



THE RESEARCH INSTITUTE OF INDUSTRIAL ECONOMICS

Working Paper No. 624, 2004

**Commercialization of Patents and External Financing
during the R&D-Phase**

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June 2004

Key words: Patents, R&D, commercialization, external financing, survival models.

JEL Classification: O31, O38, G30, M13.

Abstract

Using a unique database on individual Swedish patents, a survival model estimates how different factors influence the time it takes until commercialization starts. To the best of my knowledge, such an analysis has not been undertaken before. For external financing of patent projects and small technology-based firms, Sweden has during long time relied on government support rather than private venture capital firms. The empirical results show that the larger share of the patent-owners' costs during the R&D-phase that are covered by government financial support, the longer time it takes until the patents are commercialized. It seems like the government financing creates a pool of patents with bad perspectives of commercialization. The reasons to the bad performance are: 1) the design of the government loans, where the patent owner can escape from paying back the loan if the project failures; and 2) the competence and incentives of the government institutions, which are not profit maximizing. A policy implication is therefore that the government should either change the conditions of the loans or, preferably, stop acting as a venture capital firm. The government should instead facilitate private solutions and the growth of private venture capital firms.

* The author would like to thank Lars Persson, IUI, and Erik Mellander, IFAU, for constructive comments, as well as Jakob Eliasson for collection of, and work with, the database.

1. Introduction

It is well known that innovations are crucial for economic growth. The ultimate value of an innovation is the increase in economic value it creates. In order to understand the factors important for innovations, empirical studies have evaluated how different factors affect the number of granted patents. However, many patents are not commercialized and will not contribute to economic welfare. Thus, by using patents as measure, wrong conclusions might be drawn. More precisely, the purpose of this study is to analyze which factors are important for the choice to commercialize patents. The term commercialization means that the owners of the patent have taken measures with the purpose to generate incomes from the patent.¹ Patents rather than inventions are here chosen as the unit of observation, because the former are much easier to identify and follow.

In the empirical analysis, a unique database of Swedish patents granted to medium-sized and small firms as well as individuals is used. Here, information about individual patents has been collected, for example, the place where the invention behind the patent was created, the ownership of the inventors, the financing during the R&D-phase, whether the patent has been commercialized or not, etc. By using survival analysis, it is then statistically tested how different explanatory factors influence the time it takes until patents are commercialized. To the best of my knowledge, such a statistical survival analysis on the choice to commercialize patents has never been done earlier.

Sweden is one of the countries in the world that spends most resources on R&D compared to GDP – both totally and at the universities (SOU 1996:70). At the same time, Sweden is top-ranked with respect to publications in international academic journals in relation to GDP (National Science Board, 1997), and granted patents per capita (EU, 2001). On the other hand, there are not so many small technology-based fast-growing firms in Sweden, which use the knowledge and innovations created by the R&D. The commercialisation of the patents and the intellectual capital seems not to be so efficient in Sweden (Utterback and Reitberger, 1982; Rickne and Jacobsson, 1996, 1999; Goldfarb and Henrekson, 2001). A comparison can be made with the U.S., which also spend a lot of resources on R&D. However, the U.S. has had many small firms,

¹ There are several commercialization modes, for example, commercialization in a new or existing firm, licensing the patent or selling the patent.

which – by basing their competitiveness on innovations – have grown large in sectors like medicine, microbiology, IT and electronics.

During the last decade, there has been a debate in Sweden whether lack of venture capital and external financing for entrepreneurs and inventors restrains economic growth and development of small technology-based firms (Braunerhjelm, 1999; Karaömerlioglu and Jacobsson, 2000). Since investments in technology projects often are characterized by asymmetrical information for insiders and outsiders, focus in the debate has also been on whether the external financiers are competent or not. In contrast to the U.S. where the external financing is private, firms have since long time been financially supported by the government in Sweden. Some government institutions and foundations assist also individuals and small firms with financing of patent projects – especially during the early part of the projects (R&D-phase) before the commercialization starts. The assistance takes the form of grants or favorable loans. These loans do not need to be repaid if the project fails, and if commercialization is undertaken then the repayment is connected to the turnover. In the present study, I argue that these conditions create moral hazard problems, because there are few incentives for the patent owners to continue with commercialization. Therefore, I will especially analyze how different financing alternatives during the R&D-phase affect the choice to commercialize patents.

The paper is organized as follows. Previous studies about commercialization of patents and adequate theories are discussed in section 2. In section 3, the database and basic statistics are described. The statistical model and hypotheses are set up in section 4. In section 5, the empirical estimations are shown, and the final section concludes.

2. Previous studies and theoretical discussion

2.1 Previous studies

Most previous studies analyzing patents use data from one or several national patent offices. This means that the researchers do not know whether the patents have been commercialized or not. Patent databases with detailed information (which are not available from the national patent offices) have seldom been collected earlier. The few previous studies with such databases have focused on estimating the profits from patenting rather than analyzing problems related to the commercialization (Rossman

and Sanders, 1957; Sanders *et al.*, 1958; Sanders, 1962, 1964; Schmookler, 1966; Cutler, 1984; SRI International, 1985).

Other studies of commercialization of inventions have mostly used technology offices in connection to universities, government laboratories (Jaffe and Lerner, 2001) or the firm (Utterback and Reitberger, 1982, Olofsson and Wahlbin, 1993; Rickne and Jacobsson, 1996, 1999; Lindholm-Dahlstrand, 1997a, 1997b; Cohen *et al.*, 2000) as the unit of observation and then specifically start-up firms, although a majority of the patents and inventions probably are commercialized in existing firms. In the US, for example, 90% of the patents are commercialized in already existing firms (AUTM, 1998). Furthermore, the interesting question is not whether inventions and patents lead to new firms, but whether they translate into a higher standard of living.

Morgan *et al.* (2001) describe the commercialization rate of American patents across different groups. Industrial patents had a commercialization rate of 48.9%, whereas inventors in the education sector had a rate of 33.5%. However, the authors never try to relate this commercialization rate to other explanatory factors and do not run any survival model – perhaps due to lack of data.

2.2 *Theoretical discussion*

Patents, like R&D-projects, are typically characterized by high costs and no incomes in the early R&D-phase, and high uncertainty about future incomes. Apart from technological problems, lack of financial resources is one of the largest problems during the R&D-phase. In the later commercialization phase, several complementary resources are needed, e.g., financing, marketing and manufacturing capabilities. Large firms have these complementary capabilities as well as information about the market. Small firms have these resources in-house to a lower degree and individuals have none of these capabilities. Thus, large and small firms as well as individuals have completely different conditions under which they commercialize their inventions. It is therefore likely that external financing and advices are needed by individuals and to some degree also by small firms.

Clearly, the inventors have more knowledge about the invention / patent than potential external financiers. Thus, problems with asymmetrical information and adverse selection are present. The search and transaction costs to find interesting projects and to evaluate the technical and commercial potential are in other words large for external financiers. It is especially difficult to make this evaluation in the R&D-

phase, when the uncertainty about the project is very high. The Swedish government has during long time intervened on the market for external financing, because it has been claimed that there are market imperfections. However, this does not need to be true, because private PVC-firms exist private market solutions work well in other countries, e.g., in the U.S.

Among the Swedish government institutions, SIC and NUTEK almost purely assist with financial resources during the R&D-phase, whereas ALMI enters when it is time for commercialization.² An inventor can during the R&D-phase apply for grants from SIC. These grants can be used to cover patent costs, which sometimes are very high. The application costs for a Swedish patent are around 3-5,000 Euro, but for a patent covering Europe they are around 25-50,000 Euro. A further step for SIC is to lend capital to the inventors. A typical SIC-loan is designed in the following way. The borrower pays a subsidized interest rate and begins to pay back the loan some years after the commercialization has started, but if there is no commercialization, then there is a possibility that the borrower does not need to pay back the loan at all. NUTEK lends money to a subsidized interest rate primarily to firms during the R&D-phase (although grants are also possible). Similarly to SIC, these loans can wholly or partly be written off after some years, if the commercialization fails or turns out to be less successful than expected.³

Even more interesting is what happens if the borrower does receive incomes during the commercialization. The repayment of the loan is then connected to the turnover. This means that projects, which have a low or medium expected profit-level, will probably not be commercialized at all, since the repayment of the loan would then erase the whole profit. However, this will not stop the commercialization if the expected profit-level is high. Due to the design of the loans assisted by the government institutions, it is likely that there exist problems related to moral hazard. The inventors, who have received loans from the government, do not need to care about further commercialization of the patent, since they know that there is a high probability that they do not need to pay back the loans at all. If the expected profit of the project is of mediocre size, the incentives to continue the commercialization are low, since the

² In contrast to ALMI, SIC has no local offices in Sweden. Therefore, ALMI evaluates many local patent projects and decide whether loans from SIC will be approved. SIC was winded up in 2003, but similar loans are since 2003 offered by ALMI.

³ In 2004, 60% of the SIC-loans had been lent to projects that had failed. In the case of NUTEK, 50% of the borrowers pay back at least parts of the loans, whereas 1/3 of the lent money is paid back.

repayment is connected to the turnover rather than the profit. It is often better to exit the project, escape from paying back the loans and start a new project.

Private venture capital (PVC) firms and private persons (business angels), who assist with financing during the R&D-phase, own shares in the patent project / firm. The repayment is then connected to the profit when the patent is commercialized. In contrast to the projects financed by the government, this means that even if the expected profit is of mediocre size, the inventors have incentives to undertake a commercialization.

Furthermore, the government financing institutions do not maximize the profit. Their employed administrators have therefore few incentives to search for really good patent projects to lend money to. On the other hand, PVC-firms and business angels are profit maximizing. It is therefore more likely that they are more careful than government institutions in which patent projects they invest and that they have a more active, and advisory, role already during the R&D-phase. The PVC-firms not only provide financial capital, but also networks and competence in terms of knowledge about the market, marketing, juridical assistance, etc. An inventor or firm, which has received contacts and financing during the R&D-phase from a PVC-firm or business angel, should easier receive financing and advice during the commercialization phase.

3. Database and descriptive statistics

In order to analyze commercialization of patents, it is necessary to have a detailed database about individual patents.⁴ In a previous pilot study (Svensson, 2002), most patents were commercialized within 5 years after they had been applied. Therefore, the year of 1998 is chosen for the current database. In 1998, 2760 patents were granted in Sweden. Of these, 776 were granted to foreign firms, 902 to large Swedish firms with more than 1000 employees, and 1082 to Swedish individuals and firms with less than 1000 employees. Information about inventors, applying firms and their addresses 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.⁵ In the pilot

⁴ All inventions do not result in patents. However, as an invention, which does not result in a patent, is not registered anywhere, there are two problems to empirically analyze the invention rather than the patent. Firstly, it is impossible to find these new ideas, products and developments among all firms and individuals. On the other hand, all patents are registered. Secondly, even if one finds the "inventions", it is difficult to judge whether they are enough improvements to be called inventions or not. Only the national and international patent offices make such judgements. Therefore, the choice of the patent rather than the invention is the only alternative for an empirical study of the commercialization process.

⁵ Each patent has always 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 be owners of the patent indirectly,

survey carried out in 2002, it turned out that large Swedish firms refused to give information about individual patents. Furthermore, it is impossible to persuade foreign firms to fill in questionnaires about patents. These firms are almost always large multinationals firms. Therefore, the population consists of 1082 patents granted to Swedish individuals and firms with less than 1000 employees.

In the questionnaire, we asked the inventors about the work place where the invention was created and the financing of the invention during the R&D phase, whether the invention had been commercialized, which kind of commercialization mode was chosen, how the commercialization was financed, about the inventors' incomes and profits from the patent, and if there were any problems with the commercialization – alternatively why the patent never was commercialized. As many as 867 of the inventors filled in and returned the questionnaire, i.e., the response rate was 80% (867 of 1082). This response rate is satisfactorily high, if one takes into account that such a database has seldom been collected before and that the inventors or the applying firms usually consider information about inventions and patents secret.

The application year of the 867 patents is described as light-gray staples in Figure 1. 85% of the patents were applied between 1994-97. In 2003, 537 of these patents (61%) had started commercialization. The starting year of the commercialization are represented by dark staples, which almost follow a normal distribution. Although the last year of observation is 2003, it is not likely that many of the 330 non-commercialized patents will be commercialized after 2003.

The 867 patents and the commercialization rate are described across firm groups and ownership in Table 1. As many as 408 patents (47 %) were granted to individual inventors, and 116, 201, 142 patents were granted to medium-sized firms (101-1000 employees), small firms (11-100 employees) and close companies (2-10 employees). The commercialization rate of the firm groups is between 66 and 74%, whereas the rate of the individuals is not higher than 52%. A contingent-table test suggests that there is a significant difference in the commercialization rate between firms and individuals. The chi-square value is 30.55 (with 3 d.f.), significant at the 1 percent level. In the lower part of Table 1, it is shown that the commercialization rate is lower if the inventors are owner of the patent. The chi-square value is 4.43 (with 1 d.f.), significant at the 5%-

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, then the questionnaire was sent only to one inventor.

level. However, the ownership is closely related to the firm size, the larger the firm size, the lower share of the patents is (directly or indirectly) owned by the inventors.

[Table 1]

In Table 2, the commercialization rate is related to external financing during the R&D phase. Patents with external financing during the R&D-phase have a significantly lower commercialization rate than those that have not. When dividing the external financing on different sources, the commercialization rate is significantly lower only for patents supported by government funds.⁶ However, it is neither shown when the commercialization started nor how large share of the R&D that was financed with government or private capital. Such a survival analysis will be undertaken in the statistical part.

[Table 2]

4. Statistical model and hypotheses

4.1 Statistical model

Since the analysis focuses on an “event” to occur, survival (duration) analysis is used in the statistical estimations. The event is here that the patent has been commercialized, and it is also measured when this commercialization started. Preliminary in the empirical analysis, a survival distribution function and a Hazard function will be estimated and plotted. The survival function, $S(t)$ in equation 1, shows how large share of the patents that survive beyond a time point t . The Hazard function, $h(t)$ in equation 2, shows the conditional probability that a patent will be commercialized in a specific time period Δt , given that it has “survived” (not been commercialized) until the beginning of t . The Hazard can also be expressed as a function of the probability density function, $f(t)$, and the survival function.

⁶ In the group with other external financing, the financing might be government or private, but the intention with the financing is not to finance a patent application / project, but rather research in general. Here, the inventors often use the resources to the patent without the financiers’ (mostly a university) knowledge about this. Therefore, this kind of financing is regarded as passive. In contrast, the government and private groups represent active financing, where the financier support, or invest in, a specific patent.

$$S(t) = \Pr(T > t) = 1 - F(t) \quad , \quad (1)$$

$$h(t) = \frac{f(t)}{S(t)} = \lim_{\Delta t \rightarrow 0} \frac{\Pr(t \leq T < t + \Delta t \mid T \geq t)}{\Delta t} \quad . \quad (2)$$

In the main empirical analysis, it is estimated how different explanatory factors affect the survival time of the patents. The dependent variable, T_i , is a random variable showing how many years it takes until commercialization started for patent i , measured from the time point of patent application. Most patents in the database were applied between 1994-97 and the end point of observation in the dataset is 2003. Patents that have not yet been commercialized in 2003 are “right-censored” (337 observations). If the owners have started the commercialization before they applied for the patent, then the patents are “left-censored” (37 observations). The measurement of the starting point of commercialization in years is a rather rough measure. Therefore, T is “interval-censored” for those patents, which were commercialized after the patent application occurred and not later than 2003, i.e. the rest of the patents (493 observations). If the patent is commercialized within the first year, T gets an interval-censored value between 0.1 and 1, within the second year T is between 1.1 and 2, etc.

Since both left-censored and interval-censored observations are included, the most popular survival model, the Cox (1972) survival model, cannot be used.⁷ Instead the accelerated failure time (AFT) model is the appropriate statistical model (Allison, 1995):

$$\log(T_i) = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \dots + \beta_k x_{ik} + \sigma \varepsilon_i \quad , \quad (3)$$

where ε is a random disturbance term, the β s and σ are parameters to be estimated, and the x 's are explanatory variables. The ε 's can have various distributions, corresponding to different AFT-models, e.g., the log-normal, log-logistic, exponential, Weibull and gamma models. In the empirical part, all of these models will be run. By using likelihood-ratio tests, it is possible to decide which of the models that fits the data best.

⁷ The fact that there are left- and interval-censored observations is also the reason why a usual logit survival model cannot be used.

4.2 Hypotheses

Turning to the explanatory variables, such factors are included that are expected to affect: 1) the time it takes to commercialize the patent (survival time); or 2) the probability that patent will be commercialized at all. Basic statistics and hypotheses of these factors are described in Table 3, and correlations are shown in Appendix Table A1. When interpreting the sign of the hypotheses in Table 3, it is important to remember the definition of equation (3). A positive parameter estimate means that the survival time increases (or in other words that the conditional probability of commercialization decreases) when the explanatory variable gets a higher value.

Other factors that are specific for the commercialization, e.g., commercialization mode (licensing, new company, selling the patent, etc.), financing during the commercialization or whether the inventors are active or passive during the commercialization, are not included in the estimations, since they cannot be measured for non-commercialized patents.

It is expected that firms, which have marketing, manufacturing and financial resources in-house, have better possibilities to commercialize their patents compared to individuals. *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 taking the value of 1 for close companies with 2-10 employees, and 0 otherwise. Thus, the firm dummies are here related to the reference group of individual inventors. Therefore, the parameter estimates are expected to be negative, implying a shorter “survival” time of the patents and a higher probability that the patents will be commercialized. Which of the three dummies that has the highest value is difficult to predict. It is true that large firms have more resources available for a commercialization, but it is not clear that larger firms are more likely to commercialize patents than smaller firms. Previous studies have, for example, shown that large multinational firms tend to patent more inventions (“shadow patents”) in order to protect other patents (Cohen *et al.*, 2000).

As discussed above, the Swedish government institutes, which assist with financing of patent projects, have a curious design of their loans. The borrower can escape from paying back the loan if the patent is not commercialized. If the patent is commercialized, repayment is connected to the turnover rather than the profit. This means that the expected profit of a commercialization must be higher than a threshold value – otherwise the repayment will erase the profit. It is therefore likely that the

government financing during the R&D phase will create moral hazard problems. The loan conditions will attract inventors, who own inventions with no perspectives of commercialization, and will deter many good patents from being commercialized, because the expected profit level is not high enough. *GOVFIN* measures how large share of the patent's R&D-costs (in percent) that was financed through government capital.⁸ A positive influence on the survival time is expected.

In a similar way, the variable *PRIVFIN* shows how many percent of the R&D costs that were financed through external private venture capital. Private venture capitalist can be regarded as strict profit maximizing and they only invest in projects they believe in. The external financiers should therefore push harder for that the patents will be commercialized and create incomes. It is also likely that patents that had external private financing during the R&D phase, have more easy to attract external venture capital (from the same private venture capitalists) during the commercialization phase. Therefore, a negative effect of *PRIVFIN* on the survival time is expected.

There is also a third kind of external financing. *OTHERFIN* measures how large share of the R&D costs, which was financed through universities and research foundations. Typically, patents created at universities have this kind of external financing. The intention of this financing is not to assist a patent project, but rather to finance R&D in general. The financiers have, however, no control of what the resources actually are used for. It is difficult for the inventors to use the resources for patent applications, but more easy to hide labor costs necessary for creating the invention within this financing. A problem with this kind of financing is that it cannot be used for commercialization. Consequently, the inventors stand often alone without financing when considering commercialization. A positive parameter estimate is therefore expected.

Basic research is relatively more common at universities. It is then likely that university patents also are more related to basic research and have a lower probability of commercialization (Jaffe and Lerner, 2001). In contrast to the U.S., the university researchers in Sweden are wholly owners of their patents. The Swedish universities have no ownership and consequently no interest in that employed researchers commercialize their patents. The dummy *UNIV*, which equals 1 for university patents, is therefore expected to have a positive influence on the survival time.

⁸ Patent application costs are included in the R&D costs.

