it takes until patents expire.

essential in the present model, I cannot estimate the model used in Maurseth (2005). It is also out of the scope of the present paper to estimate a distribution of patent values, along the same lines as e.g. Schankerman (1998), which I instead accomplish in a separate study.

4. Explanatory variables

4.1 Main variables

The explanatory variables consist of factors that are expected to affect, or to be correlated with, the probability that the patent will be renewed or expire. Patents that are commercialized or used for defensive purposes are expected to survive for longer periods.[21] Table 6 reports basic statistics for the explanatory factors. Hypotheses are shown for the main variables only. A positive (negative) expected parameter estimate means that the hazard rate of letting the patent expire increases (decreases), when the explanatory variable obtains a higher value.

[Table 6]

The most obvious explanatory variable is whether the patent is commercialized or not. This factor, and related factors, e.g., the commercialization mode (licensing, new company, acquiring the patent, etc.) can only be included as time-dependent covariates. The commercialization decision is represented by an additive dummy, *COM*, which takes on the value of 1 once the commercialization has started, and 0 otherwise. The expected impact on the hazard is negative.

Alternatively, the commercialization mode can be used instead of *COM*. There are four different commercialization modes in the data: acquisition, licensing, commercialization of the patent in the original firm or commercialization of the patent in a new firm. These are represented by the four time-dependent additive dummies *ACQ*, *LIC*, *COMORIG* and *COMNEW*. These dummies equal 1 at that time point when the associated commercialization mode starts and keep this value as long as the mode is present and 0 otherwise. If the mode of commercialization changes, which occurs in 47 cases (see Table 2), the dummy variables also change values. In each case, the

[21] Commercialization and defensive purposes are the two main reasons why inventors choose to patent their inventions at all (Griliches, 1990).

commercialization mode is expected to have a negative impact on the hazard of letting the patent expire. I also estimate a similar model in which acquired and licensed patents are merged into one time-dependent dummy, *AL*, which substitutes for *ACQ* and *LIC*.

Since the focus of this study is on the structure of payment terms (variable and fixed fees) for acquired and licensed patents, I also explore another definition of the commercialization modes. *ALVandF* is a time-dependent dummy that equals 1 at the time point when the licensing/acquisition contract including both variable and fixed fees starts and it keeps this value as long as the mode is present and 0 otherwise. Similarly, *ALVorF* is a time-dependent dummy for licensing/acquisition contracts with either variable or fixed fees. *ALVandF* and *ALVorF* substitute for *LIC* and *ACQ*. In line with the discussion above, I predict that *ALVandF* has a more negative impact on the Hazard than *ALVorF*, since the former group of contracts provides incentives to both inventors and the external firm to make an effort during the commercialization.

I also test the performance of patents with contracts relying uniquely on variable or fixed fees, in order to find out if it is the lack of variable or fixed fees which cause moral hazard problems with respect to inventor or firm effort. *ALonlyV* is a time dependent dummy which equals 1 at the time point when the licensing/acquisition contract including only variable fees starts and keep this value as long as the contract is in force and 0 otherwise. Similarly, the time dependent dummy *ALonlyV* takes on the value of 1 for contracts with only fixed fees. *ALonlyV* and *ALonlyF* substitute for *ALVorF*. I predict that *ALVandF* has a more negative impact on the Hazard than both *ALonlyV* and *ALonlyF*.

Keeping a patent for defensive purposes is the second main explanatory factor for the renewal decision, besides commercialization. If the patent is not commercialized but kept as a shadow patent to protect other closely related patents, the additive dummy *SHADOW* equals 1 and 0 otherwise. The expected impact on the hazard is negative. The fact that only non-commercialized patents can take on the value of 1 for *SHADOW* is important for the interpretation of the parameter estimates for this variable as well as the commercialization variables. The parameter estimate for *SHADOW* will show the difference as compared to other non-commercialized patents, since a patent cannot take on the value of 1 for both *SHADOW* and *COM*. By the same reason, the commercialization variables show the difference as compared to non-commercialized patents, which are not shadow-patents.

4.2 Control variables

The included control variables might be correlated with the renewal scheme. Firms and individuals have different resources for renewing their patents, so I include additive dummies for different firm sizes. *FIRM1* is a dummy that takes on the value of 1 for medium-sized firms with 101-1000 employees and 0 otherwise. *FIRM2* equals 1 for small firms with 11-100 employees and 0 otherwise. Finally, *FIRM3* is a third dummy variable taking the value of 1 for micro companies with 2-10 employees and 0 otherwise. The firm group dummies relate here to the reference group of the individual inventors.

The additive dummy *UNIV* equals 1 for university patents and 0 otherwise. *MOREPAT* is an additive dummy, which equals 1 if the inventors or the applying firm have other competitive patents in the same technology area and 0 otherwise. The dummy *COMPL* takes on the value of 1 if complementary patents are needed for commercialization and 0 otherwise. The variable *INVNMBR* measures the number of inventors of the patent. Some specific characteristics of the inventors are also included in the mode. *SEX* measures the share of inventors who are female. *ETH* measures the share of inventors who belong to ethnic minorities, i.e. immigrants from other countries than Western Europe.

Different technologies are likely to be associated with different risks. Consequently, the type of technology can affect the conditional probability of a patent expiring. Patents are divided into 30 technology categories according to Breschi *et al.* (2004). These groups are based on the patents' main IPC-Class.[22] The data is divided into six different kinds of regions according to NUTEK (1998): Large-city regions, university regions, regions with important primary city centers, regions with secondary city centers, small regions with private employment, and small regions with government employment. Five additive dummies are included in the estimations for these six groups. Additive dummies are also included for different application periods, to control for economic chocks that may affect all patents in a given year. The data has five

[22] All technology categories are not represented in the data set and some categories do not have enough observations. Therefore, only 26 categories and 25 additive dummies are used in the present study The technology classes without enough observations are instead merged with other closely related classes (Breschi *et al.*, 2004).

application year periods (1985-90, 1991-92, 1993-94, 1995-96 and 1997-98) and four additive dummies are assigned for these periods.[23]

5. Empirical estimations

5.1 Survival functions

Figure 1 shows the survival and hazard functions for the whole sample of patents as estimated by the Life-table method (actuarial method). The patent application year is set to 0. The survival function for the whole sample does not decline from the outset, since a patent cannot expire until it has been granted, but starts to fall after 2-3 years. The corresponding hazard function is the highest around 4-11 years after the application.[24]

[Figure 1]

Since patents are not at risk of expiring until they have been granted, a more accurate estimation of the survival and hazard functions is shown in Figure 2. The starting year is set to either 1997 or 1998, depending on whether the grant date occurs before or after the annual renewal (application) date.[25] Year 1 is the first possible year when the patent can expire. In Figure 2, the survival function is declining from the outset and declines more steeply for each year. The corresponding hazard function has an increasing trend.[26] It would have been interesting to estimate the survival and hazard functions for acquired and licensed patents with different payment terms, but such estimation cannot be done for time-dependent variables. Instead, I rely on the Cox model here.

[Figure 2]

---

[23] Time dummies for individual application years were also used, but within this specification one of the models failed to converge. Instead, I used time dummies for two-year periods. The usage of two-year periods does not alter the results for the other estimated parameters. Note that only one patent was applied for in 1985 and in 1986, respectively, and no patents were applied for during the 1987-89 period. Therefore, 1985, 1986 and 1990 have been merged into one group.

[24] About ten years after the application year, the survival and hazard functions are less reliable, because patents renewed in 2004 are right-censored.

[25] Left-truncation is not possible when using the Life-table method.

[26] The survival and hazard functions are less reliable for the seventh year, since there is no year seven for those patents with a starting year of 1998.

5.2 Cox proportional hazard estimations

The results of the Cox survival model estimations are shown in Tables 7 and 8. In order to test for robustness, several model specifications are estimated. In Model I, *COM* is the only included commercialization variable. In Models II and III, the different modes of commercialization substitute for *COM*. In Model IV, acquired and licensed patents are divided into two groups: those with both variable and fixed fees and those with either variable or fixed fees. In Model V, a similar comparison is made between acquired/licensed patents with both variable and fixed fees, with only variable fees and with only fixed fees. Several variants of Models IV and V are estimated – using different combinations of region and technology dummies. I also attempted to include including additive dummies for unique owners (firms/inventors) in the estimations, but this did not work out well due to multicollinearity problems.[27]

********** [Table 7] **********

Table 7 shows that the parameter estimate of *COM* in Model I is negative as expected and highly significant. The size interpretation of the parameter estimate is that the hazard of expiration decreases by 48 percent for commercialized patents as compared to non-commercialized ones (excluding shadow-patents). As expected, patents used for pure defensive purposes, *SHADOW*, also have a significantly negative impact. The hazard decreases by more than 70 percent for shadow patents as compared to other non-commercialized patents (in Models I-V). Thus, there is an even stronger impact than for commercialized patents. It should be remembered, however, that many more patents are commercialized than used as shadow patents in this data set.

The main variables in the model are those measuring modes of commercialization. In Model II, all modes of commercialization have a significant and negative impact on the hazard. However, when acquired and licensed patents are separated in Model III, only *LIC*, *COMORIG* and *COMNEW* have a negative and significant impact on the Hazard. Thus, licensed patents and those commercialized by

[27] Among the 867 patents in the sample, there are 740 unique owners (firms/inventors). 663 owners have only one commercialized patent in 1998, 54 owners have two patents, and only 23 owners have at least three patents. Dummies can only be assigned to the 54 owners with at least 2 patents. However, when including dummies for unique owners, the models were characterized by severe multicollinearity problems with very large standard errors for the owner dummies. These problems occurred even when all technology and region dummies were excluded and when dummies were included only for those 23 owners with at least three commercialized patents.

the original owner survive for longer periods than non-commercialized patents, excluding shadow-patents. The size interpretation of the significant parameters (Model III) is that the hazard of patent expiration decreases by 52, 48 and 57 percent for patents that are licensed and commercialized in original and new firms, respectively, as compared to non-commercialized patents (excluding shadow-patents). The estimated parameter of *ACQ* is not significant. Thus, acquired patents do not survive longer than non-commercialized patents. However, the results are inconclusive in the sense that the difference between the parameters of *ACQ* and *LIC* is not significant. The results for acquired and licensed patents might depend on that licensed and acquired patents have different contract terms (see Table 3).[28] As discussed above, there should be no major difference between acquiring and licensing a patent, if the licensing contract is written over a sufficiently long time period. Therefore, I will look closer at the payment terms in the contracts.

5.3 Variable and fixed fees

In Model IV (Table 8), acquired/licensed patents with both variable and fixed fees (*ALVandF*) are compared to those with either variable or fixed fees (*ALVorF*). As expected, *ALVandF* has a negative and significant impact on the hazard. Combining variable and fixed fees provides incentives for both inventors and the external firm to exert effort during the commercialization process. The hazard of expiration decreases by around 61 percent for *ALVandF* compared to non-commercialized patents (Model IV-c) *ALVorF* does not have any significant effect whatsoever. This suggest that patents whose contacts include variable and fixed fees have better chances of renewal, and ultimately on commercial success. Although the difference in the point estimates of *ALVandF* and *ALVorF* is relatively large (large, for example, than the difference between *COMORIG* and non-commercialized patents), the difference is only significant at the 10-percent level in one run (Model IV-a).[29] Thus, there is no conclusive evidence that it is better to include both variable *and* fixed fees, rather than either variable fees or fixed fees, in the contracts.

[28] The result that acquired patents do not survive longer than non-commercialized ones differs from the finding in Serrano (2007), who found that acquired patents survive longer than other patents. However, Serrano (2007) only includes acquisitions which have been reported to the American national patent office, whereas we asked the original patent owners directly about acquisitions in the present study. In Sweden the old or new owners of a patent are not obliged to report the ownership transfer to the Swedish National Patent Office.

[29] It is likely that this lack of statistical significance is due to the small sample size. *ALVandF* and *ALVorF* contain 38 and 70 observations, respectively.

Similar Cox estimations, in which acquired/licensed patents with only variable fees (*ALonlyV*) and acquired/licensed patents with only fixed fees (*ALonlyF*) are substituted for (*ALVorF*), are shown in Model V (Table 8). Neither *ALonlyV* nor *ALonlyF* have any statistically significant impact on the hazard. Furthermore, the differences between their parameter estimates and the parameter estimate of *ALVandF* are not statistically significant.

********** [Table 8] **********

5.4 Other explanatory variables

Turning to the other explanatory variables, all firm size dummies have a negative and significant impact on the hazard. The larger is the firm, the lower is the probability that patents expire. If the patent is owned by a medium-sized firm (*FIRM1*), a small firm (*FIRM2*) or a micro company (*FIRM3*) as compared to ownership by an individual, the hazard that the patent expires decreases by around 77, 56 and 40 percent, respectively (Model IV-c). This finding is not surprising, since large firms have more resources and capabilities to exploit their patents and also may be able to make better judgements about when it is profitable to patent at all.

The only other significant variable is *OWNER*, which also reduces the probability of patent expiration. If the inventor's ownership of the patent increases by 1 percent, the Hazard decreases by 0.5 percent. This result raises the question of whether it is good or bad that inventors own their patents for long time periods. One could imagine, for example, a psychological bias on behalf of inventors, such that external firms have an easier time letting the patent expire, whereas inventors cling to the hope that they have come up with an important invention. *MOREPAT* measures if the owner has more similar patents and would be some indication of whether patents are used for defensive purposes, but it may also show that the owner is experienced. This variable has a negative impact, but is only significant if *SHADOW* is excluded, indicating that these two variables partly measure the same thing.

5.5, Endogenity, causality and multicollinearity

An objection against the model specification would be that the decisions of renewal, commercialization and using the patent for defensive purposes are taken by the owner. Thus, the decision of commercialization or using the patent for defensive purposes would be endogenously determined by other factors in the model. However, there is not a simultaneous relationship between commercialization and renewal decisions. Commercialization clearly determines the renewal decision. The former decision is made before the latter, and the main reason why inventors patent their inventions at all is to protect a product in the market or deter competitors from using the invention (Griliches, 1990). Thus there is a causal relationship. However, Svensson (2007) shows that the commercialization decision is correlated with other explanatory factors in the model, for example, the firm size variables and whether the owner has more similar patents (*MOREPAT*). But these relationships should rather be seen as correlations. It seems unlikely that the firm size is the reason why the patent was commercialized or not. In this case, there might be multicollinearity between the explanatory variables. I test for multicollinearity by alternatively excluding variables that were correlated with the commercialization decision in Svensson (2007). In Table 9, some explanatory variables are alternatively excluded for Model V-c. The parameter estimates for the variables associated with commercialization and payment structure are not affected by these exclusions.[30] On the basis of this, I conclude that multicollinearity is not a cause of concern.[31]

********** [Table 9] **********

6. Concluding remarks

In this study, I have used patent renewal data to analyze the performance of licensed and acquired patents originating from individual inventors and small firms. I have focused on the payment structure of the contract between the inventor and the external firm, linking this to inventor and firm effort during the commercialization process. Previous theoretical studies have pointed to a moral hazard problem with respect to inventor effort when a licensing/acquisition contract only includes a fixed fee. I argue that there is also an adverse selection problem with acquired/licensed patents that only have a fixed fee. Equity sharing or a licensing contract with royalty payments should therefore be preferable. Furthermore, it can be argued that there is also a moral hazard problem

[30] The firm size dummies and the ownership variable are clearly correlated, as was seen in Table 2. By excluding *OWNER*, the parameter estimates of the firm size dummies are affected, and vice versa.

[31] An alternative statistical procedure would be to estimate instruments for the commercialization variables using a survival function, and then insert these instruments in the main Cox equation. However this would imply an instrument variable technique involving two survival functions. According to William Greene, such a two step method does not exist yet.

with respect to the effort of the external firm to undertake further investments during the commercialization if there are only variable fees and no fixed fees in the contract. On the basis of all this, I have put forward the hypothesis that acquired/licensed patents which include both variable and fixed fees should on average survive longer than those relying uniquely on either variable or fixed fees.

The empirical results are broadly in line with my expectations. On the one hand, acquired and licensed patents which include both variable and fixed fees – as well as those commercialized by the original owner in existing or new firms – are renewed for longer periods than non-commercialized ones. On the other hand, acquired/licensed patents with either variable or fixed fees do not survive longer than non-commercialized ones. This is in line with the view that there is a moral hazard and/or an adverse selection problem. These result, however, are inconclusive. The difference in the survival scheme between acquired/licensed patents with both variable and fixed fees and with either variable or fixed fees is not statistically significant.[32] The results are robust to a number of specifications, including looking at contracts uniquely relying on variable or fixed fees separately.

The findings presented in this study are not sufficiently conclusive to warrant a strong recommendation that both variable and fixed fees always be included in the licensing/acquisition contract, although the results point in this direction. However, external firms should be careful with acquisitions/licensing contracts, which only include fixed fees, and inventors should be careful with contracts which only include variable fees as a rule of thumb, since: 1) theoretically, both moral hazard and adverse selection problems are to be expected for patent contracts with only fixed fees; 2) contracts with only variable fees provide no incentive to the external firm to undertake further investments; and 3) empirically, acquired/licensed patents with either variable or fixed fees do not survive longer than non-commercialized ones.

A further conclusion is that commercialization is closely linked to the renewal decision. The hazard rate decreases by as much as 48 percent when patents are commercialized. To the best of my knowledge, this is the first time that the commercialization decision is related to the renewal decision for patents empirically. Moreover, pure shadow patents, which protect other patents, reduce the hazard rate of patent expiration by more than 70 percent as compared to other non-commercialized

[32] This might be due to the limited data set.

patents. However, there is only a small number of shadow patents in the sample. This suggests that commercialization rather than defensive strategies matters the most for patent renewal, at least among small firms and individual inventors.

References

Allison, P.D., 1995, *Survival Analysis Using SAS – A Practical Guide*, SAS Institute Inc., Cary, NC.

Association of University Technology Managers, 1998, *AUTM Licensing Survey*, Association of Technology Managers, Norwalk, CT.

Braunerhjelm, P. and R. Svensson, 2007, ‘The Inventor’s Role: Was Schumpeter Right?’, Working paper No. 690, Research Institute of Industrial Economics, Stockholm.

Breschi, S., F. Lissoni and F. Malerba, 2004, ‘The Empirical Assessment of Firms’ Technological Coherence: Data and Methodology’, in *The Economics and Management of Technological Diversification*, J. Cantwell, A. Gambardella and O. Granstrand (eds.), Routledge, London.

Cox, D.R., 1972, ‘Regression Models and Life Tables’, *Journal of Royal Statistical Society*, B34, pp. 187-220.

Dechenaux, E., B. Goldfarb, S. Shane and M. Thursby, 2007a, “Appropriability and Commercialization: Evidence from MIT Inventions”, *Management Science*, forthcoming.

Dechenaux, E., M. Thursby and J, Thursby, 2007b, ‘Shirking, Sharing Risk and Shelving: The Role of University License Contracts’, Discussion paper, Ken State University.

Griliches, Z., 1990, ‘Patent Statistics as Economic Indicators: A Survey’, *Journal of Economic Literature*, Vol. 28, pp. 1661-1707.

Harhoff, D., F. Narin, F.M. Scherer and K. Vopel, 1999, ‘Citation Frequency and the Value of Patented Citations’, *Review of Economics and Statistics*, Vol. 81, pp. 511-15.

Jaffe, A. and J. Lerner, 2001, ‘Reinventing Public R&D: Patent Policy and the Commercialization of National Laboratory Technologies’, *RAND Journal of Economics*, Vol. 32, pp. 167-98.

Jensen, R. and M. Thursby, 2001, ’Proofs and Prototypes for Sale: The Licensing of University Inventions’, *American Economic Review*, Vol. 91, pp. 240-59.

Maurseth, P.B., 2005, ‘Lovely but Dangerous: The Impact of Patent Citations on Patent Renewal’, *Economics of Innovation and New Technology*, Vol. 14, pp. 351-74.

Morgan, R.P., C. Kruytbosch and N. Kannankutty, 2001, ‘Patenting and Invention Activity of U.S. Scientists and Engineers in the Academic Sector: Comparisons with Industry’, *Journal of Technology Transfer*, Vol. 26, pp. 173-83.

NUTEK, 1998, *Småföretag och regioner i Sverige 1998 – Med ett tillväxtperspektiv för hela landet*, B1998:10, NUTEK, Stockholm.

Pakes, A., 1986, ‘Patents as Options: Some Estimates of the Value of Holding European Patent Stocks’, *Econometrica*, Vol. 54, pp. 755-84.

Schankerman, M., 1998, ‘How Valuable is Patent Protection? Estimates by Technology Field’, *RAND Journal of Economics*, Vol. 29 (1), pp. 77-107.

Schankerman, M. and A. Pakes, 1986, ‘Estimates of the Value of Patent Rights in European Countries during the Post-1950 Period’, *Economic Journal*, Vol. 96, pp. 1052-76.

Serrano, C.J., 2007, ‘The Dynamics of the Transfer and Renewal of Patents’, Discussion paper, University of Toronto and NBER.

Svensson, R., 2007, ‘Commercialization of Patents and External Financing during the R&D-Phase’, *Research Policy*, forthcoming.

Tirole, J.,1988, *The Theory of Industrial Organization*, MIT Press, Cambridge, MA:

Van Pottelsberghe de la Potterie, B. and D. Francois, 2006, ’The Cost Factor in Patent Systems’, CEPR Discussion paper No. 5944, CEPR, London.

Figure 1. Survival and hazard functions for renewal of patents. Years after application

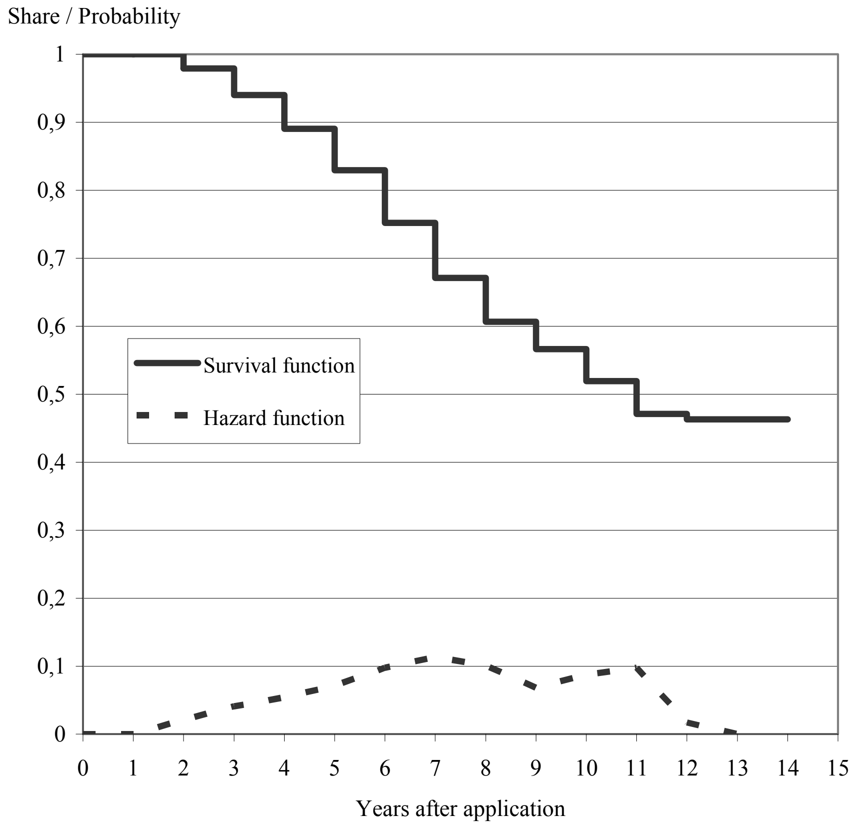

Figure 2. Survival and hazard functions for the renewal of patents. Years after granting

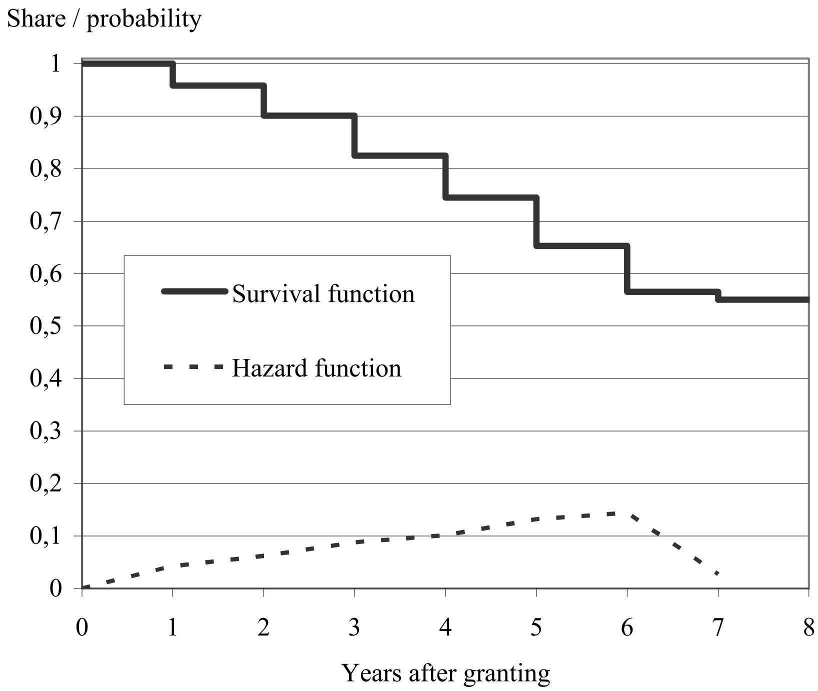

Table 1. Commercialization and renewal of patents across firm sizes, number of patents and percent.

Kind of firm where invention was created	Total number of patents	Percent latest commercialized in 2003	Percent renewed in 2004
Medium-sized firms (101-1000 employees)	116	66 %	76 %
Small firms (11-100 employees)	201	68 %	63 %
Close companies (2-10 employees)	142	74 %	61 %
Individuals (1-4 inventors)	408	51 %	44 %
Total	**867**	**61 %**	**56 %**

Table 2. Commercialization mode across firm types, number of patents.

Kind of firm where the invention was created	Commercialization mode – first choice					Total
	Acquired	Licensing	Existing firm employed	Existing firm owner	New firm	
Medium-sized firms	0	0	73	4	0	77
Small firms	2	2	67	66	0	137
Micro companies	4	7	16	77	1	105
Inventors	13	37	2	85	70	211
Total	19	46	158	232	71	526

Kind of firm where the invention was created	Commercialization mode – second choice					Total
	Acquired	Licensing	Existing firm employed	Existing firm owner	New firm	
Medium-sized firms	4	0	0	0	1	5
Small firms	8	0	0	0	1	9
Micro companies	5	6	0	0	2	13
Inventors	20	0	0	0	0	20
Total	37	6	0	0	4	47

Table 3. Payment structure of acquired and licensed patents, number of patents.

	Only fixed fees	Fixed and variable fees	Only variable fees	Total
Acquired	48	8	0	56
Licensed	0	30	22	52
Total	48	38	22	108

Table 4. Commercialized patents and patents still alive in 2004, number of patents and percent.

Patents still alive in 2004	Patents latest commercialized in 2003			Percent Commercialized
	Yes	No	Total	
Yes	340	142	482	71 %
No	186	199	385	48 %
Total	526	341	867	61 %
Percent still alive	65 %	42 %	56 %	

Note: Chi-square-value is 44.32, significant at the 1 percent level for 1 d.f.

Table 5. Renewal of patents across modes of commercialization, number of patents, percent and years.

Mode	Changed mode	Still alive in 2004	Expired	Total	% expired	Years until expired [a]
Acquired patents	0	32	24	56	43 %	2.8
Licensed patents	6	28	18	52	35 %	3.9
Existing firm, employed	9	102	47	158	30 %	5.6
Existing firm, owner	28	133	71	232	31 %	5.3
New firm	4	45	26	75	35 %	4.3
Acquired/licensed patents						
with variable *and* fixed fees	4	24	10	38	26 %	3.7
with variable *or* fixed fees	2	36	32	70	46 %	3.2
with only fixed fees	0	27	21	48	44 %	2.9
with only variable fees	2	9	11	22	50 %	3.7

[a] Measured from the date of commercialization and given that the patent has expired.

Table 6. Descriptive statistics and hypotheses for the explanatory variables.

Denotation	Description	Mean	St.dev.	Expected impact on hazard
COM	Time-dependent dummy that equals 1 when the patent is commercialized and 0 otherwise.	0.61	0.49	-
AL	Time-dependent dummy that equals 1 when the patent is acquired or licensed, and 0 otherwise.	0.12	0.32	-
ACQ	Time-dependent dummy that equals 1 when the patent is acquired, and 0 otherwise.	0.06	0.25	-
LIC	Time-dependent dummy that equals 1 when the patent is licensed, and 0 otherwise.	0.06	0.24	-
COMEXIST	Time-dependent dummy that equals 1 when the patent is commercialized in the existing (original) firm and 0 otherwise.	0.45	0.50	-
COMNEW	Time-dependent dummy that equals 1 when the patent is commercialized in a new firm and 0 otherwise.	0.09	0.28	-
ALVandF	Time-dependent dummy that equals 1 when the patent is acquired / licensed *and* includes both variable and fixed fees, and 0 otherwise.	0.04	0.20	-
ALVorF	Time-dependent dummy that equals 1 when the patent is acquired / licensed *and* includes either variable or fixed fees, and 0 otherwise.	0.08	0.27	?
ALonlyV	Time-dependent dummy that equals 1 when the patent is acquired / licensed and includes only variable fees, and 0 otherwise.	0.03	0.16	?
ALonlyF	Time-dependent dummy that equals 1 when the patent is acquired / licensed and includes only fixed fees, and 0 otherwise.	0.06	0.23	?
SHADOW	Dummy that equals 1 if the patent is a pure shadow patent and 0 otherwise	0.02	0.13	-
Control variables				
FIRM1	Dummy taking the value of 1 for medium-sized firms (101-1000 employees), and 0 otherwise.	0.13	0.34	
FIRM2	Dummy taking the value of 1 for small firms (11-100 employees), and 0 otherwise.	0.23	0.42	
FIRM3	Dummy taking the value of 1 for micro companies (2-10 employees), and 0 otherwise.	0.16	0.37	
UNIV	Dummy that equals 1 if the patent was created at a university, and 0 otherwise.	0.04	0.19	
MOREPAT	Dummy taking the value of 1 if the inventors have more similar (competitive) patents.	0.41	0.49	
COMPL	Dummy that equals 1 if complementary patents are needed to create a product, and 0 otherwise	0.23	0.42	
INVNMBR	Number of inventors of the patent.	1.34	0.66	
OWNER	Percent of the patent that is directly or indirectly owned by the inventors.	65.2	45.2	
SEX	Share of inventors who are females	0.02	0.14	
ETH	Share of inventors with an ethnical background other than Western European or North-American	0.03	0.16	

Table 7. Basic estimations of the Cox model.

Dependent variable: log $h(t)$	Statistical model: Cox hazard model with left-truncation		
Explanatory variables	Model I	Model II	Model III
COM	-0.65*** (0.12)	------	------
AL	-----	-0.47** (0.19)	------
ACQ	------	------	-0.22 (0.25)
LIC	------	------	-0.73*** (0.27)
COMORIG	------	-0.66*** (0.14)	-0.65*** (0.14)
COMNEW	------	-0.84*** (0.23)	-0.84*** (0.23)
SHADOW	-1.32** (0.61)	-1.32** (0.61)	-1.31** (0.61
FIRM1	-1.48*** (0.30)	-1.49*** (0.30)	-1.49*** (0.30)
FIRM2	-0.81*** (0.21)	-0.82*** (0.21)	-0.83*** (0.21)
FIRM3	-0.50*** (0.18)	-0.52*** (0.19)	-0.52*** (0.19)
UNIV	0.016 (0.32)	0.049 (0.32)	0.047 (0.32)
MOREPAT	-0.18 (0.12)	-0.18 (0.13)	-0.17 (0.13)
COMPL	-0.19 (0.15)	-0.20 (0.15)	-0.22 (0.15)
INVNMBR	-0.027 (0.093)	-0.022 (0.094)	-0.021 (0.093)
OWNER	-5.2 E-3** (-2.1 E-3)	-5.3 E-3 (3.1 E-3)	-5.3 E-3** (2.1 E-3)
SEX	-0.61 (0.40)	-0.57 (0.40)	-0.57 (0.40)
ETH	0.19 (0.36)	0.17 (0.36)	0.22 (0.36)
Regional dummies	Yes	Yes	Yes
Technology dummies	Yes	Yes	Yes
Difference between parameter estimates			
ACQ-LIC	------	------	0.51 (0.39)
Log-likelihood	-1230.5	-1229.6	-1228.4
Likelihood-ratio test	158.9***	160.8***	163.0***

Note: The total number of observations equals 867, 482 of which are right-censored. Standard errors are in parentheses and ***, ** and * indicate significance at the 1, 5 and 10 percent level, respectively. Region, technology and time dummies are not shown, but are available from the author upon request.

Table 8. Cox estimations with variable and fixed fees.

Dependent variable: log *h*(*t*)	Statistical model: Cox hazard model with left-truncation					
Explanatory variables	Model IV-a	Model IV-b	Model IV-c	Model V-a	Model V-b	Model V-c
ALVandF	-0.93***	-0.90***	-0.94***	-0.93***	-0.90***	-0.93***
	(0.34)	(0.35)	(0.35)	(0.34)	(0.35)	(0.35)
ALVorF	-0.22	-0.27	-0.26	------	------	------
	(0.21)	(0.22)	(0.22)			
ALonlyV	------	------	------	-0.32	-0.37	-0.35
				(0.35)	(0.35)	(0.36)
ALonlyF	------	------	------	-0.17	-0.22	-0.22
				(0.25)	(0.26)	(0.26)
COMORIG	-0.61***	-0.64***	-0.66***	-0.61***	-0.64***	-0.66***
	(0.13)	(0.14)	(0.14)	(0.13)	(0.14)	(0.14)
COMNEW	-0.76***	-0.80***	-0.84***	-0.76***	-0.80***	-0.84***
	(0.23)	(0.23)	(0.23)	(0.23)	(0.23)	(0.23)
SHADOW	-1.23**	-1.30**	-1.33**	-1.23**	-1.30**	-1.32**
	(0.60)	(0.61)	(0.61)	(0.60)	(0.61)	(0.61)
FIRM1	-1.49***	-1.45***	-1.49***	-1.50***	-1.45***	-1.50***
	(0.29)	(0.30)	(0.30)	(0.29)	(0.30)	(0.30)
FIRM2	-0.79***	-0.81***	-0.83***	-0.80***	-0.81***	-0.83***
	(0.21)	(0.21)	(0.21)	(0.21)	(0.21)	(0.21)
FIRM3	-0.51***	-0.50***	-0.50***	-0.51***	-0.51***	-0.51***
	(0.18)	(0.19)	(0.19)	(0.18)	(0.19)	(0.19)
UNIV	0.14	0.083	0.039	-0.15	0.083	0.040
	(0.29)	(0.32)	(0.32)	(0.29)	(0.32)	(0.32)
MOREPAT	-0.22*	-0.17	-0.16	-0.22*	-0.17	-0.16
	(0.12)	(0.13)	(0.13)	(0.12)	(0.13)	(0.13)
COMPL	-0.22	-0.17	-0.20	-0.22	-0.17	-0.20
	(0.15)	(0.16)	(0.15)	(0.15)	(0.15)	(0.15)
INVNMBR	-0.10	-0.028	-0.020	-0.096	-0.029	-0.020
	(0.091)	(0.093)	(0.094)	(0.091)	(0.093)	(0.094)
OWNER	-4.9 E-3**	-5.6 E-3**	-5.3 E-3**	-4.9 E-3**	-5.6 E-3**	-5.3 E-3**
	(2.0 E-3)	(2.1 E-3)	(2.1 E-3)	(2.0 E-3)	(2.1 E-3)	(2.1 E-3)
SEX	-0.39	-0.54	-0.56	-0.39	-0.54	-0.56
	(0.39)	(0.40)	(0.40)	(0.39)	(0.40)	(0.40)
ETH	0.10	0.17	0.21	0.10	0.17	0.22
	(0.35)	(0.36)	(0.36)	(0.35)	(0.36)	(0.36)
Regional dummies	Yes	No	Yes	Yes	No	Yes
Technology dummies	No	Yes	Yes	No	Yes	Yes
Difference between parameter estimates						
ALVorF - ALVandF	0.71*	0.63	0.67	------	------	------
	(0.42)	(0.43)	(0.43)			
ALonlyV – ALVandF	------	------	------	0.61	0.53	0.58
				(0.50)	(0.51)	(0.51)
ALonlyF – ALVandF	------	------	------	0.75 *	0.68	0.72
				(0.44)	(0.45)	(0.45)
Log-likelihood	-1250.1	-1233.4	-1227.9	-1250.1	-1233.3	-1227.9
Likelihood-ratio test	119.6***	153.1***	164.0***	119.7***	153.2***	164.1***

Note: The total number of observations equals 867, 482 of which are right-censored. Standard errors are in parentheses and ***, ** and * indicate significance at the 1, 5 and 10 percent level, respectively. Region, technology and time dummies are not shown, but are available from the author upon request.

Table 9. Robustness tests.

Dependent variable: log *h*(*t*)	Statistical model: Cox hazard model with left-truncation			
Explanatory variables	Model V-c	Model V-c	Model V-c	Model V-c
ALVandF	-0.87***	-0.98***	-0.97***	-0.95***
	(0.34)	(0.34)	(0.35)	(0.35)
ALonlyV	-0.23	-0.37	-0.36	-0.36
	(0.36)	(0.36)	(0.36)	(0.36)
ALonlyF	-0.21	-0.22	-0.25	-0.22
	(0.26)	(0.26)	(0.26)	(0.26)
COMORIG	-0.77***	-0.66***	-0.68***	-0.64***
	(0.13)	(0.14)	(0.14)	(0.14)
COMNEW	-0.67***	-0.89***	-0.84***	-0.83***
	(0.23)	(0.23)	(0.23)	(0.23)
SHADOW	-1.24**	-1.43**	-1.33**	-1.23**
	(0.61)	(0.61)	(0.61)	(0.61)
FIRM1	------	-1.53***	-1.51***	-1.00***
		(0.30)	(0.30)	(0.23)
FIRM2	------	-0.85***	-0.83***	-0.50***
		(0.21)	(0.21)	(0.16)
FIRM3	------	-0.53***	-0.51***	-0.34***
		(0.19)	(0.19)	(0.17)
UNIV	0.36	0.068	0.053	0.14
	(0.31)	(0.32)	(0.31)	(0.32)
MOREPAT	-0.22*	------	-0.19	-0.14
	(0.13)		(0.12)	(0.13)
COMPL	-0.23	-0.23	------	-0.19
	(0.15)	(0.15)		(0.15)
INVNMBR	-0.04	-0.027	-0.021	-0.030
	(0.093)	(0.094)	(0.094)	(0.094)
OWNER	2.5 E-3*	-5.1 E-3**	-5.2 E-3**	------
	(1.4 E-3)	(2.1 E-3)	(2.1 E-3)	
SEX	-0.47	-0.54	-0.56	-0.56
	(0.40)	(0.40)	(0.40)	(0.40)
ETH	0.25	0.20	0.22	0.23
	(0.35)	(0.36)	(0.36)	(0.36)
Regional dummies	Yes	Yes	Yes	Yes
Technology dummies	Yes	Yes	Yes	Yes
Difference between parameter estimates				
ALonlyV – ALVandF	0.63	0.61	0.61	0.59
	(0.51)	(0.51)	(0.51)	(0.51)
ALonlyF – ALVandF	0.66	0.75	0.72	0.73
	(0.45)	(0.45)	(0.45)	(0.45)
Log-likelihood	-1241.6	-1228.7	-1228.8	-1231.0
Likelihood-ratio test	136.7***	162.5***	162.4***	157.8***

Note: The total number of observations equals 867, 482 of which are right-censored. Standard errors are in parentheses and ***, ** and * indicate significance at the 1, 5 and 10 percent level, respectively. Region, technology and time dummies are not shown, but are available from the author upon request.