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

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Abstract

Using a unique database on Swedish patents, owned by small firms and individuals, survival models estimate how different factors influence the decision to commercialize the patents. To the best of my knowledge, such an analysis has never previously been undertaken. Since the owners know more about the patents than potential external financiers, problems related to asymmetrical information are present. To overcome these problems when inventors and small technology-based firms need financing, Sweden has, for a long time, relied on government support rather than private venture capital firms. The empirical results show that the larger is the share of patent-owners' costs covered by government financial support during the R&D-phase, the lower is the probability of patents being commercialized. This bad performance is likely to depend on: 1) the soft terms of the government loans, where the patent owner can avoid paying back the loan if the project fails, or if the patent is never commercialized; and/or 2) the fact that government employees have no incentives to find good projects to which to lend money. The first explanation is related to moral hazard and the second one to adverse selection.

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1. Introduction

Patents are used to protect new products introduced in the market or for defensive strategic reasons, e.g. they serve as shadow patents defending other patents. One strand of studies has analyzed patent citations, with the purpose of measuring technology transfer from patents and evaluating the social welfare effects of patenting (see, e.g. Griliches, 1990). As concerns the private market value of patents, some studies have analyzed the renewal fees of patents (Pakes, 1986; Schankerman and Pakes, 1986). In these studies, it is expected that owners will only renew their patents if it is economically profitable. A drawback when studying renewal fees is that the observer never knows whether the patents are commercialized and, thus, whether innovations are introduced in the market. In the long run, a sufficient share of patents must be commercialized if they are to contribute to economic welfare.

The purpose of the present study is to analyze which factors are important for the choice of commercializing patents. The term commercialization means that the owners of the patent have taken measures to generate income from it. They have introduced an innovation in an existing or in a new firm, licensed or sold the patent. Patents rather than inventions are here chosen as the unit of observation, since 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, financing during the R&D-phase, whether the patent has been commercialized, etc. Using survival analysis, it is 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 of commercializing patents has never previously been done.

Sweden is one of the countries in the world that spends most resources on R&D as 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). However, the number of small technology-based fast-growing firms in Sweden that use the knowledge and innovations created by R&D is not large. Commercializing patents and intellectual capital does not seem 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 spends considerable resources on R&D. However, the U.S. has had many small firms, which – by basing their competitiveness on innovations – have grown large in sectors such as medicine, microbiology, IT and electronics.

During the last decade, there has been a debate in Sweden on whether the lack of venture capital and external financing for entrepreneurs and inventors restrains economic growth and development of small technology-based firms (Braunerhjelm, 1999, 2000; Karaömerlioglu and Jacobsson, 2000). Since investments in technology projects are often characterized by asymmetrical information for insiders and outsiders, the focus in the debate has also been on whether the external financiers are competent. In contrast to the U.S. where external financing is mainly private, Swedish firms have, for a long time, received financial support from the government. Some government institutions and foundations also assist individuals and small firms with financing of patent projects – especially in the early stage of the projects (R&D-phase) before commercialization has begun. 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 repayment is connected to turnover. In the present study, I argue that these conditions create moral hazard problems, because there are few incentives for patent owners to continue with commercialization. Therefore, I will especially analyze how different financing alternatives in the R&D-phase affect the choice of commercializing patents. In the previous literature, external financing has empirically been shown to be important for patenting (e.g., Kortum and Lerner, 2000). However, external financing has not been empirically related to the commercialization decision.

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

2. Previous studies and theoretical discussion

2.1 Previous studies

Previous studies, which have analyzed commercialization of new technologies, have mainly used technology offices connected 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.[1]

Earlier patent studies have used data from one or several national patent offices, which means that the researchers did not know whether the patents had been commercialized. Patent databases with detailed information (which are not available from the national patent offices) have seldom been collected. The few previous studies with such databases have focused on estimating the profits from patenting or the market value of patents, rather than on analyzing problems related to commercialization (Rossman and Sanders, 1957; Sanders et al., 1958; Sanders, 1962, 1964; Schmookler, 1966; Cutler, 1984; SRI International, 1985).

Morgan et al. (2001) describe the commercialization rate of American patents across different groups. Industrial patents had a commercialization rate of 48.9%, whereas the rate for inventors in the education sector was 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.

Another strand of the patent literature has analyzed the renewal of patents (see e.g. Pakes, 1986 and Schankerman and Pakes, 1986). Every single year, the owners must pay a renewal fee to keep their patents in force. It can be argued that the owners will only renew their patents if it is economically profitable to keep them. The percentage of renewed patents indicates how large a share of the patents that have an economic value after different numbers of years. The models in these studies are based on the assumption that more valuable patents are renewed for longer periods than less valuable patents. The authors estimate both the distribution of the patent values and their rate of depreciation. The main conclusions of these studies are that most patents

[1] Some of these studies analyze start-up firms, although a majority of the patents and inventions are probably commercialized in existing firms. In the U.S., for example, 90% of the patents are commercialized in existing firms (AUTM, 1998).

have a low value and that it depreciates fast, and only a few have a significant high value. In other words, the value distribution of patents is severely skewed to the right.

Although most commercialized patents can be expected to be renewed, and most non-commercialized patents to be killed, this is not always true, as will be seen later in the statistical part. The main defect of the renewal measure is that it does not say anything about whether the patent has been commercialized and whether the patents have been associated with any innovations and entrepreneurship. Furthermore, the renewal fee is a relatively low annual cost, implying that patents renewed the whole statutory period (20 years) might still have a low value. There is an identification problem. It is impossible to say which patents have a high value and which ones have a low value. Finally, patents that are not renewed do not necessarily have a low value, since the product based on the patent might have been commercialized with a short lifetime. In this lifetime, the product could either have been profitable or not for the owner. The renewal statistics say nothing about this either.

Measuring the choice to commercialize the patent does not take into account whether the patent is profitable or the fact that also non-commercialized patents might be profitable for the owner. But it does say something about whether innovations are introduced in the market, and whether the owners are involved in some form of entrepreneurship activities, which have been neglected in the previous literature. An objection against the commercialization measure would be that some patents are never commercialized, although they are renewed during the whole statutory period (20 years) for strategic reasons; for example, they serve as shadow patents. However, this is a strategy primarily used by large firms. Shadow-patents are relatively rare among individuals and small firms, as will be shown in section 3.

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 by high uncertainty about future incomes. Besides 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, the conditions under which inventions are commercialized differ completely between large and small firms and individuals. Therefore, external financing and advice are likely to be needed by individuals and, to some degree, also by small firms.

Clearly, 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 of finding interesting projects and evaluating the technical and commercial potential are, in other words, large for external financiers (Kaplan and Strömberg, 2001). It is especially difficult to make this evaluation in the R&D-phase, when uncertainty about the project is very high. Therefore, market imperfections are likely to exist on the market for financing of innovation projects. To overcome market failures and the gap between inventors and external financiers, different countries have applied various strategies (Braunerhjelm, 1999, and Bottazzi *et al.*, 2004). In the United States, the government has facilitated private market solutions and the growth of private venture capital (PVC) firms (Gompers and Lerner 2001). In Sweden, the government has intervened by offering financial assistance and loans to inventors and small technology-based firms.

In the early R&D-phase – before manufacturing has started – the Swedish Government offers loans with soft loan terms to inventors and small technology-based firms.[2] The borrower pays a subsidized interest rate and begins to pay back the loan some years after the commercialization has started. However, if there is no commercialization or if the commercialization fails, there is a high probability that the borrower need not pay back the loan at all.[3] If the borrower does receive incomes during the commercialization, the repayment of the loan is connected to the turnover. This means that projects with a low or medium expected profit level would probably not be commercialized at all, since the repayment of the loan would then erase the whole profit. However, this will not prevent commercialization if the expected profit level is high. Due to the design of the loans from government institutions, problems related to moral hazard are likely to emerge. Inventors, who have received soft loans from the government, need not care about further commercialization of the patent, since they know that there is a high probability of their not having to pay back the loans at all. It is

[2] The government institutions SIC and Nutek have provided such soft loans during the late 1990s until 2003. Similar loans are provided by the government firm ALMI since 2003.
[3] In 2004, 74% of the SIC-loans had been to projects that failed. In the case of Nutek, 50% of the borrowers pay back at least part of the loans, but only 1/3 of the money lent is paid back.

often better to exit the project, escape from paying back the loans and start a new project.

PVC-firms and private persons (business angels), who assist with financing in 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 government-financed projects, this means that even if the expected profit is mediocre, the inventors have incentives to undertake a commercialization.

Furthermore, government-financing institutions do not maximize their profit. Therefore, their administrators have few incentives to search for really good patent projects to which they lend money. The employees do not invest their own private money. On the other hand, PVC-firms and business angels are profit maximizing. Therefore, they are more likely to be careful than government institutions about which patent projects they invest in and they should have a more active, and advisory, role already during the R&D-phase. PVC-firms do not only provide financial capital, but also networks and competence in terms of knowledge about the market, marketing, juridical assistance, etc (Bottazzi *et al.*, 2004; Hellmann and Puri, 2002). An inventor or firm, which has received contacts and financing from a PVC-firm or business angel in the R&D-phase, should more easily receive financing and advice in the commercialization phase.

3. Database and descriptive statistics

To analyze the commercialization of patents, it is necessary to have a detailed database about individual patents.[4] In a previous pilot questionnaire, most patents were commercialized within five years after they had been applied for. Therefore, the year of 1998 is chosen for the current database. 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 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,

[4] All inventions do not result in patents. However, since an invention, which 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 new 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 be called inventions. 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.

a questionnaire was sent out to the inventors of the patents.[5] In the pilot survey carried out, it turned out that large Swedish firms refused to provide information on 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. This sample selection is not a problem, as long as the conclusions are drawn for small firms and individuals.

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, the inventors' incomes and profits from the patent, and if there were any problems with the commercialization – alternatively why the patent was never commercialized. As many as 867 of the inventors filled in and returned the questionnaire, i.e., the response rate was 80% (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.

The application year of the 867 patents is described as light-gray staples in Figure 1. 85% of the patents were applied for between 1994-97. In 2003, commercialization had been started for 537 of these patents (61%). The starting year of the commercialization is 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.

******** [Figure 1] ********

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)

[5] 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 indirectly be owners of the patent, 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.

respectively.[6] 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 there to be 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 one-percent level.

******** [Table 1] ********

In Table 2, the commercialization rate is related to external financing in the R&D phase. Patents with external financing in the R&D-phase have a significantly lower commercialization rate than those without. When dividing the external financing on different sources, the commercialization rate is significantly lower only for patents supported by government funds.[7] However, it is neither shown when the patents were commercialized nor how large a 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] ********

The distribution of external financing among firm groups is described in Table 3. It is obvious that external financing – irrespective of source – is more common among individuals and close companies. The risk should be higher in patent projects owned by individuals as compared to projects owned by companies. It would then be expected that the government finances projects with higher risk than the average patent project. This might be an explanation for the lower commercialization rate among government-financed projects. However, in the group of 408 patents owned by individuals, the commercialization rate is 45% for government-financed projects and 54% for projects with no government financing.

******** [Table 3] ********

[6] 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.

[7] In the group with other external financing (universities, research foundations), the financing might be government or private, but the intention with this kind of financing is not to finance a patent application/project, but rather research in general. Here, inventors often use the resources for the patent without the financers' (mostly a university) knowledge. Therefore, this kind of financing is regarded as passive. In contrast, the government and private groups represent active financing, where the financier supports, or invests in, a specific patent.

In Table 4, commercialized patents are compared to renewed patents. 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 one single year, the patent expires. As expected, renewed patents (71%) have been commercialized to a higher degree than expired patents (49%). The chi-square value below the table shows there to be a strong correlation between commercialized and renewed patents. However, 189 patents have been commercialized, but are already expired. This is either due to the products having a short lifecycle or the commercialization having failed. On the other hand, 139 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% of the owners have at least one more similar patent. Among the non-commercialized patents, this percentage is only 33%. If the patent was not commercialized, the inventor was also asked: why? Among the 337 non-commercialized patents, only 15 inventors answered that the patent served as a shadow-patent as one of the reasons for its not having been commercialized.[8] 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] ********

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, a survival distribution function and a hazard function will be estimated and plotted in the empirical analysis. The survival function, $S(t)$ in equation 1, shows how a large share of the patents survives beyond a time point, t. The hazard function, $h(t)$ in equation 2, shows

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

the conditional probability of a patent being commercialized in a specific time period Δt, given that it has "survived" (has not been commercialized) until time point t. The hazard can also be expressed as a function of the probability density function, $f(t)$, and the survival function:

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

$$h(t) = \frac{f(t)}{S(t)} = \lim_{\Delta t \to 0} \frac{\Pr(t \le T < t + \Delta t \mid T \ge t)}{\Delta t} \quad . \tag{2}$$

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.[9] Most patents in the database were applied for between 1994-97 and the end point of observation in the database is 2003. Patents that have not yet been commercialized in 2003 are "right-censored" (337 observations). Measurement of the starting point of commercialization in years is a rather rough measure. Therefore, T is "interval-censored" for the commercialized patents (530 observations). If the patent is commercialized within the first year, T obtains an interval-censored value between 0.1 and 1, within the second year T is between 1.1 and 2, etc.

Since interval-censored observations are included, the accelerated failure time (AFT) model is the appropriate statistical model (Allison, 1995):

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

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. All these models will be run in the empirical part. Using likelihood-ratio tests, it is possible to decide which of the models that best fits the data. After recalculation of the parameters, one can estimate how an increase in the explanatory variables influences the survival time.

[9] The application year is the easiest starting time point to measure. In fact, this variable is directly available from the Swedish National Patent Office (PRV). The invention can, of course, be finished earlier, evidenced by the fact that some inventions are commercialized before the patent is applied. However, such a time point is difficult to measure, with a risk of large measurement errors.

I will also estimate how the explanatory variables affect the choice to commercialize the patent using the Cox (1972) proportional hazard model:

$$\log h_i(t) = \log \lambda_0(t) + \alpha_1 x_{i1} + \alpha_2 x_{i2} + ... + \alpha_k x_{ik} \quad , \tag{4}$$

where log $\lambda_0(t)$ is a baseline hazard function, the α's are parameters to be estimated, and the x's are explanatory variables. A disadvantage with the Cox model is that the dependent variable cannot be interval-censored. I make two adjustments to minimize this problem. First, if the patent is commercialized within the first year, T obtains the mid-point value of that period, i.e. 0.5, within the second year, T is 1.5, etc. Second, I use an approximation of the Cox model, called the "exact method", to take account of that two events actually do not occur at the same moment, even if there are tied event times in the sample (Allison, 1995). On the other hand, an advantage with the Cox model compared to the AFT-model is that one does not need to choose between different residual distributions. Thus, the baseline hazard function, log $\lambda_0(t)$, can be left unspecified. Another advantage is that the quantitative effects can be interpreted in terms of how an increase of the explanatory variables affects the hazard. However, all in all, the AFT-model is considered as the main model, due to the interval censoring.

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 the hazard of commercialization; and 2) the probability that the patent will be commercialized at all. Basic statistics and hypotheses of these factors are described in Table 5, and correlations are shown in Appendix Table A1. Since the AFT-model is the main model, the sign of hypotheses in the table and in the text below is in accordance to the definition of equation (3). A positive parameter estimate means that the survival time is expected to increase, when the explanatory variable obtains a higher value. For the Cox model, the expected sign is the opposite. A positive sign in Table 5 means that the conditional probability (the hazard) of commercialization is expected to decrease, when the explanatory variable gets a higher value.

******** [Table 5] ********

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 of commercializing their patents as 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 of the patents being commercialized. Which of the three dummies that has the strongest impact 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) to protect other patents (Cohen *et al.*, 2000).

As discussed above, Swedish government institutes, which assist in the 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, or if the commercialization fails. 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. Therefore, it is 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 sufficiently high. *GOVFIN* measures how large a share of the patent's R&D-costs (in percent) that was financed through government capital. A positive influence on survival time is expected.

In Table 3, it was described that the government especially finances patent projects owned by individuals. Such projects should have a higher risk than projects owned by companies. To take account of the higher risk associated with patents owned by individuals, an interaction dummy, *D*, taking the value of 1 if the patent is owned by a firm, and 0 otherwise, is used for *GOVFIN*.[10] In practice, the parameter of *GOVFIN*, β_{GF}, is divided into two parts:

$$\beta_{GF} = \beta_{Ind} + \beta_D D \quad . \tag{4}$$

β_{Ind} shows the parameter value of *GOVFIN* for individual inventors, $\beta_{Ind} + \beta_D$ is the parameter value for the firm groups and β_D shows whether there is a significant difference for *GOVFIN* between firms and individuals.

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 capitalists can be regarded as strictly profit maximizing and they only invest in projects in which they believe. External financiers should therefore push harder for patents to be commercialized and create incomes. It is also likely that patents, which had external private financing during the R&D phase, more easily attract external venture capital (from the same private venture capitalists) during the commercialization phase. Therefore, a negative effect of *PRIVFIN* on survival time is expected.

There is also a third kind of external financing. *OTHERFIN* measures how large a share of the R&D costs that was financed through universities and research foundations. Typically, patents created at universities have this kind of external financing, the purpose of which is not to assist a patent project, but rather to finance R&D in general. However, the financers seldom have any control of for what the resources actually are used. It is difficult for inventors to use the resources for patent applications, but easier to hide the 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, inventors often stand alone without financing when considering commercialization. A positive parameter estimate is therefore expected.

Basic research is relatively more common at universities. Thus, university patents are also likely to be more related to basic research and have a lower probability

[10] Preferably, three different interaction dummies would be included – one for each firm group. However, as described in Table 3, there are only three patents with government financing in each of the groups of medium-sized and small firms. When estimating the model with three interaction dummies, the small variation with respect to government financing in these two groups causes extremely high values of the standard errors of two of the interaction dummy parameters. Therefore, the three firm groups must be pooled into one group.

of commercialization (Jaffe and Lerner, 2001). In contrast to the U.S., university researchers in Sweden wholly own their patents. Swedish universities have no ownership and consequently**,** no interest in employed researchers commercializing their patents. The additive dummy *UNIV*, which equals 1 for university patents and 0 otherwise, is therefore expected to have a positive influence on survival time.

More complex products that require several patents might be more difficult to commercialize. On the other hand, if such a product is commercialized, then the owner will have a good protection against competitors. In the latter case, there should be a strong incentive for commercialization. If complementary patents are needed to create a product, then the dummy *KOMPL* equals 1, and 0 otherwise. However, the impact on the commercialization decision is unsettled.

MOREPAT is an additive dummy, which equals 1 if the inventors or the applying firm have more competitive patents in the same technology area and 0 otherwise. To apply for many similar patents is a strategy often chosen by owners – especially large firms – that want to protect a main patent. These additional patents are called shadow patents and are seldom commercialized. However, many patents can also be an indication of the owners having more knowledge and experience of the area, and should therefore increase the probability of commercialization. Therefore, the impact on survival time remains unsettled. Finally, *INVNMBR* here measures the number of inventors of the patent. This variable should be seen as an additional control variable and there is no specific expected impact on survival time.

Different technologies are likely to be connected with different risks. Consequently, the technology class can affect the survival time and the conditional probability of a patent being commercialized. Patents are divided into 30 technology groups according to Breschi *et al.* (2004). These groups are based on the patents' main IPC-Class. However, all technology groups are not represented in the dataset and some groups do not have enough observations. Therefore, only 26 groups and 25 additive dummies are used in the present study.[11]

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,

[11] The technology classes without enough observations are instead merged with other classes that are closely related (Breschi *et al.*, 2004).

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 years, since the level on the business cycle may affect when and whether a patent will be commercialized. The data has five application year periods (1985-90, 1991-92, 1993-94, 1995-96 and 1997-98) and four additive dummies are assigned for these periods.[12]

5. Empirical estimations

In Figure 2, the survival and hazard functions for the sample are estimated by the Life-table method (actuarial method). The patent application year is set to 0. The survival function falls steeply at the beginning, but it levels away after 4-5 years. The hazard function (conditional probability) is the highest during the first three years after the application. In Figure 3, the same survival and hazard functions are estimated, but now the sample is divided into two groups: one with and the other without government financing. The survival functions suggest that the gap increases over time and the hazard is mainly higher for patents with no government financing. Both a Log-rank test and a Wilcoxon test (see, e.g. Allison, 1995) show the difference between the survival functions to be highly significant. The chi-square statistics are 9.45 and 9.66, respectively, significant at the 1%-level for 1 d.f. The survival functions for patents with and without private venture capital are similar (not shown), and with respect to other external financing, the survival function is lower (higher commercialization rate) for those patents with no other external financing (not shown).

******** [Figure 2] ********

******** [Figure 3] ********

[12] Preliminary, time dummies for individual application years were used. But one of the models (the gamma model) did not converge for some reason. Therefore, time dummies for two-year periods are instead used. 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 during the 1987-89 period. Therefore, 1985, 1986 and 1990 have been merged into one group.

5.1 Estimations of the Accelerated Failure Time model

The AFT-model is run using three different variants to test for robustness: Model I with region dummies, Model 2 with technology dummies and Model III with both region and technology dummies. Furthermore, there are five different models based on the residual distributions: the exponential, Weibull, log-logistic, log-normal and gamma models. Before turning to the estimated parameters of the explanatory variables, I first analyze the goodness-of-fit statistics of the models.

Goodness-of-fit tests based on the log-likelihoods of the models are presented in Table 6. The gamma model, which is the most general model, has the highest log-likelihood. The other models are tested against this model. As can be seen, the exponential, the Weibull and the log-normal models are all rejected. The log-logistic model has a very low log-likelihood, but it is not nested with the other models. No test can therefore be applied.

******** [Table 6] ********

Another way of analyzing goodness-of-fit is to consider the hazard function, which is closely connected to the residual characteristics of the different models. In Figure 2, the hazard function is a declining function, but not monotonously decreasing The exponential model corresponds to a constant hazard function, the Weibull model to a monotonously declining or increasing hazard and the log-normal to an inverted U-shape hazard. Thus, it is not surprising that these models are rejected. A log-logistic model may also have a declining hazard, provided that the scale parameter is estimated to be larger than 1. In the estimation of the log-logistic model**,** the scale parameter equals 3.1. However, the log-logistic hazard is then – like the Weibull model – monotonously declining. Based on the hazard function in Figure 2, it is therefore somewhat dubious whether the log-logistic model is appropriate.

The estimations of both the log-logistic and the gamma models are shown in Table 7, but I rely most on the gamma model, since this is the most flexible model. The parameter estimates are higher in the log-logistic model, reflecting the fact that this model has a high value of estimated scale parameter. The significance levels of the estimated parameters are similar across the log-logistic and gamma model, with the exceptions of *UNIV*, which is significant in the log-logistic model. However, the results are robust across Models I-III, where different dummy variables for regions and technologies are included, within each of the two residual models. As expected, the estimated time until commercialization starts is significantly shorter for the three firm-size groups (*FIRM1-FIRM3*)**,** as compared to individuals. Thus, patents owned by firms have a shorter time until commercialization starts**,** as compared to patents owned by individuals, indicating that firms have more complementary financial, manufacturing and marketing capabilities. However, the difference between the three firm groups is not significant. The quantitative interpretation of the estimated parameters in the gamma Model III is as follows: if the firm group dummies take on the value of 1 instead of 0, the survival time decreases by 43.0%, 36.7% and 45.1% for *FIRM1*, *FIRM2* and *FIRM3*, respectively, as compared to individuals.[13] Since the AFT-model is not a proportional hazard model, the *quantitative* interpretation of the estimated parameters can only be made in terms of survival time. However, a longer survival time is equivalent to a lower conditional probability (hazard) of commercialization in each time period and, accordingly, a lower probability of the patent being commercialized in the long run.

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

Turning to the financial variables, *GOVFIN* has a positive and strongly significant influence on survival time in all estimations. The quantitative interpretation of the estimated parameter in the gamma Model III is as follows: if government financing during the R&D-phase increases by 1 unit (in this case one percentage unit), survival time increases by 1.21%. This is equivalent to the conditional probability (the hazard) of commercialization being lower in each time period, thereby implying a lower probability of the patent being commercialized. It may be suspected that the government's loan conditions create a sample selection bias of patents with no or bad perspectives of commercialization. It is likely that many of the inventions behind the patents would never have been patented without government assistance. The loan conditions also deter many good patents from being commercialized, since the repayment, which is connected to the turnover, erases the profit. If it is considered that

[13] The quantitative interpretation of the effect of the explanatory variables (also dummies) on survival time is done in the following way. If the explanatory variable increases by 1 unit, the survival time changes by $100(e^{\beta}-1)\%$.

this selection bias would "disturb" the estimated effects of the other explanatory variables in the regressions, then it is fortunate that the variable, which creates this disturbance, *GOVFIN*, is actually included in the estimations. It is likely that *GOVFIN* will take account of the pool of bad patents.

An alternative interpretation of the bad performance of government-financed patents is that the government might assist patent projects with a higher risk level. As described in Table 3, the government mostly assists individual inventors with financing. Such patent projects should have a higher risk. Therefore, the effect of *GOVFIN* should be separately estimated for firms and individuals. In the first column of Table 8, an interactive dummy is used for *GOVFIN*. The estimated parameter of the interaction dummy is not significant, thereby indicating that there is no significant difference with respect to *GOVFIN* between individuals and firms. The parameter estimate for individuals is significant at the one-percent level and has a value of 0.011, which**,** in quantitative terms**,** means that the survival time increases by 1.11%**,** if government financing increases by a one-percent unit. For firms, the parameter estimate is 0.0173 (0.0112 + 0.0061), but it is only significant at the ten-percent level. If government financing increases by one percentage unit, the survival time for firm patents increases by 1.75%.

The estimated parameter of *PRIVFIN* has the expected negative sign, but is never significant. *OTHFIN* never turns out to have any significant effect. *UNIV* has the expected positive influence, but it is only significant in the log-logistic model. The university researchers have a commercialization rate of only 34% as compared to 61% in the whole sample. A problem here is that the typical inventor (but not all of them) who receives external financing from universities and research foundations (i.e. *OTHFIN* has a positive value) is a university researcher. Thus, *OTHFIN* and *UNIV* partly measure the same thing. The correlation between the two variables is 0.52 (see Appendix Table A1), not extremely strong, but maybe sufficiently strong to disturb the estimations. In the second and third columns of Table 8, one of the two variables is alternatively excluded when running the gamma model III. However, neither *OTHFIN* nor *UNIV* is significant.

KOMPL has a negative and significant impact on the survival time. If complementary patents are needed to create a product, then the survival time decreases by 30.4 percent. Neither *MOREPAT* nor *INVNMBR* turn out to have any significant impact on the commercialization decision. *INVNMBR* is dropped in the fourth column of Table 8**.** The other parameter estimates are not affected.

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

5.2 Estimations of the Cox Proportional Hazard model

The same seven model specifications with respect to explanatory variables that were run for the gamma AFT-model are also estimated by using the Cox model in Table 9. All firm group dummies have a significant influence on the hazard. In quantitative terms, the hazard is around 58%, 48 and 72 percent higher for medium sized firms, small firms and close companies, respectively, than for inventors.

The parameter of *GOVFIN* is highly significant with the expected negative influence on the hazard. In quantitative terms, the hazard decreases by 0.9%**,** if government financing increases by one percentage unit. Also in this case, there is no significant difference between inventors and firms (see columns 4-7). If government financing increases by one percentage unit, the hazard for inventors decreases by 0.8%. For firms, the parameter estimate is -0.0118 (-0.0077 - 0.0041), but only significant at the 10 percent level. If government financing increases by one percentage unit, the hazard for firms decreases by 1.2%. *PRIVFIN* has no significant influence on the hazard. *OTHFIN* has only a significant and negative impact on the hazard, when the university dummy is excluded in the fifth run.

Another difference between the gamma AFT- and Cox models is that *UNIV* turns out to have a significant and negative impact on the hazard, which is in line with the hypothesis. In quantitative terms, the hazard is 51-60% lower for university patents compared to other patents. A similar result was obtained in the log-logistic AFT-model – a positive and significant impact on the survival time – but not in the gamma model. *KOMPL* has a strong influence on the commercialization decision also in the Cox model. If complementary patents are needed to create a product, the hazard increases by 51-57%.

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

I consider the results from the gamma AFT-model as the most reliable, since this was the most flexible model, which also made interval censoring possible. The results from the AFT- and Cox models are at least not contradictory. Additive dummies for unique owners (firms/inventors) were also included in the estimations, but this did not work out well. Among the 867 patents in the sample, there are 740 unique owners (firms/inventors). 663 owners have only one granted patent in 1998, 54 owners have two patents, and only 23 owners have at least three patents. Dummies can only be assigned to the 77 owners with at least 2 patents. However, when including dummies for unique owners, the AFT gamma model never converged, the AFT log-logistic model and the Cox model were characterized by severe multicollinearity problems with extremely high standard errors. 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 patents.

6. Concluding remarks

In the present study, survival models were run to estimate how different explanatory factors affect the decision that patents are commercialized. This has never previously been done. A unique database on Swedish patents, owned by small firms and individuals, was used. Here, it is possible to observe if and when the patents were commercialized, i.e. whether the owners put effort into introducing innovations in the market. Such data has not been available in previous studies. In particular, I have analyzed how financing during the R&D-phase influences the probability of patents being commercialized. External financing from government institutions, private venture capitalists as well as universities and research foundations was analyzed. This distinction is interesting, since as compared to the U.S. where external financing mainly occurs on a private market, Sweden has, for a long time, relied on government support.

The most interesting conclusion from the estimations is that the larger is share of the costs covered by financial support from government institutions during the R&D-phase, the longer it takes until the commercialization starts. An equivalent interpretation is that the conditional probability (the hazard) for commercialization is lower in each time period for these patents, implying a higher probability that they will never be commercialized at all. One potential explanation is that the bad performance of government financed patents depends on moral hazard problems, due to the design of the government loans. The borrower can avoid paying back the loan if the project fails, or if the patent is not commercialized. If commercialization is undertaken, repayment is connected to the turnover. This means that patents that have a low or medium expected profit would seldom be commercialized. Private venture capital firms, on the other hand, are repaid as a share of the profit. Thus, there is always an incentive for the owners to commercialize, even if the expected profit is low. In fact, it seems that government financing creates a pool of patents, which have few perspectives of commercialization. Many of the owners of these inventions would never apply for a patent at all, had it not been for the design of government loans.

An alternative explanation for the low commercialization rate among government projects would be that the government chooses to lend money to riskier projects than the average. For example, patent projects owned by individuals should be riskier than firm projects. By using an interaction dummy in the estimations, it is possible to take account of this effect of riskier projects. The estimations showed that government projects had a longer time period until commercialization started, both within the group of projects owned by individuals and for projects owned by firms. Although there is no significant difference between individuals and firms, the effect is not so statistically strong for firms. Finally, there is also a possibility that the bad performance of government projects depends on government employed administrators having no profit incentives and, consequently, no incentives to find promising patent projects to which to lend money. Thus, there might be problems with adverse selection.

Patents with private external financing during the R&D-phase are commercialized to the same extent as patents on average. On the other hand, university patents have a significantly lower conditional probability of commercialization in some of the estimations. Different sizes of firms had a strongly significant impact on the commercialization decision in the estimations. Patents created in firms (medium-sized and small firms as well as close companies) are commercialized more quickly and with a higher probability than patents owned by individuals, thereby indicating how important complementary resources, like financing, marketing and manufacturing, are for commercialization.

Considering policy implications, the government should change the design of the loans. All loans should also be repaid to the government, even if the project fails or the patent is never commercialized. This would deter opportunists with bad inventions from applying for government loans. Furthermore, the repayment should be connected to the profit of the commercialization, instead of the turnover. Then, there are incentives to commercialize, even if the expected profit is low.

This study does not draw any conclusions on whether the government should support firms and inventors with external capital. There might be other positive effects of government financing beyond our measure (commercialization). For example, one argument for the government to intervene in the market would be that there are knowledge spillovers from patenting with a positive impact on social welfare. However, the most important argument for government intervention is that there might be imperfections in the market for external financing. As could be seen in Table 2, 16% of the patents had government financing during the R&D-phase, whereas only 6% had private financing. According to Braunerhjelm (1999, 2000), there is a lack of private venture capital in the early R&D-phases in Sweden, which is due to the tax system. The tax system discourages: 1) PVC-firms from investing in small projects and start-up firms; as well as 2) private persons, or “business angels”, from investing in non-listed projects and close companies. Changes are especially urgent with respect to taxation of PVC-firms and close companies. Compared to government institutions, PVC-firms also have the advantage that not only do they supply financial resources, but also networks and competence in the form of marketing and management.

Finally, I give some suggestions for future research. In the present study, I have analyzed how different factors affect the choice of commercializing patents or not. I have not measured the value of the innovation. There are further steps to investigate, for example how different factors influence the performance of the commercialization. Some kind of patent projects might have a higher expected profit level than others, depending on their characteristics (e.g., financing, risk, technology). The probability of success, and the expected profit given that the project is successful, are other success dimensions to investigate and to which the explanatory factors can be related.

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Figure 1. Application year and starting year of commercialization, number of patents.

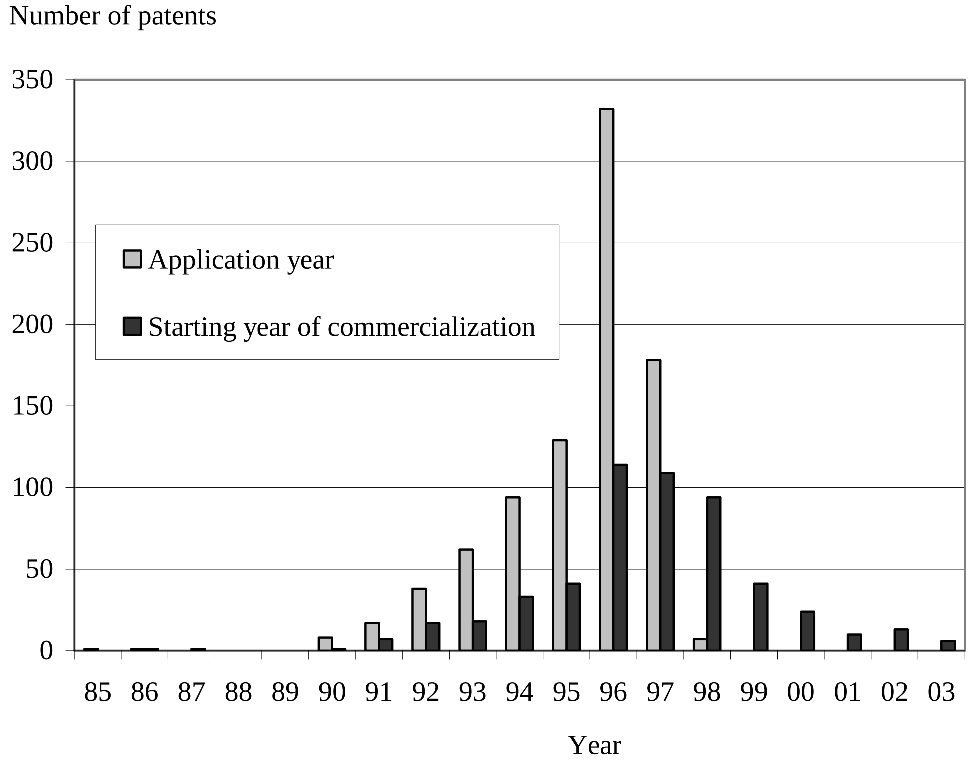

Figure 2. Survival distribution and Hazard functions for Swedish patents.

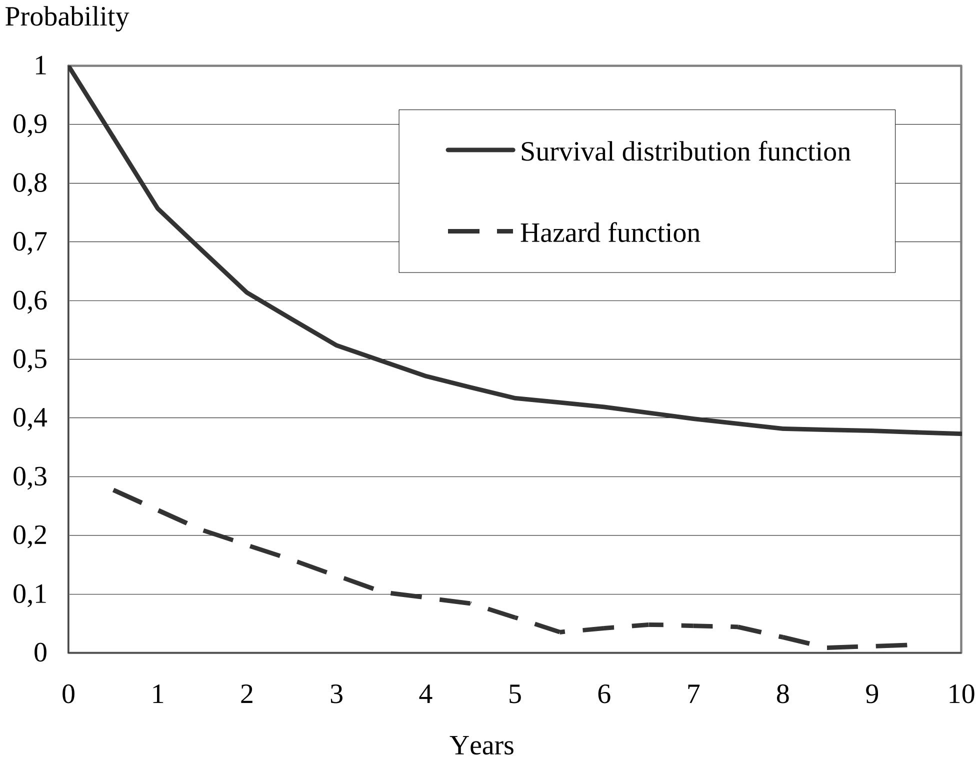

Figure 3. Survival distribution and Hazard functions across financing for Swedish patents.

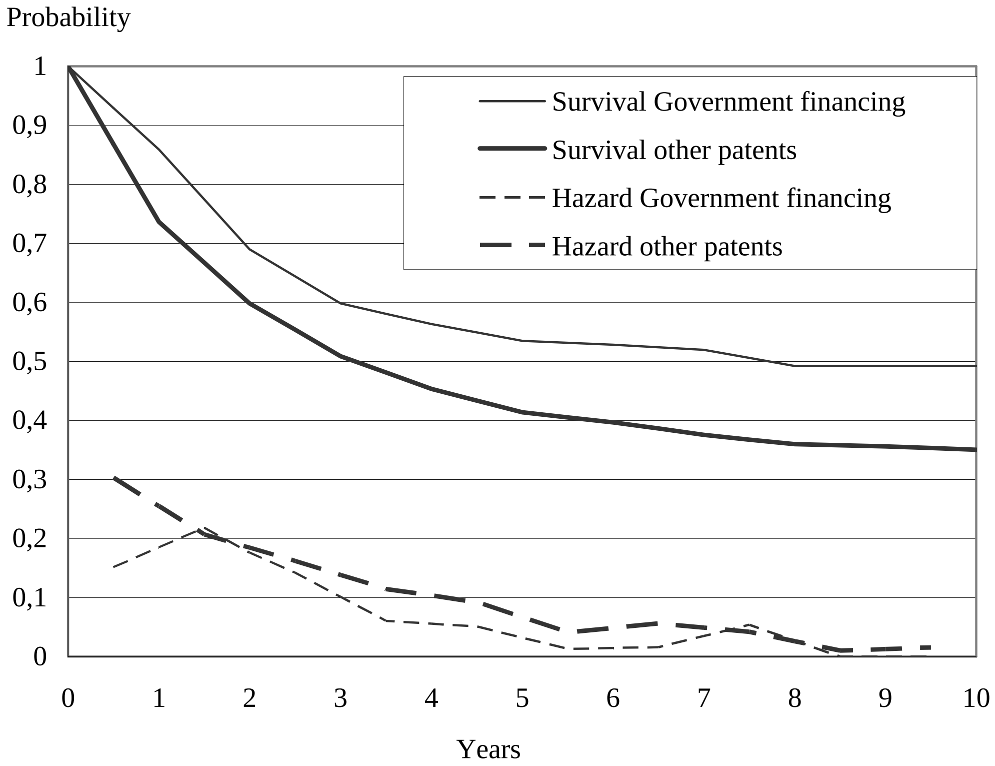

Table 1. Commercialization of patents across firm sizes and inventors' ownership, number of patents and percent.

Kind of firm where invention was created	Number of patents: Commercialization Yes	Commercialization No	Total	Percent Commercialized
Medium-sized firms (101-1000 employees)	77	39	116	66 %
Small firms (11-100 employees)	137	64	201	68 %
Close companies (2-10 employees)	105	37	142	74 %
Inventors (1-4 inventors)	211	197	408	52 %
Total	**530**	**337**	**867**	**61 %**

Table 2. External financing during the R&D-phase and commercialization, number of patents and percent.

Any external financing				
External financing during the R&D-phase	Commercialization Yes	Commercialization No	Total	Percent
No	422	238	660	63.6 %
Yes	108	99	207	52.2 %
Total	530	337	867	61.1 %
Chi-square-test = 9.18 ***				
Government external financing	Commercialization Yes	Commercialization No	Total	Percent
No	460	265	725	63.4 %
Yes	70	72	142	49.3 %
Total	530	337	867	61.1 %
Chi-square = 10.01 ***				
Private venture capital	Commercialization Yes	Commercialization No	Total	Percent
No	500	319	819	61.1 %
Yes	30	18	48	62.5 %
Total	530	337	867	61.1 %
Chi-square = 0.04				
Other external financing (e.g., universities, research foundations)				
Other external financing	Commercialization Yes	Commercialization No	Total	Percent
No	513	318	831	61.7 %
Yes	17	19	36	47.2 %
Total	530	337	867	61.1 %
Chi-square = 3.06 *				

Note: 207 patents have external financing, but some patents have external financing from more than one source.

Table 3. External financing across firm groups, number of patents.

Firm groups	Number of patents with external financing during the R&D-phase: Government financing	Private financing	Other financing	Total number of patents
Medium-sized firms	3	1	4	116
Small firms	3	7	6	201
Close companies	25	3	0	142
Inventors	111	37	26	408
Total	142	48	36	867

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

Patents still alive 2004	Commercialized patents latest in 2003: Yes	No	Total	Percent Commercialized
Yes	341	139	480	71 %
No	189	198	387	49 %
Total	530	337	867	61 %
Percent still alive	64 %	41 %	55 %	

Note: Chi-square-value is 44.46, significant at the 1 percent level for 1 d.f.

Table 5. Descriptive statistics and hypotheses for the explanatory variables.

Denotation	Description	Mean	St.dev.	Expected impact on survival time
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 close companies (2-10 employees), and 0 otherwise	0.16	0.37	-
GOVFIN	Percent of R&D financed by government	7.69	21.1	+
PRIVFIN	Percent of R&D financed by private venture capital	3.14	14.4	-
OTHFIN	Percent of R&D financed by universities/research foundations	2.73	14.4	+
UNIV	Dummy that equals 1 if the patent was created at a university, and 0 otherwise	0.04	0.19	+
KOMPL	Dummy that equals 1 if complementary patents are needed to create a product, and 0 otherwise	0.23	0.42	?
MOREPAT	Dummy taking the value of 1 if the inventors have more similar (competitive) patents, and 0 otherwise	0.41	0.49	?
INVNMBR	Number of inventors of the patent	1.34	0.66	?

Table 6. Goodness-of-fit tests with Likelihood-ratio statistics.

Model	Log-likelihood	Test between models	d.f.	Likelihood-ratio Chi-square statistics
Exponential	-1567.85	Exponential vs. Weibull	1	77.96 ***
Weibull	-1528.87	Exponential vs. Gamma	2	217.62 ***
Log-logistic	-1971.33	Weibull vs. Gamma	1	139.66 ***
Log-normal	-1488.16	Log-normal vs. Gamma	1	58.24 ***
Gamma	-1459.04			

Note: The log-likelihoods are taken from Model III. ***, ** and * indicate significance at the 1, 5 and 10 percent level, respectively. The conclusion with respect to significance of the tests would be the same, if log-likelihoods from Models I or II are used. The log-logistic model is not nested with the other models.

Table 7. Empirical estimations of the AFT-model.

Dependent variable	log (*T*)					
Statistical model	Accelerated failure time (AFT) model					
Explanatory variables	Log-logistic model			Gamma model		
	Model I	Model II	Model III	Model I	Model II	Model III
FIRM1 (dummy)	-1.69*** (0.632)	-1.69*** (0.641)	-1.58** (0.643)	-0.602*** (0.214)	-0.663*** (0.219)	-0.562*** (0.218)
FIRM2 (dummy)	-1.84*** (0.536)	-1.71*** (0.546)	-1.68*** (0.548)	-0.554*** (0.174)	-0.521*** (0.178)	-0.457** (0.178)
FIRM3 (dummy)	-2.31*** (0.562)	-2.48*** (0.568)	-2.46*** (0.568)	-0.578*** (0.192)	-0.667*** (0.193)	-0.599*** (0.193)
GOVFIN	0.040*** (0.011)	0.035*** (0.012)	0.036*** (0.012)	0.010*** (3.0 E-3)	0.011*** (3.2 E-3)	0.012*** (3.0 E-3)
PRIVFIN	-0.020 (0.014)	-0.013 (0.015)	-0.014 (0.015)	-4.5 E-3 (4.5 E-3)	-3.8 E-3 (4.9 E-3)	-4.1 E-3 (4.8 E-3)
OTHFIN	0.018 (0.018)	0.021 (0.018)	0.022 (0.018)	1.7 E-3 (5.8 E-3)	6.3 E-3 (6.4 E-3)	6.8 E-3 (6.3 E-3)
UNIV (dummy)	3.48** (1.48)	4.09*** (1.50)	4.00*** (1.51)	0.469 (0.390)	0.740* (0.434)	0.484 (0.449)
KOMPL (dummy)	-1.60*** (0.462)	-1.76*** (0.467)	-1.67*** (0.467)	-0.355** (0.158)	-0.409** (0.162)	-0.363** (0.160)
MOREPAT (dummy)	-0.630 (0.421)	-0.470 (0.420)	-0.579 (0.422)	-0.043 (0.136)	-9.2 E-3 (0.136)	-0.039 (0.134)
INVNMBR	0.324 (0.320)	0.368 (0.329)	0.355 (0.329)	0.021 (0.105)	8.6 E-3 (0.111)	-7.1 E-3 (0.109)
Region dummies (5 d.f.)	6.17	-----	5.74	7.32	-----	10.97*
Technology dummies (25 d.f.)	-----	22.63	22.16	-----	25.49	30.09
Time dummies (4 d.f.)	10.45**	9.76**	9.90**	1.96	3.24	2.79
Scale parameter, σ	3.17	3.13	3.12	1.44	1.34	1.25
Shape parameter	-----	-----	-----	-1.82	-2.02	-2.21
Log-likelihood	-1982.27	-1974.18	-1971.33	-1472.94	-1464.58	-1459.04
Likelihood-ratio test	109.38***	125.56***	131.26***	67.84***	84.56***	95.64***

Note: The total number of observations equals 867, 530 of which are interval-censored observations and 337 right-censored. Standard errors are in parentheses and ***, ** and * indicate significance at the 1, 5 and 10 percent level, respectively. For the region, technology and time dummies, only Wald chi-square values for the whole group of dummies are shown. Intercepts as well as individual region, technology and time dummies are available from the author upon request.

Table 8. Robustness tests of the AFT-model, gamma model.

Dependent variable	log (*T*)			
Statistical model	Accelerated failure time (AFT) model			
Explanatory variables	Gamma model			
	Model III	Model III	Model III	Model III
FIRM1	-0.567***	-0.585***	-0.579***	-0.575***
(dummy)	(0.218)	(0.217)	(0.218)	(0.217)
FIRM2	-0.469***	-0.481***	-0.462***	-0.458**
(dummy)	(0.179)	(0.179)	(0.180)	(0.179)
FIRM3	-0.641***	-0.649***	-0.648***	-0.645***
(dummy)	(0.207)	(0.208)	(0.207)	(0.206)
GOVFIN	0.011***	0.011***	0.011***	0.011***
	(3.1 E-3)	(3.0 E-3)	(3.1 E-3)	(3.1 E-3)
*GOVFIN*D*	6.1 E-3	6.7 E-3	6.0 E-3	5.9 E-3
	(0.010)	(0.010)	(0.010)	(0.010)
PRIVFIN	-4.0 E-3	-4.5 E-3	-3.8 E-3	-3.7 E-3
	(4.8 E-3)	(4.8 E-3)	(4.7 E-3)	(4.7 E-3)
OTHFIN	6.8 E-3	7.6 E-3	-----	-----
	(6.3 E-3)	(6.5 E-3)		
UNIV	0.473	-----	0.546	0.568
(dummy)	(0.452)		(0.469)	(0.458)
KOMPL	-0.362**	-0.360**	-0.345**	-0.343**
(dummy)	(0.159)	(0.159)	(0.159)	(0.158)
MOREPAT	-0.033	-0.030	-0.023	-0.021
(dummy)	(0.134)	(0.133)	(0.134)	(0.134)
INVNMBR	-3.6 E-3	0.013	0.024	-----
	(0.109)	(0.106)	(0.106)	
Region dummies (5 d.f.)	11.16**	12.75**	10.94*	11.00*
Technology dummies (25 d.f.)	30.63	32.11	29.84	29.92
Time dummies (4 d.f.)	2.80	3.14	2.82	2.88
Scale parameter, σ	1.24	1.16	1.23	1.23
Shape parameter	-2.23	-2.47	-2.27	-2.27
Log-likelihood	-1458.87	-1459.37	-1459.41	-1459.43
Likelihood-ratio test	95.98***	94.98***	94.90***	94.86***

Note: The total number of observations equals 867, 530 of which are interval-censored observations and 337 right-censored. Standard errors are in parentheses, and ***, ** and * indicate significance at the 1, 5 and 10 percent level, respectively. For the region, technology and time dummies, only Wald chi-square values (never significant) for the whole group of dummies are shown. Intercepts as well as individual region, technology and time dummies are available from the author upon request.

Table 9. Empirical estimations of the Cox proportional Hazard model.

Dependent variable	log $h(t)$						
Statistical model	Cox proportional Hazard model						
Explanatory variables	Model I	Model II	Model III	Model III	Model III	Model III	Model III
FIRM1	0.408***	0.470***	0.460***	0.474***	0.514***	0.470***	0.442***
(dummy)	(0.144)	(0.149)	(0.149)	(0.151)	(0.151)	(0.151)	(0.150)
FIRM2	0.381***	0.373***	0.393***	0.403***	0.440***	0.404***	0.395***
(dummy)	(0.119)	(0.121)	(0.123)	(0.124)	(0.124)	(0.125)	(0.124)
FIRM3	0.482***	0.535***	0.544***	0.568***	0.606***	0.574***	0.571***
(dummy)	(0.125)	(0.130)	(0.130)	(0.136)	(0.136)	(0.136)	(0.136)
GOVFIN	-8.8 E-3***	-8.0 E-3***	-8.6 E-3***	-7.7 E-3**	-7.6 E-3**	-7.6 E-3**	-7.5 E-3**
	(2.8 E-3)	(2.8 E-3)	(2.9 E-3)	(3.2 E-3)	(3.1 E-3)	(3.2 E-3)	(3.2 E-3)
*GOVFIN*D*	-----	-----	-----	-4.1 E-3	-4.3 E-3	-4.1 E-3	-3.7 E-3
				(6.9 E-3)	(6.9 E-3)	(6.8 E-3)	(6.9 E-3)
PRIVFIN	4.9 E-3	4.4 E-3	4.5 E-3	4.5 E-3	3.2 E-3	4.6 E-3	4.5 E-3
	(3.0 E-3)	(3.2 E-3)	(3.1 E-3)	(3.1 E-3)	(3.1 E-3)	(3.1 E-3)	(3.2 E-3)
OTHFIN	-3.4 E-3	-3.2 E-3	-3.5 E-3	-3.5 E-3	-7.9 E-3**	-----	-----
	(4.0 E-3)	(4.3 E-3)	(4.3 E-3)	(4.3 E-3)	(4.0 E-3)		
UNIV	-0.715**	-0.800**	-0.794**	-0.790**	-----	-0.917***	-0.930***
(dummy)	(0.348)	(0.369)	(0.372)	(0.372)		(0.341)	(0.340)
KOMPL	0.414***	0.449***	0.436***	0.436***	0.413***	0.434***	0.439***
(dummy)	(0.103)	(0.107)	(0.107)	(0.107)	(0.107)	(0.107)	(0.107)
MOREPAT	0.068	0.046	0.075	0.076	0.084	0.079	0.076**
(dummy)	(0.094)	(0.097)	(0.098)	(0.098)	(0.097)	(0.098)	(0.098)
INVNMBR	-0.064	-0.097	-0.101	-0.103	-0.100	-0.111	-----
	(0.071)	(0.077)	(0.078)	(0.078)	(0.077)	(0.077)	
Log-likelihood	-1380.58	-1374.75	-1369.98	-1369.80	-1372.39	-1370.15	-1371.23
Likelihood-ratio test	95.45***	107.12***	116.65***	117.02***	111.83***	116.31***	114.15***

Note: The total number of observations equals 867, 337 of which are right-censored. Standard errors are in parentheses, and ***, ** and * indicate significance at the 1, 5 and 10 percent level, respectively. Time dummies are included in all runs, region dummies in models I and III, and technology dummies in models II and III. Estimates of intercepts as well as individual region, technology and time dummies are available from the author upon request.

APPENDIX

Table A1. Pearson correlation matrix for the explanatory variables.

FIRM2	-0.22***								
FIRM3	-0.17***	-0.24***							
GOVFIN	-0.10***	-0.19***	-0.03						
PRIVFIN	-0.06*	-0.06*	-0.05	-0.06*					
OTHFIN	0.02	-0.04	-0.08**	-0.05	0.10*				
UNIV	-0.08**	-0.11***	-0.09**	0.03	0.20***	0.53***			
KOMPL	0.10***	0.04	0.04	-0.05	0.06*	0.09*	0.11**		
MOREPAT	0.12***	0.12***	0.05	0.13***	0.10***	-0.01	-0.04	0.19***	
INVNMBR	0.08**	0.02	-0.04	0.04	0.14	0.25***	0.14***	0.05	0.09***
	FIRM1	*FIRM2*	*FIRM3*	*GOVFIN*	*PRIVFIN*	*OTHFIN*	*UNIV*	*KOMPL*	*MORE-PAT*

Note: The number of observations equals 867. ***, ** and * indicate significance at the 1, 5 and 10 percent level, respectively.