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Academic inventors' choice of transfer channels dependent on commercialisation experience – a theoretical model

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Abstract:

Academic inventions have to be transferred to industry to become an innovation. Scientists face multiple options for this transfer, from informal knowledge transfers to patents, licences, and spin-offs. These transfer channels require different efforts and inhibit different degrees of complexity. We want to theoretically explain the inventor's choice of a certain transfer channel. Under the assumption that (i) dealing with complexity is similar to facing risk, and (ii) scientists are risk averse, we show that the chosen transfer channels are path-dependent: with increasing commercialisation experience inventors choose more complex channels, up to a certain limit of complexity.

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1. Introduction

Since Schumpeter the value of innovations as a driver for economic growth has been esteemed highly. Much research was conducted on the conditions enabling innovativeness in order to create the basis of future growth. An innovation is usually understood as a commercialised invention. Newly generated knowledge alone is not sufficient to foster economic growth, the practical utilisation of it is essential. Nevertheless, new knowledge, especially technological one, is the base of most innovations. Next to companies that conduct research, knowledge generating institutions like universities and research institutes play an important role for enhancing the knowledge base of an economy. Because this knowledge can spill over to industry involuntarily or by explicit transfer, academic research is widely acknowledged to support technological change and economic growth (see e.g. Jaffe 1989, Mansfield 1998 and Adams 1990). Effects are generated for example by additional jobs that are based on innovations resulting from successful commercialisation of academic research. There are growth effects at the regional level (cf. Lee 1995; Fritsch et al. 2007) as well as on the national level (cf. Heher 2006).

Research on university-industry technology transfer consists of several research branches. Questions that are studied are: Why is there and should there be technology transfer, what different channels are available for the transfer, what is the relative importance of different transfer channels, and which factors hinder or promote technology transfer? All these topics are interrelated and not mutually exclusive but in most studies one of them is addressed separately.

This paper belongs to the studies that examine different transfer channels, especially what influences academic inventors in their decision about the channels feasible for their inventions. Although there are quite some empirical studies on the relative importance of different transfer channels (see e.g. Czarnitzki et al. 2000, Agrawal and Henderson, 2000, Cohen et al., 1998/2002), there are hardly any studies on what influences the inventor's decision for one transfer channel or the other. D'Este and Patel (2007) are a remarkable exemption, analysing the influence of individual, departmental and university characteristics on the variety of used transfer channels in the UK. The aim of this paper is to fill this gap with a theoretical analysis. To the authors' knowledge, theoretical studies of this issue are completely missing in the literature.

Different forms of technology transfer require different skills and capabilities from the inventor and, thus, are characterised by different degrees of complexity. These differences in the characteristics of the various transfer channels can be expected to influence the inventors' decisions on how to commercialise an invention.

We build a theoretical model that describes the choice of a transfer channel by an inventor dependent on personal characteristics, such as risk-aversion and past experience, and the characteristics of the transfer channels. The starting point is the assumption that a researcher has made an invention. Subsequently, he has a number of possibilities what to do with the invention, such as publishing the results, licensing them to a firm, or start an own firm. The theoretical model is used to make predictions about this choice, which are compared to the empirical findings in the literature.

The remainder of the paper is structured as follows. The second section provides an overview of the most important empirical findings in the field of technology transfer from university to industry, which are used to build the model and conduct some first checks of the theoretical implications. In the third section the building blocks of the theoretical model are set up. This includes especially a discussion of the various transfer channels, the concept of complexity of the transfer channels, and how scientists gain experience in coping with this complexity. The formal model is built in section 4, which gives explanations for inventors' decisions about the use of transfer channels. In the fifth section some implications of the model are deduced and their meaning as well as the support by empirical findings is discussed. Section 6 concludes.

2. Empirical findings on technology transfer

Due to the comparatively large data sets that are available, much research on technology transfer deals with patents and spin-offs. These are only two of several ways to transfer new knowledge, but politics often assumes them to be most important. Consulting, research cooperation, publications, diploma and PhD theses, conferences, informal contacts, the employment of experienced researchers in companies, temporary work of company researchers at university labs, licenses of not-patentable technologies and software, and combinations of these are additional channels of technology transfer. It is not possible to measure the absolute importance of certain technology transfer channels, and the relative one can only be measured roughly by proxies or subjectively by questionnaires.

Both scientists at universities and scientists at companies have been repeatedly surveyed. Schmoch et al. (2000) presented a detailed study on technology transfer activities from academic institutions in Germany and concluded that there are a lot of activities with and connections to industry, but often in an informal way. Research cooperation in Germany tends to be industrially funded research where the company holds the intellectual property rights of the results. This is in line with a study by Verspagen (2006), who found that in Europe the number of patents, which are not university-owned and have no university inventor but for which university knowledge was important is much higher than the number of patents owned by a university. Czarnitzki et al. (2000) asked scientists to rank different transfer channels and found the highest valuation for publications followed by research cooperation, while spin-offs and patent applications were ranked quite low. The transfer by scientists' mobility was not included in this questionnaire, even though the OECD (2000) ranks this channel the most important (p. 165) as do Crespi and Geuna (2005). In Europe there is a lot of collaborative research, which could be due to concrete problem solving tasks that companies like to outsource to universities (cf. Verspagen 2006 and Broström and Lööf 2006). Agrawal and Henderson (2002) conclude in a study of MIT technology transfer that patents account for only 10% of all transfer activities. A complementary view is that of companies: A lot of companies do not restrict on one form of collaboration with universities, they use different transfer channels in parallel (cf. Cohen et al., 2000, Czarnitzki et al. 2000). This can be easily explained by different tasks and problems which need different solutions.

When starting a research project in co-operation with a company, the transfer form is often already determined, at least to a certain degree. But in the case of commercially useful findings resulting from pure academic research, the inventor or the team of inventors has to decide about the use of one or several transfer channels. According to D'Este and Patel (2007), the university and department characteristics have less influence on this decision than the individual. This situation will be modelled in the next sections.

3. Inventor's decision on the transfer channels

In science, publishing is the common first way of presenting a research result to public (except the presentation to scientific colleagues on conferences). On the one hand, it is a risk free way to diffuse knowledge because it usually does not incorporate financial risk. On the other hand, it does not generate direct monetary income, although it generates scientific reputation which might lead to higher incomes and more career options. Most scientists publish regularly and great parts of the academic system are based on publications.

Increasingly, policy makers expect more engagement by universities and public research institutes in technology transfer. Publications are seen as not sufficient for turning inventions into marketable products and a shift from a pure patronage system (open science; tax funded research) to one combined with property rights takes place. Intermediary institutions shall help to bridge the gap between science and industry. While technology transfer offices offer support for many transfer forms and universities want their scientists to engage more intensive in technology transfer, scientists still face the problem to decide on the use of one of the different possible channels. These channels require different amounts of time effort and skills and differ in their profitability.

The emphasis of university-industry technology transfer is a newer development in Europe than in the USA and one can argue that this is the reason for the continuing heavy focus of scientists on publications. But the increasing number of university patents (see figure 1) shows the change in behaviour and scientists and universities seem to be increasingly thinking about advanced forms of knowledge transfer.

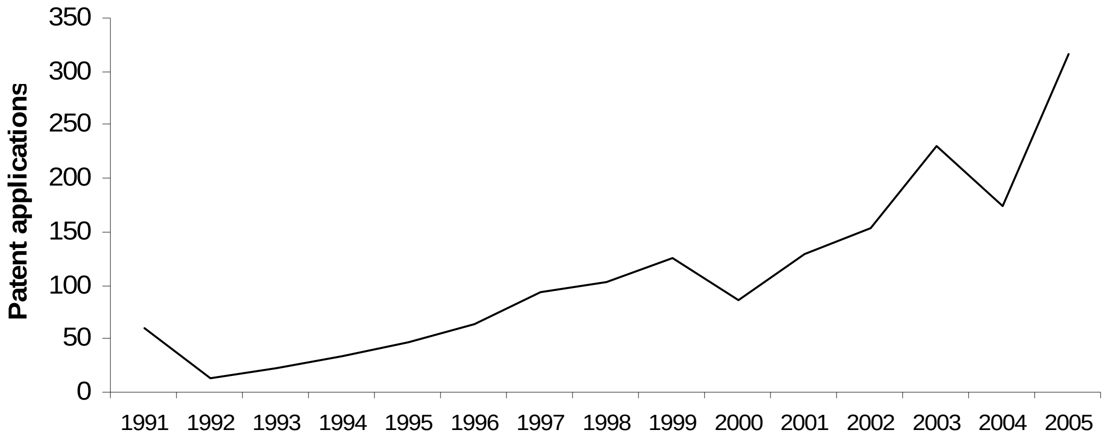

Figure 1: Patent applications from German universities with priority country Germany and with at least one professor involved.

In the USA transfer intermediaries seem usually to choose the way of commercialisation after the disclosure of an invention, while in Europe it is rather the inventor who decides. For the UK, D'Este and Patel (2007, p. 1306) found "that the characteristics of the individual researcher have a much stronger impact in explaining the variety of interactions with industry than those of the department or the university". The same can be expected for Germany: Due to the freedom of utilisation of research findings (the so-called professors' privilege), which German professors had until 2002, the TTOs are designed as a service institution that supports scientists in their way of exploiting inventions. They still do not want to act against the will of scientists who remember the times of the professors' privilege, so that normally the scientist decides on the transfer channel and we will analyse here what influences his decision.

3.1. Choice of transfer channel at different stages of a research Project

There are two points at which decisions have to be made: first, at the beginning of the research project the research team can look for industry funding or rely on public financing. In the former case a company sponsors the research, contracts a specific kind of research or conducts research jointly with the scientists, paying for their work. Sometimes the joint research is also co-funded by public programmes. If the research is purely publicly funded, the project is done independently, at least until certain results are given. When the researchers have obtained first scientific results they reach the second decision point: they have to decide whether they do more than publishing, such as, e.g., applying for a patent, finding an exclusive or multiple licensees or founding a spin-off with or without the involvement of the inventor in the operational management. While the researchers are free to choose between these options if the research was publicly financed, they usually face restrictions in contract research financed by firms. In most cases, the contract with the company specifies how the results have to be used. Usually inventions are licensed to the funding company and not to additional ones or they are patented in the name of the company. This implies a strong difference in the temporal structure between contracted research and other research (see figure 2): While normally scientists decide with the research results in their hands what to do with them, in contracted research this decision is usually taken and written down before the research is started.

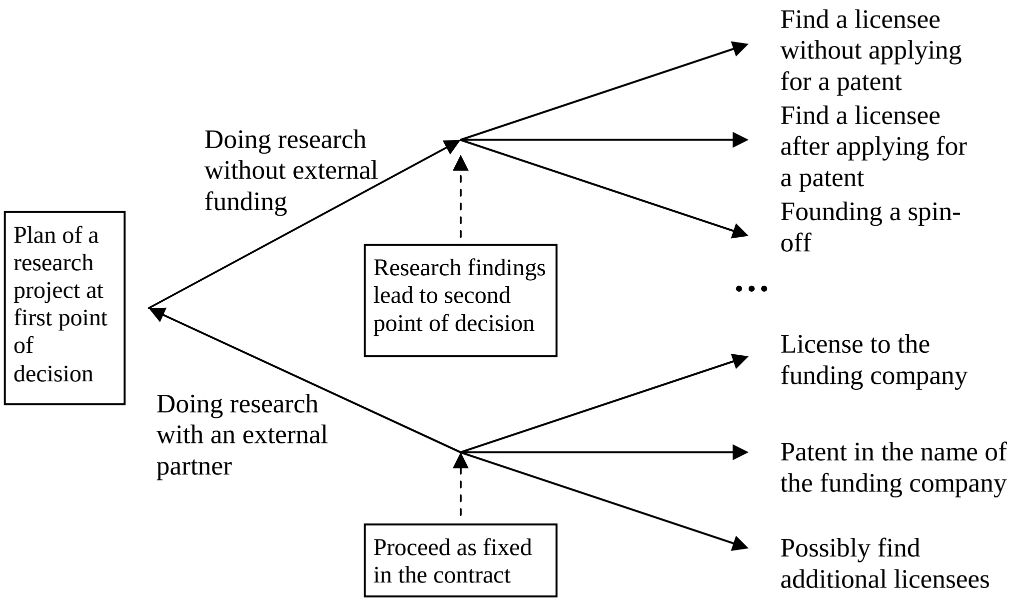

Figure 2: Different points of decision in the research process with a selection of possible transfer channels.

3.2. Complexity of different transfer channels

We assume that one important characteristic of the transfer channels that influences the scientists' decisions is its complexity. We define complexity in comparison with the complexity of the basic form of technology transfer, scientific publication. In the following we discuss how the term complexity is used here.

It is possible to order the different forms of commercialisation according to the effort that is necessary for their conduction and the challenges that they imply for the researcher. Contract research is relatively easy to manage, because you do not have to praise research findings to someone external but only offer a research plan or answer to a request of a company on a certain research task. The additional necessary capabilities (in comparison to research and publishing) are the understanding of the problems and processes in companies, the ability to write attractive research proposals and often also some networking ability. The contract contains payment for the research process, but an additional royalty for the finished invention can be negotiated. Joint research needs the least communication skills, because company researchers are involved in the research process and acquire the explicit and tacit knowledge in parallel to the academic researchers during the progress of the project. The academic scientist does not need to explain the whole technology to an external person later.

Finding a licensee for a technology involves more difficult tasks: one has to find a company for which the technology is of use, negotiate about an (exclusive) licence, and estimate a price for it. Knowledge about potential licensees has to be quite comprehensive because the technology is already specialised, in contrast to contract research where the research is specified after contacting a company.

Applying for a patent adds another degree of complexity. It requires certain administrative skills for the patent application. The licence contract for a patent is comparable to one without a patent, but topics like the duration of the licence contract in connection with renewal fees have to be added. Patenting and licensing together is certainly more complex than giving a license for a non-patented technology to a company. Similarly, finding more licensees is more difficult than finding only one. Developing a satisfying license contract with a number of licensees might well add to the complexity.

Further skills are necessary to assist a start-up that wants to use the invention (with different possible levels of involvement of the inventor). The most complex transfer channel is certainly the combination of filing a patent application and founding a spin-off on the basis of this patent, including leaving academia. Here the researcher needs a lot of organisational and management skills, and next to a network of scientists some connections to financial sources, e.g. venture capital firms are necessary.

There is another way of leaving academia: becoming employed in a company. There are scientists who take an invention with them when they leave science. If a company proposes someone a job, this is of little complexity. It belongs to commercialisation activities only in the case that the company hires the person especially because of his invention. If the scientist wants to switch to industry and has to find a company employing him, it depends on several factors how difficult that is, but then it is not a matter of commercialisation activity any more. Thus, labour mobility is a special case of only little interest for our analysis how an inventor decides on the transfer channel.

As can be seen from the discussion above there are different kinds of skills necessary depending on the transfer channel chosen. Thus, the complexity is a multi-dimensional variable containing communicative, administrative, organisational, and management skills. They have to be learned more or less in parallel, but knowing already the organisational skills of patent applications and finding a licensee makes it easier to cope with the management tasks of a spin-off compared to a scientist inexperienced in all these matters. To a certain extent skills in one area balance the lack of skills in another one. Therefore, one can model the variable "complexity" as the sum of the different skills that are required. This is useful to keep the formal model in the next section simple.

To summarise, we assume that every possible transfer channel inhibits a certain amount of complexity and they can be ordered by increasing complexity. Publications are the reference point with an assumed complexity of zero, a spin-off with a patent where the scientist is the founder and full-time engaged is the most complex form of commercialisation.

Transfer channel	**Management skills**	**Organisational skills**	**Administrative skills**	**Communicative skills**
Contract research by answering a company request	low	low – keeping deadlines necessary for the company	low – tasks must be specified clearly in the contract	high – understand the demands in the beginning and explaining the results to the company in the end
Joint research (relatively open-ended)	medium – leading a team of academic and company researchers, possibly arrange with two bosses	medium – staying in close contact in spite of spatial distance	low – tasks and aims must be specified in the contract	medium - overcoming cultural barriers
Filing for a patent and licensing	low	medium – finding potential licensees	high – filing for a patent with all related tasks, designing a licence contract	high – explaining the technology to all potential licensees
Spin-off after filing for a patent	high – running a business	high – hiring employees, extending network to funding sources	high – filing for a patent with all related tasks, establishing a company	high – explaining the technology to employees you are working with, persuading financial investors

Table 1: List of the different skills needed for a selection of transfer channels

3.3. Increasing experience in transfer activities

As explained above, a more complex channel means that more effort is needed for it. If all transfer channels would lead to the same expected earnings, the least complex channel would be used always. But because higher complexity and more involvement of the inventor mean higher expected profit, inventors can be interested in different transfer channels. This depends on two things: the utility derived from higher income and the risk aversion. Higher complexity and income can only be realised with a certain time effort and this additional income must outweigh the time less available that can be spent on other publications leading to an increase in academic reputation. The risk aversion plays a role because the higher complexity usually comes along with a higher variability of earnings. Therefore the same expectation value for the profit of two channels usually does not lead to the same utility.

The complexity of a task adds for the conductor an additional subjective variance of the profit because the conductor does not know about her ability to deal with the task and is, thus, uncertain about the outcome. Similar to the usual financial risk aversion, the impact of this uncertainty on decisions differs from person to person: There are people who like to cope with complex tasks and others that do not. However, there is one important difference between financial risk and uncertainty about complex tasks: Multiple inventors face the financial risk every time anew, while they gain experience with the handling of complex transfer channels and only those which are new and more complex for them are an uncertainty factor.

Gaining experience does not only take place by commercialising an own invention. There are also "experience spill-overs" caused by the local surrounding and individual networks. When people interact, in the research team as well as in their further environment, knowledge is transferred. This happens voluntarily as well as involuntarily. In our case, scientists of one research group will notice the commercialisation activities of a colleague and remember this when doing it later themselves. Additionally, a person embedded in a network of inventors will have a lot of useful contacts to people who can help him in commercialising an invention. Networks, which often also imply trust, make s actions regarding the commercialisation process easier. An innovative environment may also provide access to people with helpful knowledge. The experience of a technology transfer office may play a role as well. Even though this is in the narrow sense no increase in experience, it has the same effect for the inventor: a more complex transfer channel can become feasible if the barrier of finding partners is smaller and if the experience of others can be used to have a better understanding of what has to be done.

A detailed analysis of the implications of the presented concept follows after the presentation of the formal model in the next section.

4. The formal model

We denote the various options what to do with the invention by the variable x. The value of x is defined to correspond to the variance of the financial outcome of the transfer channel. We assume that this variance is related to the complexity of the transfer channel, meaning that more complex transfer channel lead to larger fluctuations in their success.

For the decision how to deal with an invention three factors play a role: first, the expected payoff $E(P(x))$ - which includes the necessary compensation for the time effort (amount of work), second, the incorporated risk, and third, the knowledge of and the experience in commercialisation activities. As discussed above, financial risk and the complexity of a transfer channel are both forms of risk and will be treated together. The definition of x implies that the profit variance is given by $\text{var} = \delta x$, with some proportional constant δ. Let us also assume that the profit increases proportionally to the profit variance as it is common in financial risk literature for a market in equilibrium: $E(P(x)) = \beta x$. Of course, the market potential of inventions differs, not only between fields of research but also within fields. Similarly, the market environment influences the profit of a commercialisation activity. We can model this by a β depending on the invention and the circumstances. In the model we first assume a fixed β and will later relax the assumption.

Furthermore, we assume that the complexity of a transfer channel increases proportionally with the standard deviation of the outcome. This assumption is based on the argument that each aspect that makes a task more complex provides also an additional source of deviations in the potential outcomes. Hence, $\sqrt{x}$ is the complexity of a transfer channel. We denote the most complex commercialisation form that is known by an individual by $\sqrt{x_{known}}$. Then the difference in complexity between a transfer channel and the known transfer channels is given by $\Delta x = (\sqrt{x} - \sqrt{x_{known}})^2$. The difference is an additional source of risk for the inventor, namely the uncertainty about the own capabilities to deal with this additional complexity and the uncertainty about the benefits from the transfer channel. As in the case of the real financial risk – meaning the real variation in profits – this risk enters the utility function in quadratic form.

For every invention, the complexity can reach a limited number of values according to the limited number of commercialisation possibilities. However, x can be designed as a continuous variable. This is due to three reasons: first, the exploitation possibilities need not be the same for each invention and e.g. the difficulty to find a licensee depends on the kind of invention. Second, applying for a patent once or several times gives a different level of experience. The known level of complexity after using a transfer channel for the first time is still a bit lower than the actual complexity of it, because not all skills are learned completely and one experience does not remove uncertainty about possible profits completely. A successful commercialisation may lead to a higher learning effect than an unsuccessful one. Third, we assumed the complexity to be composed of different kind of skills. These can develop at different speed. Therefore, we define x as a continuous variable.

Let us first look at the utility without complexity The standard approach is to subtract from the expected profit the variance *var* of the profit, multiplied by the individual risk aversion α_i, so that the utility for an individual i is:

$$U_i(x) = (\beta - \alpha_i)x \quad (1)$$

For already known channels the complexity does not play a role, because the inventor knows how to cope with it and what to expect. Therefore, the utility function (1) with only the financial risk included holds for known channels.

The assumption of risk aversion is covered by the variable α_i. Entrepreneurs are often little risk averse and this can be represented by a low α_i. But the majority of scientists are no entrepreneurs and assumed to be more risk averse. A high α_i leads to a low utility of risky options.

A linear design of the expected profit as well as the financial risk leads to an either upward directed ($\beta > \alpha$), downward directed ($\beta < \alpha$), or constant ($\beta = \alpha$) linear dependence of the utility on the value of x. This implies that, depending on the risk aversion, scientists would always choose the least or the most risky transfer channel to commercialise an invention, if the handling of all channels were the same for all people. This is not the case of course. Unknown transfer channels ($x > x_{known}$) decrease the utility because of the complexity the scientist faces. The risk increases disproportionately in the complexity, because the complexity is composed of different kind of skills that all have to be acquired. Learning them all is more than the sum of learning the individual skills. Including the risk caused by the unknown complexity – standard deviation Δx - we obtain:

$$U_i(x) = \beta x - \alpha_i(x + \Delta x) = \beta x - \alpha_i(x + (\sqrt{x} - \sqrt{x_{known}})^2) \quad (2)$$

Figure 3 illustrates how the maximal utility is influenced by the individual risk aversion and the commercialisation experience.

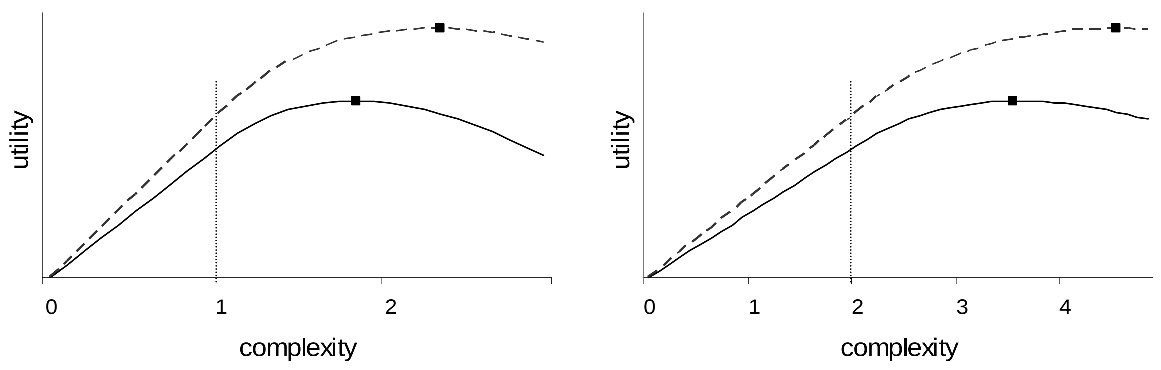

Figure 3: Example for the utility function with lower (dashed lines) and higher (solid lines) risk aversion and different levels of experience (marked with vertical lines). The quadrates show the maximum utility points.

The optimal choice of a commercialising channel for an invention maximises the utility function (2). Differentiating and solving for the complexity shows that for $\beta \geq 2\alpha_i$ always the most risky form of commercialisation is chosen, and that for $\alpha_i < \beta < 2\alpha_i$ the optimal complexity depends on the known complexity given by

$$comp = \sqrt{x} = \sqrt{x_{known}} \frac{\alpha_i}{2\alpha_i - \beta} \quad . \qquad (3)$$

This dependence is linear. The level of complexity used for the commercialisation of one invention $\sqrt{x_t}$ is the known complexity at the time of the next invention $\sqrt{x_{t+1}}$, which results in a recursive function of the optimal complexity for a series of inventions shown in figure 4.

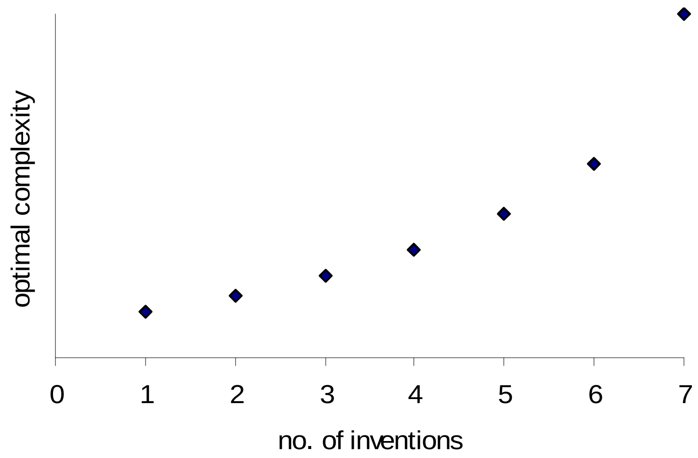

Figure 4: Example: path of optimal transfer channels (approximated by the complexity).

The function of the optimal complexity is shaped by α_i and β. We do not know which time passes between two inventions. Risk aversion usually increases with age. Regarding the lifetime of an inventor, we can not be sure of α_i staying constant. If it increases, the progress to more complex channels is slowing down and may even stop. This would explain – next to the wish to stay in academia – why most scientists do not found a spin-off. As mentioned in the beginning of this section β can not assumed to be the same for each invention an in each environment. Therefore the use of a less complex transfer channel after a more complex one is possible, when a new invention has less commercial value or the market environment is worse than before.

All considerations above are for individual inventors. Many inventions are made in teams. In a team the experience with technology transfer may differ from scientist to scientist. If the commercialisation is arranged by one scientist, the model suits like it does for an individual inventor. If it is arranged jointly the most experienced person can be relevant for the decision or the sum of experiences if they are gained in different field and each person is able to contribute her capabilities. As explained in the previous section, gaining experience can take place by learning from others. The team then leads to learning effects among its members. Thus, to a certain extent the scientists learn from the experiences of others and increase their $\sqrt{x_{known}}$ without having commercialised an own invention.

5. Implications for the choice of transfer channels

The complexity variable introduced above is abstract and not measurable. Nevertheless, we are able to deduce a number of implications from the above modelling, some of which can be tested empirically. Several implications are presented as hypotheses here and, if existing, empirical studies that support these hypotheses are reported.

The above model implies that scientists do not use the more complex transfer channel for their first invention. They have to collect experience and learn about the transfer channels. Thereby they might move step by step from less complex to more complex transfer channels. A temporal structure results in which scientists start with simple transfer channels such as collaborative research and patenting. More complex transfer channels are used only after experience is collected with other transfer channels.

Applying for a patent and then founding a firm is certainly the most complex and time-consuming way to exploit the market potential of an academic invention. The model implies that academic entrepreneurs use other transfer channels before. Thus, we can state:

Proposition 1: Scientific inventors who found a firm have used other transfer channels like applying for a patent and collaborative research before.

There is no literature available that provides individual histories of a number of scientists. Such empirical literature would be necessary to check Proposition 1. According to the proposition we would expect that scientists who found a firm have collected experience with many other transfer channels before.

This implies that scientists who found a firm have made some experience before and are therefore, on average, rather older. We state:

Proposition 2: Young scientists are rather unlikely to found a firm.

Usually, scientists at the beginning of their career start to publish and then may continue with increasingly more complex channels of technology transfer. Klofsten and Jones-Evans (2000) found in a study of Swedish and Irish academic entrepreneurs an average age of 40 and 45 respectively. This is higher than the average age of other entrepreneurs (Klofsten and Jones-Evans 2000, p. 302). Audretsch et al. (2006) analysed, which individual characteristics of the scientist influence the decision to commercialise an invention. They did not find significant influence of the scientist's age on his commercialisation activities, what does not contradict necessarily our considerations: The concept as well as the formal model does not make a statement of how often a scientist invents anything. Therefore we cannot tell at which age a scientist will found a spin-off (if he ever reaches this transfer channel).

Most scientists produce in their life only a few inventions that can be commercialised. Hence, if we consider all inventions in a given period of time, most inventions can be expected to be made by researchers with little experience in the various transfer channels. As a consequence, less complex transfer channels should be more frequently used than more complex transfer channels. In addition, there are scientists who are too risk averse to proceed with more complex transfer channels. Hence, if the frequency of used transfer channels is studied, we expect that the number of transfer channels with low complexity should be much higher than that of transfer channels with high complexity. Considering only the most common transfer channels we can state the following hypothesis:

Proposition 3: The number of collaborative research projects should exceed the number of patent applications. These should exceed the number of licensed patents. The number of start-ups by scientists is expected to be lowest.

There is much evidence for the predominant use of less complex transfer as discussed in the second chapter. In sum, publications, informal contacts, consulting, and scientists' labour mobility are seen as very frequent transfer channels, whereas patents and spin-offs seem to contribute only to a limited extend (cf. Agrawal and Henderson 2002, Cohen et al. 1998 / 2000, Capron and Cincera 2004, Goddard and Isabelle, 2006).

The concave functional form of the dependence of the expected profit on the complexity of the transfer channel gives an explanation for why many scientists do not found a start-up. Scientists with medium risk averseness may try several transfer channels with increasing complexity, but there is a point from which on they are not willing to go for higher complexity. Therefore, one can state:

Proposition 4: Most scientists will never found a start-up, even if they are not completely risk averse, i.e. have used transfer channels more complex than publications before, and even if they produce a sufficiently large number of inventions.

Studies have shown the lower risk averseness of entrepreneurs compared to average people, which supports Proposition 4. However, we have little knowledge about the number of inventions per scientist. Hence, it is impossible to state whether the low number of start-ups founded by scientists is due to their risk averseness or due to the fact that most scientists do not collect enough experience with transfer channels in their lifetime.

We stated above that there are experience spill-overs potentially arising out of the local environment. Networks, cooperation and an innovative surrounding should enhance the gain of experience. Usually, both exist more in an urban area than in a rural one. The co-location of universities and public research institutions as well as companies engaged in research and development should also improve the commercialisation experience.

Proposition 5: Universities or research institutions that are located in an area with other such institutions or companies engaged in research and development use more complex transfer channels than institutions without a stimulating environment.

Research on regional innovation systems and the local interaction of universities and companies supports indirectly Proposition 5 (cf. Fritsch et al., 2007), even though to the authors' knowledge there is no study directly addressing the degree of complexity in transfer channels used in relationship with the local environment.

Summarising, the model offers us a number of predictions that are in part in line with existing empirical studies but provide in most cases new propositions that should be researched. The predictions made here have in common that financial motives are not seen as the crucial factor determining the choice of a transfer channels. The possibilities to learn and collect experience and the risk aversion of scientists are crucial.

6. Conclusion

The literature provides a number of studies on the subjective importance of different transfer channels and on reasons why scientists patent (or not) and found a spin-off (or not). This paper takes a new view in analysing the decision of scientists on transfer channels and how this depends on their earlier experience in transfer activities.

Scientists, especially working at engineering, natural and life sciences as well as medical faculties, make inventions from time to time which can be transferred to industry to become innovations. Various transfer channels exist, which differ in the complexity of necessary activities. We introduced a variable, which we called "complexity", to denote the different degrees of communicative, administrative, organisational, and management skills necessary in the transfer process. The model explains why less complex transfer channels are used so much more than the highly complex ones like spin-offs. Even scientists with medium or low risk aversion will not necessarily found a spin-off during their lifetime either because they do not collect sufficient experience with less complex transfer channels or because their risk aversion increases with age before they collect sufficient experience.

The model is used to deduce a number of predictions about the behaviour of scientists in the context of the commercialisation of their inventions. Part of the predictions are supported by empirical studies. Most of the predictions are not tested so far and, therefore, provide guidance for future empirical research on commercialisation activities of researchers.

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