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Abstract
According to Schumpeter, the creative process of economic development can be divided into the three distinguishable stages of invention, innovation (commercialization) and imitation. Following this theory, invention and innovation require different skills. This paper tests whether the invention and innovation stages should be undertaken by different agents. We also show why there is a rationale for the Schumpeterian entrepreneur to also include the inventor in the innovation process. Merging the two enhances the possibilities of successful commercialization since the inventor may further adapt the innovation to customer needs, transmit information and reduce uncertainty. This serves to expand the market opportunities for the entrepreneur. The empirical analysis is based on a survey covering Swedish patents granted to individuals and small firms. The results show that profitability increases by 21 percent when the patent is licensed or sold to an entrepreneur, or if the inventor is employed in an entrepreneurial firm, as compared to commercialization undertaken by the inventor. Another important result is that, irrespective of commercialization mode, an active involvement of the inventor is shown to have a positive impact on performance.

Key words: Entrepreneur, inventor, innovations, commercialization.

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1. Introduction

Perhaps more than any other economist, Schumpeter (1911) is explicit about the economic function of the entrepreneur. By introducing innovations to the market, the entrepreneur distorts the prevailing equilibrium, challenges existing structures and sets industrial dynamics and economic development into motion. According to Schumpeter, the process of economic development can be divided into three clearly separate stages. The first stage implies technical discovery of new things or new ways of doing things, which Schumpeter refers to as invention. In the subsequent stage innovation occurs, i.e. the successful commercialization of a new good or service stemming from technical discoveries or, more generally, a new combination of knowledge (new and old). The final step in this three-stage process – imitation – concerns a more general adoption and diffusion of new products or processes to markets.

For our purpose, the interesting part consists of the separation between the stages of invention and innovation. Schumpeter (1947, p.149) himself claims that “the inventor produces ideas, the entrepreneur ‘gets things done’ ….. an idea or scientific principle is not, by itself, of any importance for economic practice.” Thus, Schumpeter views the creation of technological opportunity as being basically outside the domain of the entrepreneur. Rather, the identification and exploitation of such opportunities is what distinguishes entrepreneurs, i.e., innovation. Nor did Schumpeter view entrepreneurs as risk-takers, even though he did not completely dismiss the idea and was aware that innovation contains elements of risk also for the entrepreneur. But basically, that task was attributed the capitalists who financed entrepreneurial ventures.

This paper seeks to answer two questions associated with the way Schumpeter disconnected inventions and innovators. The first is simply whether Schumpeter was right on this issue and to what extent disconnecting the stages influences the success of commercialization. Focusing on entrepreneurs and small firms, does invention and innovation take place in independent units and to what extent is commercialization performance influenced by the degree of integration of these activities? What are the strategic implications for inventors that consider entering the market? Over the last decades, there are plenty of examples of fast-growing entrepreneurial firms that are based on individuals’ inventions, where Microsoft probably constitutes the most conspicuous case of a successful combination of the inventor and innovator role. However, there is also ample evidence of the opposite. Going back a few decades, but remaining within the same industry, William Shockley’s invention known as the semiconductor was brilliant. Still, his company – Shockley’s Semiconductors – performed less well but inspired several entrepreneurial employees who later choose to leave and try their own inventive and innovative capabilities (the “traitorous eight"). More recently, entrepreneurial firms like Google and e-Bay have implemented (and refined) existing to technologies to exploit entrepreneurial opportunities. Thus, judging from anecdotic evidence, there seem to be examples of both inventors and innovators that have successfully commercialized new products.

The second question concerns the involvement of the inventor in the commercialization process. More precisely, can we observe that entrepreneurs and small firms that actively involve the inventor in the commercialization of new products are more profitable? This is associated with the way inventive activities are organized, i.e. the degree of vertical integration of inventive and innovative stages and access to complementary assets, which can be traced to the environment in which they operate. In particular, the institutional design and the structure of the market are decisive (Teece 1986). This issue has not been empirically examined in the previous literature, with the exception of more explorative studies.[1]

We argue that the integration of the two stages may, in fact, be considered part of entrepreneurial ability as envisioned in the Schumpeter world. That is, reflecting the "combinatorial capability" required for successful commercialization. It is also likely to reduce uncertainty in entrepreneurial activities, as defined by Knight (1921), since commercialization may also imply adaptation of the original invention to specific market and firm conditions. Such adaptation is likely to rely on the private knowledge embodied in the inventor. In addition, the entrepreneur also reduces the risks of being exposed to increased competition from follow-up innovations by the inventor, or from other firms to which the inventor may find it profitable to license an invention. In fact, this suggests a bridge between Knight's and Schumpeter's approaches to entrepreneurship.

To empirically address these issues, we will implement a unique database on Swedish patents granted to individuals and small firms. Data is collected through a survey with a response rate of 80 percent. In particular, the database contains information about the extent of commercialization of individual patents, whether the commercialization was successful and the role of the inventor in the commercialization process. Using discrete statistical models, we empirically examine how different explanatory factors (e.g., commercialization mode, firm type, activity of inventors) affect the performance. To the best of our knowledge, such an

[1] Taking all firms into account, irrespective of size, there has been a clear tendency in the 20th century towards an increased vertical integration of inventive (R&D) and producing activities according to for instance Teece (1988) and Aghion and Howitt (1998). Others challenge those findings and claim that technological progress and institutional changes have facilitated a vertically dispersed production structure (Arora et al. 2001; Grossman and Helpman 2002).

empirical analysis, where explanatory factors are related to the performance of patent commercialization, has not previously been carried out. [2]

The paper is organized as follows. Section 2 presents a brief discussion of the inventor and the entrepreneur, drawing on previous insights in industrial organization theory, contract theory and the strategic management literature. The database and basic statistics are described in section 3. The statistical model is set up and explanatory variables are described in section 4. The empirical estimations are shown in section 5, and the final section concludes.

2. Entrepreneurs, invention and innovation

Most contemporary theories of entrepreneurship build on the seminal contributions by Schumpeter (1911) who stressed the importance of innovative entrepreneurs as the main vehicle to move an economy forward from static equilibrium, Knight's (1921) proposed role of the entrepreneur as someone who transforms uncertainty into a calculable risk and, somewhat later, Kirzner's (1973) view that the entrepreneur moves an economy towards equilibrium (contrasting Schumpeter) by taking advantage of arbitrage possibilities. More generally, the research field of entrepreneurship has recently been defined as analyses of "how, by whom and with what consequences opportunities to produce future goods and services are discovered, evaluated and exploited" (Shane and Venkataraman, 2000).[3]

As regards by "whom", an eclectic definition of the entrepreneur, that has become increasingly accepted, is suggested by Wennekers and Thurik (1999). The entrepreneur: i) is innovative, i.e. perceives and creates new opportunities; ii) operates under uncertainty and introduces products to the market, decides on location, and the form and use of resources; and iii) manages his business and competes with others for a share of the market.[4] Apparently, this definition can be linked to all three contributions referred to above. Note that invention is not explicitly mentioned (albeit creation of opportunity is) in this definition, nor excluded from the interpretation of entrepreneurship. Thus, it deviates, but is not completely disentangled, from Schumpeter's (1911, p. 88-89) traditional view on innovation and invention:

> "Economic leadership in particular must hence be distinguished from 'invention'. As long as they are not carried into practice, inventions are economically irrelevant. And to carry any improvement into effect is a task entirely different from the inventing of it, and a task, moreover, requiring entirely different kinds of aptitudes. Although entrepreneurs of course may be inventors just as they may be capitalists, they are inventors

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[2] In fact, Teece (2006) stress the importance of empirical research addressing precisely these issues.

[3] A related strand of the literature focuses on differences in individual capabilities (Carroll and Hannan 2000), or the interaction between the characteristics of opportunity and the characteristics of the people who exploit them (Casson 2005). Schumpeter also considered individual's psychological capacity as the key in identifying opportunities.

[4] Here we adopt the somewhat modified version as introduced by Bianchi and Henrekson (2005).

not by nature of their function but by coincidence and vice versa ... it is, therefore, not advisable, and it may be downright misleading, to stress the element of inventions as much as many writers do".

Obviously, Schumpeter foresaw possible situations when the inventor role may coincide with the innovator, even though such situations were considered to be exceptions to the rule.

The Schumpeterian distinction between the role of the inventor and the entrepreneur has previously been challenged by Schmookler (1966). Based on case studies, he claimed that entrepreneurs discover opportunities to do promising R&D, rather than merely discovering promising outcomes of R&D that has been conducted by others. On a more aggregate level, the merging of the inventive and innovative stages is clearly stated in the neo-Schumpeterian growth models (Aghion and Howitt 1998). These models, however, share the later Schumpeter's (1942) view of innovation as becoming routinized, where markets become dominated by a limited number of large firms. Hence, this approach would not be well designed to analyze the aspects of Schumpeterian entrepreneurship addressed in this paper.

The Wennekers-Thurik definition of entrepreneurs also refers to uncertainty. Doubtlessly, Schumpeter was aware of the fact that new activities do involve elements of risk-taking, even though he did not stress that aspect as a dominating feature of entrepreneurship. Rather, the risk-taking part was orchestrated by capitalists that provided the finance required to embark on new ventures. It was Knight (1921) who developed the strand in entrepreneurial economics that stressed the entrepreneur's role as a risk-bearing agent that to some extent contrasted – but also complemented – Schumpeter's view.[5]

Thus, the earlier entrepreneurship literature suggests a plethora of different reasons as to why innovative activities are undertaken by entrepreneurs, and the specific attributes that characterizes entrepreneurs, but has little to say about the relationship between the inventor and the innovator. Since our research primarily aims to shed light on factors that explain successful commercialization, and the relationship between inventors and innovators in that process, the question is what guidance can be found in more recent theoretical contributions in the entrepreneurial literature?

2.1 The organization of inventive and innovative activities: Theoretical framework and hypotheses

[5] They were more aligned on other aspects of entrepreneurship. For instance, both Knight and Schumpeter shared the belief that entrepreneurial talent was a scarce resource. Such scarcity is not so much associated with entrepreneurs' alertness, or with their professionalism, as with their psychology. More recently, Lazear (2005) suggests that entrepreneurs posses more balanced talents that span a number of skills. This could be argued to strengthen their "combinatorial capacity", as compared to the more limited role of specialists. In the perspective of the issue we raise, the entrepreneur could be viewed as being endowed with multi-task talent, while the inventor is more of a specialist (Lindbeck and Snower 2000).

The role of the inventor in the commercialization process, and in the organization of innovative activities, can be traced to at least two strands in the contemporary economic literature. The first refers to contractual arrangements, uncertainty and transaction costs, while the second emphasizes the institutional setup, market structure and strategic consideration associated with innovative activities. These two strands are not mutually exclusive but stress different aspects of crucial importance to comprehend the organization of production activities characterized by experimentation and uncertainty, and the implications for commercialization. We will briefly refer to each of these strands in the literature.

Concerning the contractual aspects of organizing commercial activities that involves inventing and innovating segments, it goes back to Grossman and Hart's (1986) seminal article on vertical integration. The degree of integration is related to market characteristics and the ex ante uncertainty about the outcome of inventive activities. More precisely, consider the following basic structure of an economy, where agents are assumed perfectly informed. Let *v* denote the value of an innovation for the customer, while *e* refers to research efforts, and *E* captures investments by the entrepreneur required in the commercialization process. Assume the probability (*p*) of a successful innovation to be increasing, strictly concave and separable in e and *E*, then

$$p(e,E) = q(e) + r(E)\,. \qquad (1)$$

Both the inventor and the entrepreneur are assumed to be risk-neutral, and to have a reservation utility that equals zero ($q,\ r\ \geq 0$) while costs are assumed to be linear. The welfare maximization problem can then be written in the following way,

$$\max\{p(e,E)\ \ v - e - E\}. \qquad (2)$$

The equilibrium inputs of inventive and innovative efforts is then determined in a standard way by the first-order condition,

$$dq/de(e^{*}) = dr/dE(E^{*}) = 1\,. \qquad (3)$$

Hence, if perfect information prevailed about the outcome of the inventive activities, the equalization of the marginal contribution of research efforts and investments required for commercialization would form the basis of a contract between the inventor and the entrepreneur. However, as pointed out by Grossman and Hart (1986), the presence of asymmetric information between the inventor and the innovator, and the inherited uncertainty in such processes, incur excessive transaction costs in setting up and monitoring such contracts. Therefore, the alternatives available to the entrepreneur are to integrate – employ – the inventor, or to buy or license the invention once it has materialized. Similarly, the inventor must ponder whether to supply research efforts as an independent agent or if integration with an entrepreneur is more lucrative.

From a dynamic point of view, commercialization is likely to include a gradual adaptation (specific customer requirements) and follow-up inventions based on the original invention. In that case, the transmission of proprietary information is crucial for successful innovation, which may call for closer interaction between the entrepreneur and the inventor or research unit.[6] Assume that future inventions originate in the individual-specific knowledge of the inventor. Consider the *non-integrated case* where inventions are sequenced over two periods and knowledge transfers (e) between the inventor and the entrepreneur influence the occurrence of an innovation. The value of the innovation is split evenly between the inventor (α) and the entrepreneur ($1-\alpha$). If the inventor chooses to transfer information about invention in the first period, all revenue will be collected in that period. Alternatively, the inventor can wait to the second period and either commercialize the invention or sell the invention to another firm. The decision whether to transfer ($e=1$) knowledge or not ($e=0$) is non-contractible and must be incentive compatible, implying that[7]

$$\alpha_1 q_0 v_1 \geq v_2, \quad \alpha_1 \geq v_2 / q_0 v_1. \tag{4}$$

In the alternative, *integrated*, case the entrepreneur is dependent on knowledge transfers by the inventor to accomplish successful commercialization. If the invention – or the customers' required modification of the invention – is not transferred to the entrepreneur in the first period, the inventor will get half of the (expected) value in the first period. The reward to the inventor in the integrated case is then,

$$\alpha_1 q_0 v_1 \geq v_2 / 2, \quad \alpha_1 \geq v_2 / 2 q_0 v_1, \tag{5}$$

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[6] See Frankel (1955), Teece (1988) and Aghion and Howitt (1992).

[7] Where $p = q_0 e + r(E), \quad q_0 > 0$. See Aghion and Howitt (1998) for details.

implying that the costs (of invention) are lower in the integrated case as compared to the disintegrated case. Thus, in the case of incomplete contracts, there are strong incentives for entrepreneurs to vertically integrate with inventors or research units. Integrating the two stages implies cost savings and risk reduction.[8] In contrast to Schumpeter, we argue that integration of the inventive and innovative stages may be desirable since it facilitates communication between the entrepreneur and the inventor that serves to maintain competitiveness, facilitate customer-specific adaptation, and reduce the risks for the entrepreneur.

A more profound microeconomic basis as regards the strategic choice between commercializing an invention in an independent firm, or licensing it to an incumbent firm, is provided by Teece (1986; 2006). He describes his 1986 model as a "nascent neo-Schumpeterian theory".[9] Teece (1986) identified three key factors that determine whether it would be the inventor/innovator, the following firms, or firms with related capacity – or complementary assets – that extract the profits from an invention. Those factors are i) the institutions tied to intellectual property rights (IPRs), ii) the extent to which complementary assets were needed for commercialization, and, iii) the emergence of a dominant design.[10] Teece was thus not primarily preoccupied with the organizational regime between the inventor and the innovator rather he stressed the prerequisites governing the entry mode irrespective of whether it was the inventor or the innovator/entrepreneur that was about to launch a new product.

The first of these factors, the appropriability or IPR regime, concerns the possibilities to protect the core know-how needed for invention, The critical issue is whether "iron clad" patents rights prevails or, alternatively, whether the components of the new product or process could be kept secret, i.e. remain within the firm without the risk of being copied or subject to disclosure in some other way. Obviously, this is associated with the degree of tacitness of the knowledge embodied in the invention.[11]

The second factor, and perhaps the most insightful ingredient in Teece's framework, introduces the concept of complementary asset. Such assets could be described as

[8] Arora (1995) presents an alternative model for the specific case where tacit knowledge (embodied in the inventor) can be bundled with arm's length licensing contracts. The decisive factor is strong IPRs, which promote commercialization and a functioning market for know-how.

[9] Or, as noted in Teece (2006), partly based on Penrose (1959), partly on Schumpeter (1911).

[10] Note Scherer's (1980) contribution, who claimed that innovative entry by entrepreneurs and innovative entry by large firms seem to fulfill complementary roles in the process of turning an innovation into full-scale, welfare enhancing new production activities. Major innovations often emanate in a serendipitous way from individual entrepreneurs (Baumol 2007).

[11] As noted by Mansfield et al. (1981), it takes imitators about four years to duplicate an invention for approximately 65 percent of the original costs. Process technology innovation tends to leak somewhat slower than product innovation (Mansfield 1985).

competencies and resources needed to successfully introduce a product to the market. Examples are different kinds of after-sale services, marketing resources, specialized manufacturing assets, etc. More precisely, complementary assets allude to different functions that normally are resource demanding and costly to invest in, but strategically important in order to reach the market. The type and structure of such assets influence the mode of commercialization. In particular, the more generic character of such assets, the more risky for the inventor/innovator to undertake in investment in them. Teece also mentions the capability to provide follow-up innovations as a particular complementary asset.[12]

The final item mentioned by Teece is the emergence of a dominant design. Typically, an industry that has been in an evolutionary stage characterized by fluid knowledge, experimentation and uncertainty, will at some point adopt a dominant design that become standard. Such standards may effectively preclude entry even though novel products/processes may be superior (Abernathy and Utterback 1978; David 1985; Arthur 1989). Dynamic increasing returns to scale and path dependencies set in, and first mover advantage may become an important strategy. It is an evolutionary stage, which is particularly risky and difficult to predict.

To summarize Teece's (1986) article, the inventor/innovator entry strategy should be contingent upon the weight of different factors referred to above, and the character of complementary assets needed for commercialization (generic characteristics). In many circumstances the probability that the entrepreneur will emerge as the winner is low, particularly if intellectual property rights are weak. Basically, if the inventor seeks to enter a market where incumbent firms control complementary assets, development and prototyping costs are huge, and intellectual property rights are strong, then the optimal strategy of the inventor/innovator is to contract out the novel product/process through licensing or selling the patent. A functioning "market for ideas" is thus crucial in Teece's model. Moreover, it is not the market share of incumbents as such that matters, rather the "complementary" asset structure of the innovator, entry of timing and the contractual structure to access missing complementary asset.[13]

Building on Teece, Gans and Stern (2003) further develop the obstacles that firms encounter in the commercialization process.[14] Stressing the interaction between the inventor and the innovator, they argue that effective commercialization requires careful screening of the institutional environment in which firms operate. If IPRs are poor and no competitor has

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[12] Teece (1986) discusses this in terms of ccumulative innovations.

[13] Mansfield (1968) was perhaps the first to observe that there was no statistical relationship between concentration in an industry and rate of technological change.

[14] See also Gans, Hsu and Stern (2007), analyzing the impact of uncertainty and timing of entry, either as a start-up or in terms of licensing, high-technology products.

control of complementary assets it opens up opportunities for "attackers" and tend to foster integrated structures. On the other hand, if established firms control complementary assets (or markets depend on firms' reputational capital) then cooperation is the strategy to pursue. Successful commercialization depends on bargaining power and how incumbents could be outplayed against each other. Thus, the drivers of commercialization strategy are dependent on i) excludability environment, IPRs, and technological design, together with, ii) the complementary asset environment which often is costly to duplicate.[15]

Hence, being first to the market in order to pre-empt commercial opportunities for competitors is one option facing inventors. A first-mover advantage could originate in technological leadership, securing strategic assets or by implementing a dominant design that preclude later entrants due to the appearance of buyer and switching costs (Lieberman and Montgomery 1988). Being first to market is not however a guarantee for success. The most common reasons for first-mover disadvantages to accrue are that free-riders are likely to incur lower costs since they can take advantage of competitors outlays on R&D and information, enhance their learning and exploiting spillovers, as well as act from a position where potential market (and technological) uncertainties may have been resolved. Dominant incumbents may be slow innovators but could transform into highly aggressive followers. Again, this depends on the institutional regime and the market structure.

In summary, taking a dynamic perspective and drawing on theoretical insights, there seem to be compelling reasons why incumbent entrepreneurs should undertake commercialization. The absence of complementary assets in start-up firms, and the costly investments required to build up such assets, constitutes one set of reasons as to why established firms have an advantage as compared to inventors. In addition, several factors points to the advantages of integrating the inventive and innovative stages into the same organization, thereby contrasting Schumpeter's original ideas. An integrated structure should increase the probability of successful commercialization if communication of technological knowledge is important for commercialization, firms have previous experience in commercialization of inventions yielding a cost advantage as compared to start-ups by inventors, and if cooperation between inventors and entrepreneurs enhances technological and

[15] The type of innovation could also influence the strategic choice of entry, i.e. whether it is radical or incremental and to what extent the innovation challenges technological or organizational knowledge. Innovation characterized as a reshuffling of the way in which different components are linked to each other while the core concept remains – architectural innovation – often take place in larger firms and give smaller firms an innovative edge in terms of more flexibility (Henderson and Clark 1990).

market knowledge within a firm.[16] This could be condensed to the following two testable hypotheses:

Hypothesis 1: If the inventor sells or licenses the patent, or if the inventor is employed (and not owner) by a firm which commercializes the patent, then the performance of the commercialization should be more profitable as compared to commercialization undertaken by the inventor.

Hypothesis 2: If the inventor is active in the commercialization process the inventor may further adapt the innovation to customer needs, transmit information and reduce uncertainty. This is expected to positively influence profits, particularly if commercialization is undertaken by someone else than the inventor.

2.2 Measuring inventions and commercialization: Empirical findings

To measure inventions, the most frequently used variable is patents, where data has been collected from national patent offices. Patent offices do however not know whether the patents have been commercialized, or whether commercialization was successful, since detailed information on performance has seldom been collected.[17] The few previous studies using such databases have focused on estimating the market value of patents, rather than analyzing how different strategies are related to the performance (Rossman and Sanders, 1957; Sanders *et al.*, 1958; Sanders, 1962, 1964; Schmookler, 1966; Cutler, 1984; SRI International, 1985; Griliches *et al.*, 1987; Hall, 1993).[18] The main conclusions of these studies are that the mean value of patents is positive, but the median value is zero or negative, thus indicating a very large dispersion in economic value.

Another strand of the patent literature has analyzed the renewal of patents (see e.g. Pakes 1986; Schankerman and Pakes 1986; Griliches, 1990). The owners must pay a renewal fee to keep their patents in force – in many countries every year. Griliches argues that the percentage of renewed patents indicates how large a share of the patents has a positive

[16] We would expect inventors and innovators to be endowed by heterogeneous ability as regards information activities. It depends on their technological and market knowledge, i.e. learning from previous experience and occupation (von Hayek 1937, Frank 1988). Hence, it can be assumed that inventors possess more of technological knowledge and less of market knowledge, whereas the opposite is the case for the entrepreneur.

[17] Very few studies have used questionnaires. See, for instance, Griliches (1990).

[18] A highly promising and recent research initiative is the PatVal-EU project (Giuri *et al.*, 2007). The ambition is to gather data through questionnaires sent out to a large number of EU-countries (presently six countries are covered). The questionnaire targets inventors and will focus on data related to value of patents, source of innovations, degree and mode of commercialization, etc. Gambardella *et al.* (2007) implement the PatVal-EU database to analyze the determinants of licensing. Their study deviates from the current insofar that the focus of the current paper is the profitability of commercialization and the role of the inventor in the commercialization process.

economic value after different numbers of years. The models in Pakes (1986) and Schankerman and Pakes (1986) are based on the assumption that more valuable patents are renewed for longer periods than less valuable patents. The main conclusions of these studies are that most patents 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.

There are some problems with the renewal measurement. First, the renewal fee is a relatively low annual cost, implying that patents renewed for the whole statutory period may still have a low value. There is also an identification problem, where it is almost impossible for the observer to know whether the renewed patent has a low or a high value. Second, patents that are not renewed need not 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 for the owner or not. Finally, the renewal studies do not say anything about whether the patent has been commercialized and whether any innovation has been introduced on the market. Although most commercialized patents can be expected to be renewed and most non-commercialized patents to expire, there are many exceptions as shown in section 3. One obvious advantage with renewal studies is that patents can be valuable for the owner even if they are never commercialized. The owner might either wish to deter competitors from using the invention or the patent serves as a shadow patent protecting other similar patents.

Finally, there is another interesting aspect of previous studies: Irrespective of how the success, or the value, of patents has been measured, these studies have seldom related this measure to explanatory factors. An exception is Maurseth (2005), who tested how patent citations across and within technology fields influence the renewal of patents.

3. Database and descriptive statistics

In order to test how different strategies influence the performance of patent commercialization, we use a detailed database on individual Swedish patents granted to individual inventors and small firms.[19] In a previous pilot study (Svensson, 2002), the commercialization started within five years after the application year for most patents.[20]

[19] 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. In the pilot survey carried out in 2002, it turned out that large Swedish firms refused to provide information on individual patents. Furthermore, it proved very difficult to persuade foreign firms to fill in questionnaires about patents. These firms are mostly large multinationals firms. Therefore, the population consists of 1082 patents granted to Swedish individuals and firms with less than 1000 employees.

[20] 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

According to Pakes (1986), most of the uncertainty about the value of the patent is resolved during the first three-four years after the patent application. Therefore, patents granted in 1998 were chosen for the current database.[21] 1082 patents were granted to Swedish individual inventors and small firms in 1998. This sample selection is not a problem, as long as the conclusions drawn refer to small firms and individuals. 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.[22]

In the questionnaire, we asked the inventors about the work place where the invention was created, if and when the patent was commercialized, which kind of commercialization mode was chosen, as well as the outcome of the commercialization. As many as 867 of the inventors filled in and returned the questionnaire, i.e., the response rate was 80 percent (867 out of 1082). This response rate is satisfactorily high, considering that inventors or applying firms usually regard information about inventions and patents to be secret. Non-responses are primarily due to the addresses from PRV being out of date and to a smaller degree due to inventors refusing to reply.

3.1 Descriptive statistics

The commercialization rate of the 867 patents is described across firm groups in Table 1. The major share – 85 percent – of the patents was applied for between 1994 and 1997. As many as 408 patents (47 percent) were granted to individual inventors,[23] while 116 (13 percent), 201 (23 percent) and 142 (17 percent) patents were granted to medium-sized firms (101-1000 employees), small firms (11-100 employees) and close companies (2-10 employees), respectively. In 2003, commercialization had been started for 530 of these patents. The term commercialization here means that the owners of the patent have introduced an innovation in an existing or in a new firm, licensed or sold the patent. The commercialization rate of the firm groups varies between 66 and 74 percent, whereas the corresponding rate of the individuals is not higher than 52 percent. A contingent-table test suggests there to be a

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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.

[21] The database was collected in 2003-04. The year the patent is granted is used here, but patents filed in a specific year might have been preferable. The choice of patents granted in a specific year is, however, not a problem in the statistical estimations.

[22] 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.

[23] 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.

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] ********

At the end point of observation (year 2003), the inventors were asked to estimate whether the commercialized invention would yield profit, attain break-even or result in a loss. If they did not know, the reply was registered as a missing value (uncertain outcome).[24] In Table 2, discrete values of the outcome in profit terms are described across firm groups. It would have been desirable to measure the outcome in money terms. However, such information was impossible to collect.[25] Since the patents were granted in 1998 and some of them were commercialized even later, the expected profit level could not be determined for around 12 percent of the commercialized patents. As described in the table, the outcome is quite different across firm groups, where the group of individual inventors has the least favorable outcome, but there may be other underlying factors explaining this difference, e.g., the commercialization mode or the fact that the new product replaced an earlier one.

******** [Table 2] ********

In Table 3, outcomes are described across commercialization mode and whether inventors were active during the commercialization. Patents commercialized in new firms have a worse performance than the other modes. Let us divide the modes into two groups: 1) somebody else than the inventor is responsible for the commercialization (selling, licensing the patent or the existing firm where the inventor is employed); and 2) the inventor commercializes in his own firm (existing firm where the inventor is an owner, and new firms). It is then obvious that the former group has a better performance. A contingent table test based on the subtotals gives the chi-square-value 28.70, significant at the one-percent level. In the lower part of Table 3, there is no evidence that the activity of inventors during the commercialization has any impact on the performance. Thus, based on descriptive statistics, it seems like the Schumpeter view that the stages of invention and innovation should be separated activities is correct.

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[24] For a vast majority of the patents, the commercialization had reached such a stage that there was no uncertainty at all about the performance.

[25] It is very complicated to estimate profit flows, because most firms have many products in their statement of account, and many individuals do not have any statement of account at all.

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

One objection against the measurement of success in this study would be that the patent might be profitable for the owners, even if it is never commercialized, e.g., if it serves as a blocking or shadow patent. If this is the case, the owner should have more similar granted patents. Among the commercialized patents in the database, 46 percent of the owners have at least one more similar patent. Among non-commercialized patents, this percentage share is only 33 percent. If the patent had not been commercialized, the inventor was also asked: why? Among the 337 non-commercialized patents, only 15 inventors answered that the patent served as a defensive patent – with the purpose of deterring competitors from using the invention or defending other patents (shadow-patent). Thus, we conclude that keeping patents to defend other patents is less common among individuals and small firms. This strategy is more frequent among large multinational firms.

In Table 4, the outcome of commercialization is shown for expired and 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. The general pattern is that patents still alive have a higher share of successful outcomes as compared to expired patents, but the probability of a successful outcome also increases the longer the life of the expired patent. However, there are many exceptions. For example, some patents, which expired after only 1-5 years, were profitable, while many patents still renewed and commercialized have been losses to the owners. Thus, by only studying the pattern of renewal rates, as most previous studies has done, incorrect conclusions might be drawn about the profitability of patents.

******** [Table 4] ********

4. Econometric model and explanatory variables

4.1 Econometric model

The dependent variable, *PERFORM*, in the empirical estimations measures the performance in profit terms of the commercialization for the original owner of the patent. It can take on three different discrete values denoted by index k:

- Profit, k=2;
- Break-even, k=1;
- Loss, k=0.

Since it is possible to order the three alternatives, an ordered probit model is applied.[26] A multinomial logit model fails to take the ranking of the outcomes into account. On the other hand, an ordinary regression would treat the outcomes 0, 1 and 2 as realizations of a continuous variable. This would be an error, since the discrete outcomes are only ranked. The ordered probit model can be described in the following way (Greene, 1997):

$$y_i^* = X_i \alpha + \varepsilon_i \quad , \tag{6}$$

where $\mathbf{X_i}$ is a vector of patent-specific characteristics. The vector of coefficients, α, shows the influence of the independent variables on the profit level. The residual vector $\boldsymbol{\varepsilon_i}$ represents the combined effects of unobserved random variables and random disturbances. The residuals are assumed to have a normal distribution and the mean and variance are normalized to 0 and 1. The vector with the latent variable, $\mathbf{y_i^*}$, is unobserved. The model is based on the cumulative normal distribution function, $F(X\alpha)$, and is estimated via maximum likelihood procedures. The difference with the two-response probit model is here that a parameter (threshold value), ω, is estimated by α. The probabilities $P_i(k) = P_i(y=k)$ for the three outcomes are:

$$P_i(0) = F(-X\alpha) \quad ,$$

$$P_i(1) = F(\omega - X\alpha) - F(-X\alpha) \quad , \tag{7}$$

$$P_i(2) = 1 - F(\varpi - X\alpha) \quad ,$$

$$\text{where} \sum_{k=0}^{2} P_i(k) = 1 \quad .$$

The threshold value, ω, must be larger than 0 for all probabilities to be positive.

An objection against the sample and the chosen statistical model would be that the patents, which are commercialized, are not a random sample of patents, but have specific characteristics that led to them being commercialized in the first place. This could result in misleading parameter estimates. An appropriate statistical model is therefore an ordered

[26] There were 86 observations in the database, where the owner could not specify the expected profit level of the commercialization. These missing values could also be treated as a fourth, uncertain, outcome of *PERFORM*. A multinomial logit model, where all four alternatives were included, was estimated. Then, we accomplished a test for independence of irrelevant alternatives (Hausmann and McFadden, 1984). When excluding the uncertain alternative in the multinomial logit model, this test cannot be rejected. Thus, the parameter estimates between the other outcome alternatives are almost unaffected if the uncertain alternative is excluded. Then, there is no problem in excluding those patents with unknown profit-levels from the estimations.

probit model with sample selectivity (Greene, 2002). In the first step, a probit model estimates how different factors influence the decision to commercialize the patent:

$$d_i^* = Z_i \theta + u_i \quad , \tag{8}$$
$$d_i = 1 \;\; if \;\; d_i^* > 0 \;\; and \;\; 0 \;\; otherwise,$$

where d_i* is a latent index and d_i is the selection variable, indicating whether the patent is commercialized or not. $\mathbf{Z_i}$ is a vector of explanatory variables, which influence the probability that the patent is commercialized and $\boldsymbol{\theta}$ is a vector of parameters to be estimated. $\mathbf{u_i}$ is a vector of normally distributed residuals with zero mean and a variance equal to 1.

From the probit estimates, the selection variable d_i is then used to estimate a full information maximum likelihood model of the ordered probit model (Greene, 2002).[27] At the same time, the first step probit model is re-estimated. The residuals [ε, u] are assumed to have a bivariate standard normal distribution and correlation ρ. There is selectivity if ρ is not equal to zero.

4.2 Main explanatory variables

In this section and the next one, we will present the explanatory variables. The basic statistics of these variables are shown in Table 5. Our prime interest concerns how the role of the inventor influences the commercialization outcome.

There are five main modes of commercialization: 1) selling the patent; 2) licensing the patent; 3) commercialization in an existing firm where inventors are employed; 4) commercialization in an existing firm where inventors are owners; and 5) commercialization in a new firm. We define four different groups of dummies for the commercialization mode, which are included in four different models.

In our first definition, we use the first mode of commercialization chosen by the owners when the commercialization starts. Since the five modes are mutually exclusive, four different additive dummies are assigned. *SELL* takes on the value of 1 if the patent was sold and 0 otherwise. *LIC* equals 1 if the patent was licensed, and 0 otherwise. *EMPL* takes on the value of 1 if the patent was commercialized in an existing firm where inventors are employed and 0 otherwise. If the patent was commercialized in a new firm, *NEW* equals 1, and 0 otherwise. The reference group is here patents commercialized in an existing firm where the inventor is the owner.

[27] This is not a two-step Heckman model. No Lambda is computed and used in the second step.

In the second definition, we merge the three dummies *SELL*, *LIC* and *EMPL* into one dummy *EXTERN*. Thus, *EXTERN* takes on the value of 1 if somebody else than the inventor is responsible for the commercialization, and 0 if the inventor commercializes in his own firm (existing or new). The expected impacts of these variables on the profitability were set up in section 2 and are shown in Table 5.

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

According to the hypothesis 2, activity of the inventors should be important for the commercialization performance. We measure inventor activity (*ACTIVE*) as a dummy, which equals 1 if the inventors had an active role during the commercialization and 0 otherwise. *ACTIVE* is expected to have a positive influence on the profit level.

However, the influence of the inventors' activity should also depend on the commercialization mode. When inventors are also owners and commercialize in an existing firm or start a new firm, they are almost always active. When the patent is sold, the activity of inventors should have no impact on the original owners' profit, since the owners have already been paid. The interesting issue to test is when somebody else than inventors is responsible for the commercialization and inventors have an incentive to work hard during the commercialization. *ACTIVE1* is an interaction dummy between *ACTIVE* and *LIC* or *EMPL*. Thus, it takes on the value of 1 when inventors are active and when the patent is licensed or commercialized in an existing firm where inventors are employed. *ACTIVE2* is also an interaction dummy between *ACTIVE* and the other three modes of commercialization. *ACTIVE2* equals 1 when inventors are active and the patent is sold or commercialized in a new firm or an existing firm where inventors are owners.

4.3 Control variables

The control variables might be correlated with the profitability of the commercialization. Firms and individuals have different resources for renewing their patents, so additive dummies for different firm sizes are included. *MEDIUM* is a dummy that takes on the value of 1 for medium-sized firms with 101-1000 employees and 0 otherwise. *SMALL* equals 1 for small firms with 11-100 employees and 0 otherwise. Finally, *MICRO* is a third dummy taking the value of 1 for micro companies with 2-10 employees and 0 otherwise. The firm group dummies are here related to the reference group of individual inventors.

PATSTOCK measures the owner's stock of Swedish patents at the application date and indicates the experience of the patent owner. Since patents can be commercialized directly after application, the patent stock is measured at the application date rather than the grant date.[28] *REPLACE* is a dummy that equals 1 if the product based on the patent replaces a previous product of the patent owner, and 0 otherwise. If the new product replaces an earlier product, the commercialization is expected to be facilitated. *MOREPAT* is an additive dummy, which equals 1 if the inventors or the applying firm have more competitive Swedish patents in the same technology area, and 0 otherwise. A further variable measuring the complexity of the product is included. *PARTSYST* equals 1 if the patent is part of a larger system/product, and 0 otherwise.

COMYEAR measures the year when the commercialization started. The later is the starting year, the fewer are the years until the end of the observation (2003). *WAITYEAR* measures the number of years between the application year and the starting year of the commercialization. *COMYEAR* and *WAITYEAR* might, but need not be correlated since the patents have different application years. Some specific characteristics of the inventors are also included. *ETH* measures the share of inventors who belong to ethnical minorities, i.e. an ethnical background other than West European or North American. *SEX* measures the share of inventors who are females.

Different technologies are likely to be connected with different payoffs and risks. Consequently, the technology class can affect the profit level, given that the patent is 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.[29] Therefore, only 16 groups and 15 additive dummies are used in the present study. The data is also divided into six different kinds of regions according to the Swedish Agency for Economic and Regional Growth (1998): Large-city regions, university regions, regions with important primary city centers, regions with secondary city centers, small regions with private employment, and small regions with government employment. Five additive dummies are included for these six groups in the estimations.

Something should also be said about the explanatory variables, which are expected to affect the commercialization decision (*COM*) and are included in the probit equation. These variables are listed in Appendix Table A1. The identification of this step is based on the model in Svensson (2007), where the commercialization decision was analyzed using

[28] The alternative to measure the owner's patent stock at the grant date does not alter the results of the estimations.

[29] A technology class must have at least one observation in each of the three outcome alternatives, to obtain an own technology dummy. Technology classes without enough observations are instead merged with other closely related classes (Breschi *et al.*, 2004).

survivals models.[30] *MEDIUM*, *SMALL*, *MICRO*, *MOREPAT*, *PATSTOCK*, *ETH*, *SEX*, the region and technology dummies, as described above, are included in the first step. Furthermore, time dummies for the application year, and six further variables (*GOVRD*, *PRIVRD*, *OTHRD*, *OWNER*, *KOMPL* and *INVNMBR*) are added.[31] On the other hand, variables characterizing the commercialization, e.g., commercialization mode (*SELL*, *LIC*, *EMPL* and *NEW*), *ACTIVE*, *REPLACE*, etc., cannot be included. This means that different explanatory variables are included in the probit and ordered probit models when sample selectivity is taken into account.

5. Empirical estimations

Two different models are estimated. In Model I, the first definition of commercialization mode is used, i.e. the first choice when the patent is commercialized. In Model II, we instead include the alternative dummy, *EXTERN*, which measure whether somebody else than the inventor is responsible for the commercialization. To test for robustness, three variants with region and technology dummies are estimated. In these variants, region dummies (A), technology dummies (B) and both region and technology dummies (C) are included. The models are also estimated by full information maximum likelihood, taking account of sample selectivity. The previous inclusion of dummy variables (A-C) is then repeated (D-F).

The results of the ordered probit estimations of Model I are shown in Table 6. In general, sample selectivity (Models D-F) decreases the significance levels of the parameters and reduces the parameter estimates. Considering the commercialization mode, licensing or selling the patent has a positive impact on the profit level as compared to commercializing in an existing firm, where the inventor is the owner. *SELL* is always significant at the five-percent level, whereas *LIC* has different significant levels. The parameter of *NEW* is negative, but not even significant at the ten-percent level. By recalculating the parameter estimates, however, it is easily seen at the bottom of the table that selling or licensing the patent has a positive influence on the profit level as compared to the new firm alternative – the differences are always significant at the five-percent level. Thus, it is more profitable that the inventors let somebody else be responsible for the commercialization than to start a new firm. This corroborates Schumpeter's stage approach and is in line with Hypothesis 1.

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[30] The difference is that a probit model is used in the first step of the present model, whereas Svensson (2007) used survival models.

[31] *GOVRD* measures how large a share of the R&D-costs that was financed from the government. Similarly, *PRIVRD* and *OTHRD* measure how large shares of this financing were from private venture capitalists and research foundations / universities, respectively. *OWNER* measures how large a share (in percent) of the patent that is directly or indirectly owned by the inventors. The dummy variable *KOMPL* takes on the value of 1 if complementing patents are needed to create a product and 0 otherwise. *INVNMBR* measures the number of inventors of the patent.

However, a result that contradicts Schumpeter is that the activity of the inventors during the commercialization is very important for the performance. We are especially interested in *ACTIVE1*, which measures if the inventors were active when somebody else than the inventor is responsible for the commercialization. *ACTIVE1* always has a positive and highly significant impact on the profit-level, which supports Hypothesis 2. Thus, it seems like inventors are more important as knowledge transmitters than as firm creators/entrepreneurs when patents are commercialized. These results also hold when we take account of sample selectivity. *ACTIVE2* is also significant, but the interpretation of this influence is problematic, since it is obvious that inventors are active if they are owners of the patent.

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

The results of Models II are described in Table 7. The estimated parameter of *EXTERN* is positive and significant, at least at the 5 percent level in all runs. Thus, there is a higher probability of successful commercialization if somebody else than the inventor is responsible for the commercialization, which is in line with Schumpeter. The results of *ACTIVE1* and *ACTIVE2* are similar to Model I. Once again, the results support both Hypotheses 1 and 2.

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

The results for the control variables are similar between Models I and II. All firm group dummies have positive and strongly significant impacts on the profit level, implying that patents commercialized by firms have a higher probability of success as compared to patents commercialized by individuals. However, the parameter of *MICRO* is not significant when sample selectivity is taken into account. Furthermore, the parameters of *MEDIUM*, *SMALL* and *MICRO* are not significantly different from each other. Among the other variables, only *REPLACE* and *MOREPAT* have significant effects on the profit level. The significance level of *REPLACE* depends on which dummy variables are included, whereas the significance of *MOREPAT* disappears when sample selection is included.

The size interpretation of the important or significant estimated parameters is shown in Table 8. These effects are calculated around the means of the x_i:s. The marginal effects on the probabilities are lower when sample selection is included (I-F). If the patent is sold instead of commercialized in an existing firm, where the inventor is the owner, the probability of a profitable commercialization increases by 21 percentage units in model I-F. At the same time, the probabilities of a breakeven or a loss result decrease by 10 and 11 percentage units, respectively. If the inventors are active during the commercialization when somebody else is responsible for the commercialization, the probability of a profitable outcome increases by 17 percentage units in model I-F. The marginal effects of the other dummy variables are interpreted in the same way. We also calculate the marginal effects for *EXTERN* in Models II-C and II-F. If the inventor is not responsible for the commercialization, the probability of a successful commercialization increases by 22 percentage units, while the probability of a breakeven or loss result decreases by 8 and 14 percentage units, respectively (Model II-F).

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

Some other variants of the models were also estimated in order to test for robustness.[32] Firstly, the owner may change the commercialization mode. This occurs in 46 cases in the data set. For example, a patent, which is originally commercialized in the inventor's, own firm may later be sold or licensed. Therefore we redefined the commercialization mode variables (*SELL*, *LIC*, *EMPL* and *NEW* as well as *EXTERN*) to take account of that a specific mode may occur at a later date. For example, *SELL* then takes on the value of 1 if the patent is sold initially or at a later date, and 0 otherwise. The other mode variables are treated in a similar manner. However, the estimations gave almost the same results – both with regard to the size of the estimated parameters and the significance levels.

Secondly, we experimented with the sample criteria. In our main sample with 466 commercialized patents, all patents where the owner is either an individual inventors or a firm with less than 1000 employees were included. According to EU, large firms have more than 500 employees and small firms less than 250 employees. Therefore, we also estimated the models with sample criteria of: a) less than 500 employees that generated a sample of 453 commercialized patents; and b) less than 250 employees, which gave a sample of 434 commercialized patents. The results of these estimations show that the effect of the commercialization mode variables (*SELL, LIC* and *EXTERN*) is approximately the same on the performance.

Thirdly, a limitation of the study is that we only have dummies for different technology classes and not for different industry/markets segments. The market segment could be a proxy of how costly or risky it is for an inventor to start a business by himself.

Finally, additive dummies for unique owners (firms/inventors) were also included in the estimations, but this did not work out very well. When including dummies for unique

[32] These estimations are available from the authors upon request.

owners, the models were characterized by severe multicollinearity problems with extremely high standard errors for the owner dummies.[33]

6. Concluding remarks

Drawing on recent insights gained in several fields of economics, we have empirically analyzed Schumpeter's (1911) original assertion that the stages of invention and innovations should be separated activities, how different levels of integration affect commercialization, and the extent to which inventor involvement in the commercialization process influences profitability.

The empirical analysis is based on a survey covering Swedish patents owned by small firms and individuals, where the response rate is 80 percent. The data allows us to observe the performance in profit terms when patents are commercialized as well as which strategies the inventors and owners have used. The estimations show that commercialization performance is superior when the inventor is not responsible for the commercialization (patent is sold or licensed, or the inventor is employed and not an owner in the firm) as compared to the alternative when the inventor commercializes in his own existing or new firm. In the former case, the probability of a successful commercialization is 21 percentage units higher than in the latter case. This is in line with Schumpeter's view that invention and innovation should be separate stages. In addition, it is shown that the activity of inventors during the commercialization is important for the performance, particularly when the patent is licensed or when the inventor is employed and not an owner. The explanation would be that the inventor is important for further adaptation of the innovation and to reduce uncertainty. In this sense, the results contradict Schumpeter's view that invention and innovation are separate stages. The overall interpretation of the estimations is that inventors are more successful as transmitters of knowledge than as firm creators or entrepreneurs.

If it is better to let somebody else be responsible for the commercialization, why do not all inventors sell or license their patents? There are two possible explanations. First, licensing and selling contracts are characterized by asymmetric information, i.e. inventors know much more about the patent than potential manufacturing firms. This causes high transaction and search costs when bringing inventors and manufacturing firms together. It is likely that too few patents are sold or licensed. The only alternative for many inventors is then

[33] Among the 530 commercialized patents in the sample, there are 460 unique owners (firms/inventors). 418 owners only have one commercialized patent, 29 owners have two patents, and only 13 owners have at least three patents. Dummies can only be assigned to those 42 owners with at least 2 patents. The multicollinearity problems occurred even when all technology and region dummies were excluded and when dummies were only included for those 13 owners with at least three commercialized patents.

to commercialize in their own firms. Second, the poor performance of inventors when they attempt to commercialize a new product may be due to lack of experience and over-optimistic behavior. Such interpretation corroborates previous research by, for instance, de Meza and Southey (1996), Arabsheibani et al. (2000) and Fraser and Greene (2006).

The analysis pursued in this paper also suggests a framework where the theories of Knight's risk defining entrepreneur and Schumpeter's innovative entrepreneur can be bridged. An entrepreneur who integrates the inventive stage in the innovation process enhances the possibilities of successful commercialization, since this facilitates customer-specific adaptation and the transmission of information, simultaneously as uncertainty is reduced. This serves to expand market opportunities for the entrepreneur. A future research task would be to provide a rigorous theoretical setting where both these aspects of entrepreneurship are included.

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

Kind of firm where the invention was created	Number of patents			Percent Commercialized
	Commercialization		Total	
	Yes	No		
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 alone (1-4 inventors)	211	197	408	52 %
Total	**530**	**337**	**867**	**61 %**

Table 2. Performance of the commercialization across firm groups, number of patents.

Kind of firm where the invention was created	Performance				Total
	Profit	Break-even	Loss	Missing value	
Medium-sized firms	53	18	3	3	77
Small firms	95	22	15	5	137
Close companies	48	12	27	18	105
Inventors alone	46	43	84	38	211
Total	**242**	**95**	**129**	**64**	**530**

Table 3. Performance of the commercialization across commercialization modes and active role of the inventors, number of patents.

Commercialization mode	Performance: Profit	Break-even	Loss	Missing value	Total
Sold patent	10	3	7	0	20
Licensed patent	19	9	14	10	52
Existing firm, inventor is employed	103	30	15	10	158
Subtotal	*132*	*42*	*36*	*20*	*230*
Existing firm, inventor is owner	100	45	62	25	232
New firm	10	8	31	19	68
Subtotal	*110*	*53*	*93*	*44*	*300*
Total	**242**	**95**	**129**	**64**	**530**
	Chi-square (3 d.f.) = 28.70 *** (based on sub-totals)				

Active role of the inventors during the commercialization	Profit	Break-even	Loss	Missing value	Total
No	26	18	20	4	68
Yes	216	77	109	60	462
Total	**242**	**95**	**129**	**64**	**530**
	Chi-square (3 df) = 5.50				

Table 4. Performance of the commercialization across renewed and expired patents, number of patents.

Renewed / expired patents		Commercialized patents: Performance: Profit	Break-even	Loss	Missing value	Subtotal	Not commer-cialized	**Total**
Expired patents, number of years after application	1–3 years	5	5	9	0	19	33	**52**
	4–5 years	11	7	23	0	41	55	**96**
	6–7 years	33	17	29	0	79	58	**137**
	> 7 years	24	6	20	0	50	52	**102**
Subtotal of expired patents		73	35	81	0	189	198	**387**
Patents renewed in 2004		169	60	48	64	341	139	**480**
Total		**242**	**95**	**129**	**64**	**530**	**337**	**867**

Table 5. Explanatory variables and hypotheses.

Variable denotation		Variable description	Mean	Std dev.	Expected impact on *PERFORM*
	SELL	Dummy which equals 1 if the owners sold the patent, and 0 otherwise	0.043	0.203	+
	LIC	Dummy which equals 1 if the owners licensed the patent, and 0 otherwise	0.090	0.287	+
I	*EMPL*	Dummy which equals 1 if commercialized in an existing firm, where inventors are employed (not owners), and 0 otherwise	0.318	0.466	+
	NEW	Dummy which equals 1 if the owners (inventors) started a new firm, and 0 otherwise	0.105	0.307	–
II	*EXTERN*	Dummy which equals 1 if somebody else than the inventor is responsible for the commercialization, and 0 if the inventor commercializes in his own firm	0.451	0.440	+
ACTIVE		Dummy which equals 1 if inventors are active during the commercialization, and 0 otherwise	0.863	0.345	+
ACTIVE1		Interaction dummy between *ACTIVE* and *LIC* or *EMPL*	0.558	0.497	+
ACTIVE2		Interaction dummy between *ACTIVE* and *SELL*, *NEW*, or if the patent was commercialized in an existing firm where inventors are owners	0.305	0.461	+
MEDIUM		Dummy which equals 1 for medium-sized firms (101-1000 employees), and 0 otherwise	0.159	0.366	
SMALL		Dummy which equals 1 for small firms (11-100 employees), and 0 otherwise	0.283	0.451	
CLOSE		Dummy which equals 1 for close companies (2-10 employees), and 0 otherwise	0.187	0.390	
PATSTOCK		The patent stock of the owner at the application date	4.61	12.13	
REPLACE		Dummy which equals 1 if the product replaced a previous product for the owners, and 0 otherwise	0.082	0.274	
MOREPAT		Dummy which equals 1 if the owners have more substituting patents, and 0 otherwise	0.453	0.498	
PARTSYST		Dummy which equals 1 if the product is a part of a larger system, and 0 otherwise	0.159	0.366	
COMYEAR		Starting year of the commercialization	1997	2.24	
WAITYEAR		Number of years between patent application and start of commercialization	1.33	1.64	
ETH		Share of inventors with an ethnical background other than Western European or North-American	0.023	0.147	
SEX		Share of inventors who are females	0.021	0.132	

Note: The roman figures I and II refer to in which model the variables are included. The signs "+.", "–" and "?" indicate a positive, a negative and an unsettled expected influence on the profit level, respectively. Expected impacts are only shown for the main explanatory variables.

Table 6. Empirical estimations of the ordered probit model. Model I.

Dependent variable: *PERFORM*	Statistical model:					
Explanatory variables	Ordered probit model (without sample selection)			Ordered probit model (with sample selection)		
	Model					
	I-A	I-B	I-C	I-D	I-E	I-F
SELL1 (dummy)	1.05 ***	1.02 **	1.09 ***	0.85**	0.77 **	0.80 **
	(0.39)	(0.40)	(0.41)	(0.35)	(0.36)	(0.36)
LIC1 (dummy)	1.09 **	0.96 *	1.11 **	0.85 *	0.73	0.79 *
	(0.51)	(0.51)	(0.53)	(0.49)	(0.46)	(0.47)
EMPL1 (dummy)	0.67	0.47	0.69	0.55	0.40	0.44
	(0.49)	(0.49)	(0.50)	(0.45)	(0.42)	(0.43)
NEW1 (dummy)	-0.35	-0.35	-0.36	-0.29 *	-0.28	-0.27
	(0.22)	(0.22)	(0.23)	(0.18)	(0.19)	(0.18)
ACTIVE1 (dummy)	0.60 ***	0.71 ***	0.63 ***	0.51 **	0.57 ***	0.51 **
	(0.21)	(0.21)	(0.22)	(0.21)	(0.20)	(0.20)
ACTIVE2 (dummy)	1.18 ***	1.12 ***	1.21 ***	0.95 **	0.87 **	0.89 **
	(0.43)	(0.44)	(0.44)	(0.41)	(0.39)	(0.39)
MEDIUM (dummy)	1.16 ***	1.28 ***	1.24 ***	0.68 **	0.70 **	0.84 ***
	(0.29)	(0.30)	(0.31)	(0.33)	(0.33)	(0.29)
SMALL (dummy)	0.97 ***	1.03 ***	0.96 ***	0.62 ***	0.61 ***	0.62 ***
	(0.20)	(0.21)	(0.21)	(0.22)	(0.22)	(0.20)
CLOSE (dummy)	0.53 ***	0.64 ***	0.61 ***	0.21	0.26	0.25
	(0.18)	(0.18)	(0.18)	(0.19)	(0.19)	(0.18)
PATSTOCK	6.6 E-3	5.4 E-3	5.8 E-3	0.010 *	8.9 E-3	8.6 E-3
	(6.1 E-3)	(6.3 E-3)	(6.4 E-3)	(5.4 E-3)	(5.8 E-3)	(5.7 E-3)
REPLACE (dummy)	0.58 **	0.46	0.50 *	0.54 **	0.42 *	0.47 **
	(0.26)	(0.27)	(0.27)	(0.24)	(0.24)	(0.24)
MOREPAT (dummy)	0.30 **	0.29 **	0.31 **	0.19	0.17	0.15
	(0.12)	(0.12)	(0.13)	(0.12)	(0.12)	(0.12)
PARTSYST (dummy)	0.19	0.16	0.16	0.12	0.059	0.043
	(0.19)	(0.19)	(0.20)	(0.19)	(0.20)	(0.20)
COMYEAR	-0.010	4.4 E-3	-8.1 E-3	-7.4 E-3	1.2 E-3	-2.0 E-3
	(0.034)	(0.035)	(0.035)	(0.031)	(0.032)	(0.032)
WAITYEAR	-0.030	-0.042	-0.036	-0.029	-0.039	-0.032
	(0.047)	(0.048)	(0.048)	(0.044)	(0.044)	(0.043)
ETH	0.031	0.17	0.13	0.040	0.16	0.10
	(0.42)	(0.43)	(0.44)	(0.43)	(0.41)	(0.44)
SEX	0.036	7.1 E-3	0.034	-0.054	-0.073	-0.031
	(0.42)	(0.43)	(0.43)	(0.38)	(0.37)	(0.37)
Intercept	19.29	7.67	14.71	14.11	2.62	3.33
Ω (threshold value)	0.69	0.69	0.70	0.60	0.57	0.57
Region dummies	Yes	No	Yes	Yes	No	Yes
Technology dummies	No	Yes	Yes	No	Yes	Yes
Log Likelihood function	-898.8	-896.7	-893.3	-896.6	-894.3	-890.5
Test vs. restricted model (1 d.f.)				4.45 **	4.76 **	5.52 **
Parameter tests						
SELL1 - NEW1	1.40 ***	1.37 ***	1.45 ***	1.14 ***	1.05 **	1.07 **
	(0.48)	(0.49)	(0.49)	(0.41)	(0.43)	(0.42)
LIC1 - NEW1	1.43 **	1.31 **	1.47 **	1.15 **	1.01 **	1.06 **
	(0.58)	(0.59)	(0.60)	(0.53)	(0.51)	(0.52)

Note: The number of observations equals 466. The dependent variable *PERFORM* takes on the values of 2, 1 and 0 for 242, 95 and 129 observations, respectively. Standard errors are in parentheses and ***, ** and * indicate significance at the 1, 5 and 10 percent level, respectively. Dummy variables as well as estimates from the first probit selection step are shown in Appendix Table A2.

Table 7. Empirical estimations of the ordered probit model. Model II.

Dependent variable: *PERFORM*	Statistical model:					
Explanatory variables	Ordered probit model (without sample selection)			Ordered probit model (with sample selection)		
	Model					
	II-A	II-B	II-C	II-D	II-E	II-F
EXTERN (dummy)	1.05 ***	0.97 ***	1.09 ***	0.83 **	0.65 **	0.70 **
	(0.37)	(0.37)	(0.38)	(0.33)	(0.28)	(0.31)
ACTIVE1 (dummy)	0.53 ***	0.61 ***	0.56 ***	0.45 **	0.46 ***	0.43 ***
	(0.19)	(0.20)	(0.20)	(0.17)	(0.14)	(0.16)
ACTIVE2 (dummy)	1.25 ***	1.24 ***	1.29 ***	0.98 ***	0.82 ***	0.86 ***
	(0.38)	(0.39)	(0.39)	(0.35)	(0.29)	(0.32)
MEDIUM (dummy)	0.98 ***	1.03 ***	1.06 ***	0.50 *	0.26	0.53 **
	(0.24)	(0.24)	(0.25)	(0.28)	(0.22)	(0.22)
SMALL (dummy)	0.91 ***	0.94 ***	0.90 ***	0.55 ***	0.37 ***	0.48 ***
	(0.16)	(0.17)	(0.17)	(0.19)	(0.15)	(0.15)
CLOSE (dummy)	0.56 ***	0.66 ***	0.65 ***	0.22	0.11	0.19
	(0.16)	(0.16)	(0.17)	(0.17)	(0.14)	(0.15)
PATSTOCK	5.8 E-3	4.5 E-3	5.3 E-3	9.8 E-3 *	0.011 *	9.3 E-3 *
	(5.9 E-3)	(6.1 E-3)	(6.3 E-3)	(5.1 E-3)	(4.8 E-3)	(5.1 E-3)
REPLACE (dummy)	0.54 **	0.42	0.47 *	0.51 **	0.42 *	0.45 *
	(0.27)	(0.27)	(0.27)	(0.24)	(0.25)	(0.24)
MOREPAT (dummy)	0.28 **	0.26 **	0.28 **	0.16	0.066	0.11
	(0.12)	(0.12)	(0.13)	(0.12)	(0.10)	(0.11)
PARTSYST (dummy)	0.23	0.21	0.20	0.15	0.086	0.069
	(0.18)	(0.19)	(0.19)	(0.18)	(0.19)	(0.18)
COMYEAR	-0.013	-6.1 E-3	-0.011	-9.1 E-3	-2.6 E-3	-2.1 E-3
	(0.034)	(0.035)	(0.035)	(0.030)	(0.028)	(0.029)
WAITYEAR	-0.023	-0.033	-0.029	-0.023	-0.028	-0.024
	(0.047)	(0.047)	(0.048)	(0.043)	(0.038)	(0.040)
ETH	0.072	0.24	0.15	0.055	0.011	0.54
	(0.42)	(0.43)	(0.43)	(0.40)	(0.37)	(0.40)
SEX	-0.042	-0.096	-0.047	-0.12	-0.16	-0.097
	(0.42)	(0.42)	(0.43)	(0.37)	(0.31)	(0.34)
Intercept	24.01	11.00	19.41	17.44	5.20	3.77
Ω (threshold value)	0.68	0.68	0.70	0.58	0.46	0.51
Region dummies	Yes	No	Yes	Yes	No	Yes
Technology dummies	No	Yes	Yes	No	Yes	Yes
Log Likelihood function	-901.9	-900.6	-896.3	-899.3	-897.2	-893.6
Test vs. restricted model (1 d.f.)				5.33 **	6.73 ***	5.48 **

Note: The number of observations equals 803. The dependent variable *PERFORM* takes on the values of 2, 1 and 0 for 242, 95 and 129 observations, respectively. Standard errors are in parentheses and ***, ** and * indicate significance at the 1, 5 and 10 percent level, respectively. Dummy variables as well as estimates from the first probit selection step are shown in Appendix Table A3.

Table 8. Size interpretation of estimated parameters. Ordered probit.

Dummy variables	Marginal effect on probabilities when dummy variables increase from 0 to 1.					
	Model I-C			Model I-F		
	P(0)	P(1)	P(2)	P(0)	P(1)	P(2)
SELL	-0,21	-0.16	0.37	-0.11	-0.10	0.21
LIC	-0.22	-0.16	0.38	-0.12	-0.10	0.22
EMPL	-0.19	-0.08	0.27	-0.09	-0.05	0.14
NEW	0.12	0.02	-0.14	0.07	0.03	-0.10
ACTIVE1	-0.17	-0.07	0.24	-0.10	-0.07	0.17
ACTIVE2	-0.38	-0.08	0.46	-0.21	-0.10	0.31
Dummy variable	Model II-C			Model II-F		
	P(0)	P(1)	P(2)	P(0)	P(1)	P(2)
EXTERN	-0.32	-0.10	0.42	-0.14	-0.08	0.22
ACTIVE1	-0.16	-0.06	0.22	-0.09	-0.05	0.14
ACTIVE2	-0.40	-0.09	0.49	-0.19	-0.09	0.28

Note: All marginal effects are calculated around the means of the **x**:s. The sum of the marginal effects on the probabilities equals zero.

Table A1. Explanatory variables included in the Probit sample selection equation.

Variable denotation	Variable description
MEDIUM	Dummy which equals 1 for medium-sized firms (101-1000 employees), and 0 otherwise
SMALL	Dummy which equals 1 for small firms (11-100 employees), and 0 otherwise
CLOSE	Dummy which equals 1 for close companies (2-10 employees), and 0 otherwise
GOVRD	Percent of R&D financed by government
PRIVRD	Percent of R&D financed by private venture capital
OTHRD	Percent of R&D financed by universities/research foundations
PATSTOCK	The patent stock of the owner at the application date
MOREPAT	Dummy which equals 1 if the owners have more substituting patents, and 0 otherwise
OWNER	Percent of the patent that is directly or indirectly owned by the inventors
KOMPL	Dummy that equals 1 if complementary patents are needed to create a product, and 0 otherwise
INVNMBR	Number of inventors
ETH	Share of inventors with an ethnical background other than Western European or North-American
SEX	Share of inventors who are females
Region dummies	Five additive region dummies
Technology dummies	Fifteen additive technology dummies
Time dummies	Five additive time dummies for application years

Table A2. Estimation of dummy variables, Model I.

Dependent variable: *PERFORM*	Statistical model:					
Dummy variables	Ordered probit model (without sample selection)			Ordered probit model (with sample selection)		
	Model					
	I-A	I-B	I-C	I-D	I-E	I-F
Region 1	0.13	------	0.25	0.20	------	0.28
	(0.23)		(0.24)	(0.22)		(0.22)
Region 2	0.28	------	0.39	0.34	------	0.43 *
	(0.25)		(0.26)	(0.23)		(0.24)
Region 3	0.49 *	------	0.63 **	0.49 **	------	0.56 **
	(0.25)		(0.26)	(0.23)		(0.24)
Region 4	0.33	------	0.46 *	0.27	------	0.33
	(0.26)		(0.27)	(0.25)		(0.25)
Region 5	-0.37	------	-0.26	-0.37	------	-0.37
	(0.37)		(0.39)	(0.37)		(0.34)
Technology 1	------	-0.20	-0.15	------	-0.091	-0.077
		(0.40)	(0.41)		(0.37)	(0.40)
Technology 2	------	0.05	0.15	------	-0.024	4.0 E-3
		(0.36)	(0.37)		(0.39)	(0.38)
Technology 3	------	0.06	0.12	------	0.030	0.073
		(0.29)	(0.29)		(0.27)	(0.27)
Technology 4	------	-0.039	-0.071	------	0.032	-4.1 E-4
		(0.28)	(0.28)		(0.24)	(0.25)
Technology 5	------	-0.41	-0.39	------	-0.27	-0.24
		(0.26)	(0.27)		(0.22)	(0.23)
Technology 6	------	0.36	0.41	------	0.27	0.29
		(0.37)	(0.38)		(0.35)	(0.35)
Technology 7	------	0.12	0.076	------	0.18	0.17
		(0.30)	(0.31)		(0.28)	(0.28)
Technology 8	------	-1.10 **	-1.15 **	------	-0.74 *	-0.70 **
		(0.50)	(0.52)		(0.44)	(0.44)
Technology 9	------	-0.22	-0.17	------	-0.089	-0.020
		(0.30)	(0.30)		(0.28)	(0.28)
Technology 10	------	0.23	0.31	------	0.23	0.30
		(0.28)	(0.29)		(0.26)	(0.26)
Technology 11	------	7.6 E-3	0.056	------	9.9 E-3	0.041
		(0.21)	(0.22)		(0.19)	(0.20)
Technology 12	------	-0.16	-0.17	------	-0.27	-0.30
		(0.29)	(0.30)		(0.29)	(0.31)
Technology 13	------	-0.076	-0.099	------	-0.041	-0.061
		(0.24)	(0.24)		(0.24)	(0.24)
Technology 14	------	-0.22	-0.32	------	-0.082	-0.14
		(0.47)	(0.47)		(0.44)	(0.41)
Technology 15	------	0.15	0.21	------	0.16	0.21
		(0.24)	(0.25)		(0.23)	(0.23)

Note: The number of observations equals 466. The dependent variable *PERFORM* takes on the values of 2, 1 and 0 for 242, 95 and 129 observations, respectively. Standard errors are in parentheses and ***, ** and * indicate significance at the 1, 5 and 10 percent level, respectively.

Table A3. Estimation of dummy variables, Model II.

Dependent variable: *PERFORM*	Statistical model:					
Dummy variables	Ordered probit model (without sample selection)			Ordered probit model (with sample selection)		
	Model					
	II-A	II-B	II-C	II-D	II-E	II-F
Region 1	0.16	------	0.29	0.22	------	0.26
	(0.23)		(0.24)	(0.22)		(0.21)
Region 2	0.31	------	0.42	0.36	------	0.44 *
	(0.25)		(0.26)	(0.23)		(0.23)
Region 3	0.55 **	------	0.70 ***	0.53 **	------	0.55 **
	(0.25)		(0.26)	(0.23)		(0.23)
Region 4	0.35	------	0.48 *	0.27	------	0.29
	(0.26)		(0.27)	(0.25)		(0.25)
Region 5	-0.34	------	-0.22	-0.13	------	0.020
	(0.37)		(0.39)	(0.34)		(0.32)
Technology 1	------	-0.18	-0.15	------	-0.11	-0.082
		(0.40)	(0.40)		(0.34)	(0.38)
Technology 2	------	-0.013	0.079	------	-0.12	-0.052
		(0.35)	(0.36)		(0.32)	(0.33)
Technology 3	------	-0.015	0.038	------	-0.070	0.017
		(0.28)	(0.29)		(0.24)	(0.24)
Technology 4	------	-0.044	-0.096	------	0.17	7.6 E-4
		(0.27)	(0.28)		(0.20)	(0.24)
Technology 5	------	-0.38	-0.38	------	-0.15	-0.16
		(0.26)	(0.27)		(0.20)	(0.21)
Technology 6	------	0.35	0.39	------	0.21	0.22
		(0.37)	(0.38)		(0.34)	(0.36)
Technology 7	------	0.073	0.026	------	0.19	0.20
		(0.30)	(0.31)		(0.25)	(0.26)
Technology 8	------	-1.15 **	-1.22 **	------	-0.52	-0.62 **
		(0.50)	(0.51)		(0.37)	(0.39)
Technology 9	------	-0.25	-0.20	------	-0.064	1.6 E-3
		(0.30)	(0.30)		(0.23)	(0.25)
Technology 10	------	0.21	0.28	------	0.17	0.27
		(0.28)	(0.28)		(0.23)	(0.24)
Technology 11	------	-0.016	0.036	------	-0.026	0.012
		(0.21)	(0.22)		(0.18)	(0.19)
Technology 12	------	-0.20	-0.22	------	-0.37	-0.34
		(0.29)	(0.29)		(0.26)	(0.28)
Technology 13	------	-0.13	-0.16	------	-0.11	-0.11
		(0.24)	(0.24)		(0.21)	(0.22)
Technology 14	------	-0.20	-0.30	------	0.053	-0.087
		(0.47)	(0.47)		(0.36)	(0.37)
Technology 15	------	0.14	0.20	------	0.11	0.19
		(0.24)	(0.24)		(0.20)	(0.22)

Note: The number of observations equals 466. The dependent variable *PERFORM* takes on the values of 2, 1 and 0 for 242, 95 and 129 observations, respectively. Standard errors are in parentheses and ***, ** and * indicate significance at the 1, 5 and 10 percent level, respectively.