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Abstract

This policy paper on science-industry technology transfer has four emphases: the rationale of recent changes in German science policy, the contribution of diverse transfer channels to economic development as well as the role of IPR in that context, the differences in the institutional framework between Europe and USA regarding academic patenting, and the organisational design of technology transfer offices (TTOs). The extensive literature review highlights the importance of TTOs, the necessity of supporting manifold transfer channels, and continuous government funding of intermediaries. Important open research questions are the relative importance of transfer channels and the optimal size of TTOs.

Keywords: science-industry links; university patenting; technology transfer offices; science policy.

JEL classification: O34, O33, O31

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1 Introduction

The availability of knowledge and the ability to implement new knowledge into products and processes is essential for an economy to compete successfully in global markets.[1] In countries that do not compete through low labour costs but by technological capability and quality, innovations and their diffusion are critical for success. Therefore national policy tries to set incentives for innovations in order to increase the innovative potential of universities and to use it effectively. The European Union presented the Lisbon strategy, which has the aim of enhancing dynamic economic growth and competitiveness based on knowledge. The focus of this paper is on some of the innovation policies concerning universities and research institutions. These policies were introduced because the contribution of universities for innovation and economic growth is important. In Germany, the so-called "professors' privilege" was abolished (in 2002) as in several other European countries. The privilege had assigned the intellectual property rights (IPR) of academic inventions to the inventing scientist but only a few scientists had made use of this possibility of additional activities. The new employee inventions act assigns patent rights to the university: each invention must be disclosed to the university, which then decides on exploiting it or giving the rights back to the inventor (see ArbEG, 2002). Other countries, for example Denmark, implemented similar legislation. There was some European consensus that technology transfer from science to industry increases financial resources of universities next to contributing to economic growth in the long run (cf. Geuna and Nesta, 2006, p.794 and OECD, 2003).

In parallel, regional patent exploitation institutions (*Patentverwertungsagenturen*, PVAs) were founded to support the favoured patent activities. The government aimed for one PVA for each of the 16 *Bundesländer* (states). In the end 21 institutions were established to cover the patenting activities of nearly 240 universities and research institutes. Eight of the PVAs were newly established institutions; thirteen had existed before as patent consultancies or technology transfer service institutions of some kind. In 2002 and 2003 the federal government subsidised them to the amount of €36m (see Krause, 2004, p.15). The subsidies

1 The European Council stated in March 2000 in the Lisbon Strategy that the aim for the EU is "to become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion". The importance of knowledge, and innovations resulting from it, for economic growth is not only an assumption of policy, but also a fact for authors such as e.g. David and Foray (1995), Agrawal (2001) and Egeln et al. (2003).

for the PVAs were limited to two years initially and then extended for another two years, because they failed to generate enough revenues. A longer funding period was not considered because the agencies were designed to generate revenues and not to receive subsidies. Up to now this aim was not reached and the latest development is that the responsibility switched over from the ministry of education and research to the ministry of economics, where the PVAs now apply for subsidies by presenting a kind of business plan. Most of them still do not generate income. A somewhat higher number of university patent applications can be observed subsequently: universities filed for about 250 patents in 2000 and 600 patents in 2004. However, since 1999 there is an overall negative trend in patent applications with academics involved as inventors (Schmoch, 2007).[2] The number of academic patents (independently of the assignee) dropped from about 3200 patents in 1999 to 2200 patents in 2004. This number had been reached already in 1992 for the first time. The downward trend could not be stopped by the law and patent applications from companies with university scientists involved are still twice as high as applications from universities.

Summarising, the policy for universities has amongst others the following two aims, which will be analysed in this paper in detail:

- to develop new sources of funding for universities, and
- to enhance technology transfer from universities as the general basis for innovations and economic growth.

While studies of the financial gains from academic research show that a significant contribution is unlikely, the aim of increasing the academic contribution to economic development in the long run is seen positively. The two aims are not complementary and to a certain extent they are rivalrous.

The new German policies were intended to strengthen science-industry links because they were perceived to be weak, but known to influence economic development positively (see section 2). While the institutes of the Fraunhofer-Gesellschaft and Max-Planck-Gesellschaft have had formal intermediaries for technology transfer for a long time, at many universities connections to industry existed mainly in the form of individual contacts of professors with

2 See Schmoch (2007), p. 5 for a graph. The database is based on a search for inventors with title "professor" (priority country Germany) and assumes that 30% of non-university-owned academic patents have academic inventors without the title (conservative estimation). The respective shares are than added. Additionally, an assumed withdrawal rate for patent applications of 20% is added.

certain companies. Hence, the extent of cooperation and of technology transfer was hardly measurable. One main explanation for low transfer activities is the problem of different cultures, which complicates collaboration between research institutions and companies.[3] An example is the not-for-profit orientation of science, which instead aims at broadening the knowledge base. Building a reputation by publishing articles is more important for scientists than potential additional income from patents (cf. Powell and Owen-Smith, 1998 and Cohausz et al., 1999). Additionally, there are information and matching problems in which companies often have a precise idea of what they need, while researchers try to find someone who will use the developed technology. The idea of intermediaries is to facilitate the relationship between science and industry, and improve technology transfer by means of faster and more profound implementation of new technologies. It has to be appreciated that policy established intermediaries in parallel to the legal change.

In the following sections the appropriateness of the aims is discussed by presenting scientific studies in this field and propositions are made how policies may make attaining the aims feasible. Critical in this context is the design of technology transfer offices (TTOs). Thus, in addition to a discussion of academic patenting the tasks of TTOs will be accentuated. Another emphasis of the article lies in the different institutional framework of the USA and Europe, especially Germany, which impedes the adoption of the American regulations. Due to the richness of studies on technology transfer from science to industry the literature review and its discussion comprise much of the article. Section 2 discusses the aims of German policy on university technology transfer, while section 3 assesses the amount of German technology transfer in comparison with other countries and presents research on the effects of different IPR ownership models on academic patenting. The fourth section focuses on the institutional differences between Europe and USA which affect the work of TTOs. A discussion of which tasks these should cover follows in the fifth section, and the sixth section concludes with an emphasis on open questions regarding academic patenting and the design of TTOs.

I bring theory and existing empirical research together what has rarely been done yet. Debackere and Veugelers (2005) published a study with a similarly extensive literature review but with the main focus on decentralisation, incentives, and monitoring processes. They compared the technology transfer office of KU Leuven with others using a descriptive

3 Cultural and other barriers for industry-science interaction are discussed inter alia in Siegel et al. (2003b), p. 3 and Cornet et al. (2006), p. 16.

approach. Verspagen (2006) emphasises the theory of patents and their possible negative effects, and presents a survey about the perceived amount of actual technology transfer in Europe beyond academic patents. In this paper the focus is on Germany, on the use of diverse transfer channels, and on open research questions. The summary of institutional differences in academic patenting between the USA and Germany/Europe has not been presented at this level of detail before.

2 Aims of German policy on university technology transfer

2.1 Patent revenues as a funding source for research

The question addressed in this section is: can an intermediary responsible for technology transfer from science to industry be designed in a way that not only covers the costs of the intermediary itself but earns revenues that can be used to fund a part of the research?

German Science Policy focuses on patents, but we should remember that patents are only one possible kind of transfer and TTOs need not restrict themselves to that channel. Certainly, licences from patents and other licensable research output like software generate most of the income of a TTO. They do not earn anything by establishing and maintaining ties and their support in the design of a collaborative research contract usually results in payments to the collaborating department only. As a result all financial arguments on TTOs have a focus on licences. I first present findings on the revenues of academic patents and then on the contribution of TTOs in the licensing process.

The amount of revenues generated by patents varies a great deal and is thus a very uncertain source of income. Most patents generate small earnings and a few “nuggets” are responsible for the lion’s share of revenues. Scherer and Harhoff (2000) show for several countries that this skewness exists for patents both from industry and from science.[4] At Massachusetts Institute of Technology (MIT) in 2000 only 0.6% of the patents earned more than $1m even though MIT is known for successfully commercialising its research results (Pressmann,

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[4] This paper does not distinguish between universities and other public research institutions, because both are non-profit-oriented and need to transfer their knowledge in order to realise innovations. Thus, expressions like “science” or “academic patenting” relate to universities and public research institutions etc. at the same time.

2002). Mowery et al. (2001) find that for three further US universities 5% of patents contributed between 66% and 94% of patent revenues in 1995.

One reason for the difficult and rarely successful commercialisation of academic patents lies in the early stage of development when disclosure occurs. A study of TTOs in the US by Jensen and Thursby (2001) indicates that most inventions were disclosed at the proof-of-concept stage. However, they find that inventions licensed at a later stage generate higher revenues. The earlier the disclosure the more difficult it is to estimate the economic potential of the invention and to find a licensee interested in developing the invention into a marketable product.

Although there are some factors enhancing the success of patent commercialisation (see section five), a large number of TTOs run at a loss (cf. Geuna and Nesta, 2006 or Turk-Bicakci and Brint, 2005). Heher (2006) estimates that 50% of TTOs in the USA run at a loss and in the UK as much as 75%. One reason for this difference could be the higher average experience (age) of the TTOs in the USA. Chapple et al. (2005) find in contrast that older intermediaries in the UK are less efficient. Thus it is not yet certain whether experience has an impact on performance in the long run. In the short run it is clear that new intermediaries have hardly any income because of the time lag between disclosing an invention and obtaining licence revenues from it. Additionally, the establishment of a pool of connections to companies which can be useful in the case of an invention takes some time. Structural differences between intermediaries in the USA and Europe that may have led to higher revenues of academic patenting in the USA (and will continue to do so) will be discussed later in section four. Generally, a TTO needs a certain endowment of specialists to work effectively. These high fixed costs face very uncertain revenues. A critical mass of inventions disclosures is necessary for a TTO to have the possibility of a highly successful patent (cf. Sellenthin, 2004). There is a positive relationship between staff size and both the number of licences and the licensing revenues, but with decreasing returns to scale (Chapple et al., 2005, p. 378). On the other hand, because of the geographical distribution of universities, the TTOs can face problems when serving too many universities. Proximity and face-to-face contacts are relevant in engagement with the inventor. In a survey of the German PVAs, the consulting firm Kienbaum (2006, p. 53) found that the satisfaction of the scientists with the intermediary decreases if more than 5000 possible patenting scientists are being attended to.

Thus it is not unusual for a TTO to have an average income from licences amounting to just 1% of the research budget of the corresponding university or research institute.[5] Even in very successful TTOs the amount does not exceed 4%. Sellenthin (2004) argues that if a private solution of technology transfer institutions were profitable, it would have been established by now.

2.2 The impact of technology transfer on the economy

At the university level, technology transfer will rarely be profitable and is not suitable as a reliable additional funding source. Nevertheless, when taking a broader view academic inventions have a significant influence on the economy. A broader view includes all kind of technology transfer – not just patents – and indirect effects exceeding the direct relationship between one university and one company. Indirect effects are generated for example by jobs and subsequent innovations resulting from successful commercialisation of an academic invention. Thus the economy as a whole benefits much more from academic inventions than individual universities or research institutes. Even unsuccessful inventions can be useful if they mark out some encouraging pathways or lead to new ideas for further research. The seminal article by Jaffe (1989) on several aspects of the impact of academic research found a positive influence on firms' innovative activities. Similar results come for instance from Cohen et al. (2002), who additionally find that patents are less important than personal contacts and publications, and from the OECD (2000a) and Rosenberg and Nelson (1994), who derive a positive impact from academic research on innovative performance. At universities where teaching and research are intertwined, continuous transfer takes place in the form of graduates who start to work in industry. This holds for bachelor and master students, but even more for doctoral students with research experience. Those who made a patentable invention while working in public research are especially likely to move to a company (cf. Crespi et al., 2007).

In a survey of companies, the researchers of the *Patval* project asked about the patents where university inventors were involved, and about those where no university-inventors were involved but university knowledge has been important for the invention (Verspagen, 2006; Lissoni et al., 2007). The share of patents with direct academic input is 3-4% for Germany,

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5 See Heher (2006), p. 404 and Polt (2001), p. 323 for universities in several countries and Buenstorf (2006) for German Max-Planck-Institutes.

France and Italy, while Spain and England have a higher share with 6% and 9% respectively. Adding the patents with indirect input increases the share of patents with academic contribution to as high as 23% for the Netherlands and 15% for Germany. Thus, scientists in Europe contribute to innovation by using several channels.

Both Carlsson and Fridh (2002) and Heher (2006) argue that the aim of technology transfer from university to industry in all its forms must be to support overall economic development because the benefits emerge mainly on an aggregated level. The term "aggregated" can have several meanings here: one can observe the influence of academic research on industries, on regional development or on a national level. At all these levels not only direct effects on individual companies are analysed, but also indirect effects on society.

3 Technology transfer evidence and policy effects

3.1 Technology transfer in Germany in comparison with other countries

In order to estimate the strength of university-industry ties, a study for the European Commission analysed how different channels of technology transfer were used by countries and industries (Polt, 2001, pp. 317-318). Out of ten examined countries, Germany and Belgium had the highest intensity of contract and collaborative research. Consulting activities of scientists and the mobility of researchers are also strong transfer channels in Germany. These three channels are stronger than in the USA. Compared to other European countries, Germany has a high number of university-owned patents, but here the USA shows higher values. After surveying companies and universities on transfer activities Verspagen (2006) argues that the amount of technology transfer is high in Europe, but it usually takes the form of research collaboration with companies or the hiring of former university scientists.[6] Regarding patents with university-related inventors, the majority is assigned to companies. As discussed above, taking those into account as well as patents where inventors are assignees themselves, the contribution of universities to national patenting is comparable in many European countries and the USA.

6 See Verspagen (2006), p. 622. Similar results only for Germany can be found in Schmoch et al. (2000), executive summary p. 3.

In Europe the number of university-owned patents has increased during recent years. Following Mowery et al. (2001) for the USA, Geuna and Nesta (2006, p.794) argue for Europe that increased technological opportunities are responsible for additional patents rather than policy decisions. The production factor of knowledge becomes increasingly protected and independent of personnel. Geuna and Nesta do not observe causality between the refusal of patenting and absence of innovations. Furthermore, the OECD (2000b) states: "patenting is not a reliable measure of scientific output".

Nevertheless, in Germany there is a strong policy focus on patents in relation to technology transfer. The rationale behind this is the linear model of innovation (see Mowery and Sampat, 2005a). This model arose from the belief that basic research leads to applied research and this in turn leads to the development of innovations. If policy focuses on patents, it follows this model and aims to decrease the time lag between basic research and innovations. However, there are newer models that can describe innovation processes more precisely, usually called innovation systems.[7] They have a greater number of actors involved at different stages of the innovation process and with different intensity. The process is recursive, i.e. trials are carried out and actors go back to earlier stages if new possibilities emerge. In particular cases a result from basic research can be commercialised directly, but this is an exception and normally the process lasts longer and has many feedback loops. Models of innovation systems show the importance of manifold communication channels for technology transfer and patenting is only one possible channel.

By focusing on patents and licences as it was done with the establishment of the PVAs, policy in Germany gives too little attention to other channels of technology transfer. Only spin-offs are noticed as being similarly important, regarding the funding for entrepreneurial activities at universities like the "EXIST" initiative of the federal government. According to Cohen et al. (2000), patenting is often not the most effective way to protect innovations. Nevertheless, due to the legislation, an invention emerging from collaborative research must be disclosed to the university and checked if a patent application is possible and sensible (for the university's purpose). From the viewpoint of the company this can bring at least three problems. First, licensing can be more expensive than just paying for the joint research, and in extreme cases it is even unprofitable. Hall et al. (2001) list difficulties with IP issues as a reason why a

7 Kline and Rosenberg (1986) have already described the weaknesses of the linear innovation model 20 years ago.

company may refrain from collaboration with a university. Second, licensing can be ineffective if other companies can easily invent around the protected technology. Third, it could be strategically better to protect the innovation in a different way, for example by bringing a product rapidly to market to have lead time instead of negotiating with a university. If these strategies do not work, the joint research project has a lower value for the company. Valentin and Jensen (2007) show evidence of less research collaboration between Danish companies and universities following the legal change, which introduced university IPR ownership in Denmark in 2000. Santoro and Gopalakrishnan (2001) found that dealing with IPR flexibly ("to customize contractual agreements for IPR, patents, and licenses in order to meet the firm's specific needs") is associated with greater technology transfer activities (Santoro and Gopalakrishnan, 2001, pp. 167-168). These studies suggest that a more flexible approach would be an improvement for technology transfer via patents and licenses.

There is no possibility of objectively measuring the amount of technology transfer by a given transfer channel. Mansfield (1998) is the only author who estimated at least the *overall* contribution of academic research based on a survey of companies. A subjective and relative estimation for individual channels was made by Czarnitzki et al. (2000) on the basis of a survey of 1600 scientists of German universities and research institutes. Publications and joint research projects with companies were valued most highly. But the PVAs have rarely engaged in the acquisition of industry funding research projects up to now.[8] Spin-offs and patent applications jointly with companies received low values – only the Fraunhofer-Gesellschaft ranked patenting highly. On average, publications were ranked three times as important as spin-offs on a 0 to 3 scale (which of course is no metric measure). The OECD's most important channel – the mobility of scientists – was not considered in the survey (OECD, 2000b, p. 165). Graduates and PhDs that are employed in a company bring with them a great deal of knowledge. Rosenfeld et al. (2005) confirm this for a German region; and Jaffe (1989) and Cohen et al. (2002) emphasise the positive impact of personal interaction on research and development for the USA. Interaction is facilitated by contacts emerging out of scientific mobility. Mowery and Sampat (2005b, p. 122) also argue that "given the importance assigned by industrial researchers to the 'non-patent/licensing' channels of interaction with universities in most industrial sectors, it is crucially important that these channels not be constricted or impeded by the intensive focus on patenting and licensing in many universities." Fritsch et al.

8 In the survey conducted by Kienbaum (2006, p. 40) 74% of the surveyed university management staff answered that the PVAs did not help in getting external funding.

(2007, chapter 6) argue that support for research collaboration can be a starting point for further transfer activities. This body of research suggests that any intermediary for enhancing technology transfer should support the inventors with the channel of transfer they prefer enabling them to exert their best efforts.

It may be that the existing rate of transfer is just *perceived* as too low or that the currently used channels are not seen as the right ones. Nevertheless there is no argument against the aim of increasing the use of academic knowledge as one basis for economic development as long there is no measure of the existing and potential amount of transfer.

3.2 Policy effects

The new employee inventions act assumes implicitly that university ownership of IPR is better than company or individual ownership. Few theoretical and empirical studies address that topic. US studies are of limited use here because individual ownership hardly exists in the US science system. Aghion and Tirole (1994) created a Principal Agent Model on the outcome of a research joint venture between a university and a company depending on the assignment of the IPR. Both partners contribute to the project. If the company owns the IPR, the university gets a fixed payment, if the university owns the IPR both parties share the pay-off through a licensing fee which the company pays to the university. Aghion and Tirole argue that in a joint research project company ownership of IPR leads to an innovation of lower value. Only if the marginal impact of the university effort on the collaboration outcome is high, the company may be willing to leave the IPR to the university and a market failure is prevented. Hence, the authors conclude that a law should ascribe IPRs to universities.

Hellmann (2005) analyses the probability of the commercialisation of an invention a professor has made in a first stage. There are three parties involved: the scientist, the TTO and the company. The TTO is assumed to have a higher probability to find a licensee, but it demands a share of the revenue. The scientist faces a trade-off between disclosure to the TTO, which raises the probability of finding a licensee but lowers the pay-off from it, and non-disclosure, which leads to less probable commercialisation but raises the pay-off from it. A scientist discloses an invention or not depending on how big the disadvantage of a scientist's own search for a company is. Hellmann does not discuss the welfare effect but because of the assumed search advantage of the TTO a non-disclosure decreases the efficiency of the commercialisation process. If there is no search advantage, i.e. if one assumes that inventors have contacts to relevant people in industry in their field, there is no incentive for an inventor to disclose an invention to the TTO. Instead, there is an incentive to circumvent the TTO.

A third theoretical model constructed by Kirstein and Will (2006) leaves the company out and focuses on the inventor and the employer. The old German law can be described as an ex-post negotiation about the commercialisation of an existing invention. The new law fixes the payment scheme ex-ante on a certain share of the returns (30%). Under the assumption that the employer increases the commercial value to a certain extent, both rules lead to less than efficient effort of the inventor. The optimal solution is a fixed payment for the inventor in case of an invention.

An empirical analysis of the commercialisation success of academic patents assigned to companies in comparison to those assigned to universities was done by Crespi et al. (2006) for six major European countries. They find that university-owned patents are licensed more often, but this does not result in an overall increase in commercial use. The result is robust with respect to ex-ante observed differences in characteristics of university-owned and non-university-owned patents. With respect to individually-owned patents, they find some evidence that university ownership is superior to individual ownership, but also to ownership by public research organisations.

Valentin and Jensen (2007) report a decrease in collaboration between Danish universities and companies after the same change in law as in Germany (only two years earlier). It is unclear if companies are just dissatisfied with the new legislation because they remember the old one. If this is the case, they may get used to the new legislation and in the long run the negative effect could disappear. However, the authors do not find an advantage of the new law.

A comparison of the inputs of academic research (i.e. funding structure) before and after the Bayh-Dole-Act in the USA was done by Rafferty (2008). Here, the Act facilitated the patenting of academic inventions with the aim of closer science-industry links (see also section four). There are no structural breaks in the time series of the funding structure and the share of basic research stayed the same, even though one could expect an increasing industry funding and a bias towards applied research, which is usually easier to patent.

The existing studies do not clearly show a predominance of the assignment of IPRs to universities. In the case of inventions resulting from collaborative research the European model seems to work well. There may be a difference compared to inventions resulting from exclusively academic research, where there is no self-evident commercialisation partner.

We have shown in the last section that focusing on patents neglects the contribution of other transfer channels. Therefore policy has to leave the IPR ownership somewhat behind and focus on the enhancement of all kinds of technology transfer by optimally designed TTOs. This shall be discussed in the next section.

The effect of the establishment of the *Patentverwertungsagenturen* cannot yet be investigated but existing empirical studies of other countries suggests that the PVAs are too narrowly defined. The aim of self-financing and even generating income has not been achieved and is unlikely to be achieved for many PVAs. Some politicians are already asking for less successful PVAs being closed down. However, this does not take into account the problems that may arise then from a greater distance between inventor and TTO.

4 Different institutional frameworks in Europe and the USA

In a previous section the difficulty of adopting US regulations has been mentioned. In the USA academic inventors never owned the IPR of their inventions as they did for instance in Germany and Norway. One of the central justifications of the Bayh-Dole Act was that government ownership of publicly funded inventions impedes their commercialisation. Thus the Act placed the property rights *nearer* to the inventor (cf. Mowery and Sampat, 2005b, p. 123). Independent of the question of whether history matters, i.e. if former regulations influence the outcome of recent ones, the increase of academic patenting in the USA cannot be ascribed to the Bayh-Dole Act, as discussed in section three.

In Germany agreements on both patent licensing and sponsored research at the same time are less common than in the USA. In the Kienbaum (2006) survey hardly any intermediary was engaged in research funding contracts, contrary to the combined agreements on patents and sponsored research in the USA (see above).

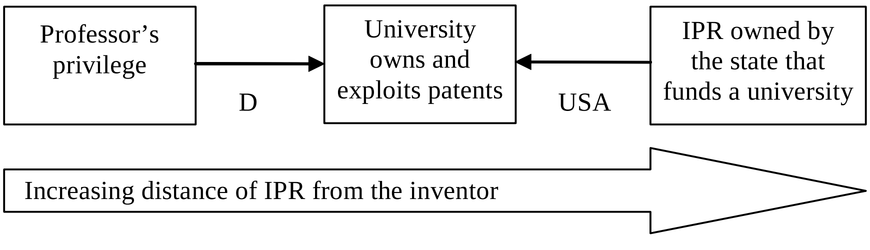

Figure 1: Change in IPR legislation in the USA and Germany.

The former legislation is not the only institutional difference between the USA and European countries. The grace period for applying for a patent after publishing the research results facilitates the combination of publishing and patenting. In Europe there is no grace period. American universities also have an important source of additional income: there are no software patents in Europe, and thus the potential patent income in the US will always be higher than in Europe. Of course, software licences without patents but on the base of copyright law can be executed as well. For patentable inventions, the scope of claims is partly broader in the USA, e.g. regarding genetic codes. While in Europe only specific applications can be patented and those unknown at the time of patenting are freely available, in the USA yet undiscovered applications are protected as well (cf. Verspagen, 2006, p. 611). Obviously, this increases the possible reward of a patent.

Another difference lies in the duration of the patent process: the US Patent and Trademark Office (USPTO) needed in 2005 on average 29.1 months to execute a patent (27.6 months in 2004), while the European Patent Office (EPO) needed 45.3 months in 2005 (46.2 months in 2004). This is more than a year longer and hinders the licensing. In addition the share of patent applications that are granted in the end by the patent offices is higher in the US than in Europe.[9] The annual report of the EPO does not indicate this ratio, unlike the USPTO where an allowance rate of 54% was reported for the patents granted in 2006 with the comment that this is the lowest ratio ever. In order to compare this allowance rate with European data the granted patents of 2005 were divided by the applications four years earlier. The result is a ratio of only 34%, one third less than in the USA. Whether the quality of patent applications is higher in the USA or the EPO is stricter in patent examination, i.e. makes higher demands, can not be stated without further research. However, it is clear that the lower acceptance rate and the longer pending period make the work of TTOs at European universities more difficult.

Traditionally, US universities have a closer connection to industry in comparison to European universities because of the decentralised education system, a greater diversity in financial sources (and greater availability of venture capital), more common interdisciplinary research and greater autonomy of young scientists (see Riccaboni et al., 2003 and Mowery and

9 See EPO (2001), EPO (2005), USPTO (2005), and USPTO (2006)

Sampat, 2005b, p. 118). Compared to the rest of Europe, in Germany the differences may be less strong: the education system is decentralised and the collaboration of small (4.4%) and large companies (22.4%) with universities is higher than in France or the UK (data from OECD, 2007). The structural difference is not easy to overcome because it developed over decades. By establishing stronger connections between science and industry transfer intermediaries are an outlet for overcoming this barrier.

5 The design of technology transfer offices

The basis of technology transfer is scientific excellence of the university or research institute (see Debackere and Veugelers, 2005, p. 327). By having competence in basic and applied research combined with a clear commercialisation orientation, the university can act as an interesting partner for industry. Thus, beyond the whole of the following discussion stands the precondition that technology transfer needs outstanding knowledge creation and excellent new technologies. As long as this does not exist at a research institution, no effort in transfer can be effective.

The following two sections will discuss the design of TTOs first focusing on the incentives for scientists and then discussing organisational issues. Thus we are leaving behind the discussion about patents behind and are focussing on the design of TTOs.

5.1 Incentives for scientists

Several papers have shown the importance of integrating the scientist into the transfer process in order to commercialise a technology successfully (e.g. Jensen and Thursby, 2001). Scientists know the details of their invention better than anyone else, i.e. they have tacit knowledge about the invention. Without the inventor no market expert of the TTO can estimate the market potential. However, at least in Germany the collaboration between inventors and PVA staff could be improved. In the Kienbaum (2006, p. 43) survey many inventors said they wanted to be involved more intensively in the transfer process. The openness of the PVAs was insufficient. About half of the inventors would have commercialised the inventions successfully even without the intermediary. In the same survey the university managers emphasised how important it is for the intermediary to know the university and its scientists well.

The current German legislation assigns 30% of the revenues to the inventor. Whether this is enough to set an incentive for optimal effort can be doubted. For the USA, Link and Siegel (2005) show that those TTOs that give a higher share of commercialisation profit to the scientists tend to work more efficiently. Several studies see a positive connection between the royalty share for the inventor and TTO success.[10] One explanation for this is the necessary engagement of the inventor in the process of licensing because it is not the number of patents that increases in a higher royalty share for the inventor but the revenues per invention. Thus the engagement of the inventor in the licensing process leads to higher financial success as well as a more substantial knowledge transfer. Using a Principal Agent model, Kirstein and Will (2006) show that the new German law fails to induce best efforts. Despite the importance of monetary rewards one can argue that money does not suffice. As previously mentioned, gaining reputation is a strong motive for the scientist. As long as this reputation is built almost solely by publications and not by effort in technology transfer activities (and teaching), the transfer will not rank highly in the awareness of the scientist. A possibility for setting incentives for technology transfer is to include disclosures of inventions next to the conventional use of publications in personnel reviews and calls for professors (although for humanities and social sciences this would have to work differently). The law allows professors to refrain from disclosing an invention. In a strict sense this also means refraining from publishing (see ArbEG §42(2)). A professor who is not interested in technology transfer can argue that he does not think of his research results as an invention, because it is difficult to decide what an invention is and what just a research finding, which a professor is freely allowed publishing. However, invention disclosures are a necessary precondition for further activities (see Owen-Smith and Powell, 2001 and Jensen et al., 2003). Thus, a reward for invention disclosures (monetary or immaterial) sets a necessary incentive for a closer link to the TTO.

Currently in Germany disclosing an invention to the TTO is mandatory (if disclosing at all) and it is not possible for scientists to commercialise inventions by themselves or to leave IPRs to a cooperating company. It may be asked whether a mandatory rule is always inferior to voluntary possibilities, because technology transfer cannot be enforced (see David and Foray, 1995). Additionally, actions cannot be supervised completely and scientists avoiding the duty of disclosure to TTO would be unlawful even though they engage in technology transfer.

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10 E.g. Lach and Schankerman (2003), Friedman and Silberman (2003), Jensen and Thursby (2001).

Also, a disclosed invention does not guarantee effort on the part of the inventor in the commercialisation process. According to a survey among German professors and university rectors the acceptance of the PVAs is low because the new law is opposed (Kienbaum, 2006, p. 39).

Summarising, possible incentives for scientists are a freely negotiable share of revenues or profits, the freedom to carry out technology transfer on their own, and the inclusion of transfer activities in the assessments of tenure tracks and possibly for salary negotiations.

5.2 Design of technology transfer offices

Technology transfer offices working on a local or regional base have a long tradition in the USA. Several studies analyse the role of these intermediaries and the critical success factors. Chukumba (2006) observes empirically that greater experience (measured by TTO age) leads to higher revenues of patents, while Chapple at al. (2005) find the opposite. Thus the role of the age is not yet conclusive. Hoppe and Ozdenoren (2005) explain this by the necessary investment in human capital for the TTO to work effectively. In the start-up phase of a TTO this is reasonable because of the time lag between applying for a patent and generating revenues from it. Siegel et al. (2003a) show that a low turnover rate among staff and sufficient business and marketing experience in the TTO are needed for a long-term relationship with companies. Jensen et al. (2003) find that faculty quality is positively associated with the rate of invention disclosures at the earliest stage (which are the most difficult to license).

These research findings on technology transfer from universities imply some more or less promising fields of action for TTOs and corresponding regulations in order to gain the greatest benefit from academic inventions. Intermediaries have to be funded publicly on a continuing basis because the returns of technology transfer emerge mainly on an aggregated level. The distribution of the individual income is so skewed that only some TTOs will be able to work at a profit.

The TTOs need highly qualified staffs that continue working there for a long time. This investment in capability serves to gain experience in order to work more efficiently as well as to build up trust among the companies (cf. Siegel et al., 2003b). The minimum amount of staff requires a minimum amount of scientists served, i.e. universities covered by one TTO. The Kienbaum (2006, p. 49) survey found that PVAs with more than five employees were more successful than smaller ones. On the other hand, Chapple et al. (2005) argue that larger TTOs are less efficient. In their survey the TTOs have on average 6.84 employees and a maximum of 35; that means they are larger than those in Germany. Thus there need not be a discrepancy between the two surveys; it is possible that there exists an optimal size. For a small TTO an additional employee can cover a new field of science, and increase the number of supported scientists, and thus lead to higher revenues. The effort for filing a new patent decreases at the beginning (Owen-Smith and Powell, 2001). When all fields of one university are covered, a larger TTO is only possible if additional universities collaborate with the TTO. The geographical distance between TTO employees and scientists necessarily increases and the relationship becomes loose. Therefore one can expect an inversely u-shaped function of TTO income dependent on the number of employees. As well as size, the structure of the TTO plays a role according to Bercovitz et al. (2001). A matrix structure seems to be best. Up to now this cannot be applied in German transfer institutions because they are still small.

In order to support all transfer channels the individual programs and institutions of the federal government should be bundled. If TTOs are the contact persons for all scientists interested in transfer independently of which transfer channel they prefer, the service for inventors is better and at the same time the high investment in TTOs could pay off sooner.

6 Conclusions and further research topics

This paper on technology transfer from science to industry focused on four things. First, the rationale of recent changes in German science policy was discussed. Then, an overview of technology transfer channels, their contribution in several countries, as well as IPR ownership questions in that context was presented, before in the fourth section the differences in the institutional framework between Europe and USA were analysed in detail. The last focus was on the design of TTOs, which includes the necessary incentives for scientists and organisational issues.

The literature review on the possible revenues generated by university-owned patents and the coexistence of several transfer channels highlighted the relevance of a broad approach. German policy puts too much emphasis on patents. For all possible channels holds: even though personal contacts of scientists to industry are helpful, technology transfer offices can contribute significantly in the transfer process. Existing studies on TTOs give a largely consistent picture of what tasks they can take over, how they have to be structured to support scientists active in transfer best, and what it is not possible to achieve.

Other things still require investigation: More research is necessary on the optimal size of TTOs regarding the number of employees as well as the geographic coverage. This matters because of the importance of personal interaction as discussed in the last section. The assumption that the more intensive industry links in the USA compared to Europe is based on a closer relationship between these two actors of the innovation system should be further verified and, where appropriate, how the connection between scientists and company employees could be improved in Europe.

The most important conclusion here after a close analysis of several studies is that the benefit of technology transfer from science is generated mainly on an aggregated level. Technology transfer intermediaries have to be funded publicly on a continuing basis. Many of them will not generate profits in the long run and those should be subsidised because society nevertheless benefits from the transfer. Even if they do not run at a loss (as the majority does) they cannot contribute to financing research substantially. This implies that every form of technology transfer should be seen as positive. If scientists engage in collaborative research with companies, by transferring the risk of commercialisation as well as the IPRs of what they devise to the company, then this is a contribution to technology transfer and should not be hindered. The intermediaries act rather as an offer to those scientists that are not interested in spending much effort on the transfer process. It is not conducive to success if some transfer channels are neglected. As long as there are no sensible conclusions on the relative and absolute importance of different transfer channels, all have to be supported. The second important finding is the danger of referring to American policy because the framework is not comparable to Europe. Here further research could investigate why the patent allowance ratios of the USPTO and the EPO differ so much and if it is an institutional difference.

The evidence on the role and effects of intellectual property rights at universities is not yet sufficiently conclusive. A high number of patents may lead to litigation against universities. There are further possible negative effects like the delay or even prohibition of publishing results or data. Hall et al. (2001) provide qualitative evidence for the US on intellectual property barriers that inhibit the formation of public-private partnerships. If these and other negative effects are aggravated, policy needs to consider the patent orientation carefully. Regarding the decrease in academic patenting as shown by Schmoch (2007), one needs to find the reasons of this development and analyse, if the lower number of patent applications goes along with a lower level of technology transfer overall.

A new research approach would be the question of whether patented knowledge makes the transfer by scientist mobility less attractive because the value of the scientist coming to a company is less if his invention is protected and has to be licensed additionally in order to use the scientist's knowledge completely.

Finally, the difficult question about the absolute and relative value of knowledge transfer and what academic research can contribute to economic development is far from being solved and remains a significant subject for wider research.

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