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Transfer of University Innovations

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"Transfer of University Innovations"

Inés Macho-Stadler (*)

The generation of knowledge in basic and applied science is one of the most important engines of economic growth. It is also one of the most reliable factors for the creation of wealth. It is generally accepted that universities and public research centers play an important role as a source of discovery, in particular for basic research. For example, Cockburn and Henderson (1998) calculate that research carried out in public institutions was used in 16 out of the 21 medicines that, according to experts, have had the greatest therapeutic impact between 1965 and 1992. Even though it might appear to be the case that basic research is less effective, Mansfield (1980) shows that in the United States its effect on the overall productivity of firms and industry is not only positive but it is in fact greater than the effect of a similar expenditure on applied R&D. When valuing the importance of basic research undertaken in universities, Mansfield (1998) estimates that without this research, the development of 15% of new products would have been seriously impaired (see Table 1 for more details). Mansfield estimates that the average lapse between academic research and industrial innovation is six years, and that the social rate of return from academic research is of the order of 40%.

At the same time, it is also generally accepted that universities and public research centers are in a better position to create new knowledge than to

Table 1:
Percentage of new products and processes based on recent academic research, 1986–1994. Mansfield (1998)

Industry	Percentage that could not have been developed (without substantial delay) in the absence of recent academic research		Percentage that were developed with very substantial aid from recent academic research	
	Product	Process	Product	Process
Drugs and medical products	31	11	13	6
Information processing	19	16	14	11
Chemical	9	8	11	11
Electrical	5	3	3	2
Instruments	22	20	5	4
Machinery	8	5	8	3
Metals	8	15	4	11
Industry mean	15	11	8	7

apply it. In general, academics do not have a comparative advantage in commercializing the results of their research. Commercialization requires a set of abilities that is not commonly found in scientific communities: the ability to identify the most adequate sector, knowledge of the needs of clients, the possibility of designing the sales or marketing strategy of the product. But at the same time, basic science is crucial if we want to improve known techniques or develop new products and processes, and collaboration with scientists in the early stages of development is also decisive. Therefore, given the revenues that can thereby be achieved, the objective of getting universities and academics to be active both in the generation of new knowledge as well as in its dissemination to the productive sector, and of getting them to collaborate with firms, has attracted the attention of regulators and those in charge of the design of R&D&i policy.

As far as universities and public research centers are concerned, there are quite a number of interesting questions (both from the positive and the normative point of view), which if answered could allow for an improvement in the scientific and competitive situation of an economy, or for which the answer that is adopted becomes decisive for the understanding of the particular situation of a country or region. For example, what should the objective of universities be? What inspires academic research? What inspires the transfer of universities' technology to the rest of society? It is indisputable that a very important part of the transfer of knowledge and technology is carried out when new scientists are educated. However, if we ignore this aspect and limit ourselves to thinking about the role of universities in providing the impulse to improving productive conditions through other mechanisms, we can ask the following questions: how might universities take on a more active role in the promotion of scientific and technological advances?, and to what extent should they take such a role? In the process of transmission of new knowledge, how important is the "proximity" to the industry?, and what is the role of the Technology Transfer Offices (TTOs) of the universities? When these offices organize the relationships between universities and industry, acting as a bridging institution, how should a TTO be designed in order that it is efficient?, how should TTOs design the patent licensing contracts?, how should a spin-off be organized? A part of the current debate on the transfer of academic innovations to industry is motivated by an interest in knowing the consequences of the Bayh-Dole Act of 1980. This law unified and reformed the intellectual property system in the United States of America. Its objective was to ensure transfers of intellectual property between research laboratories, the public administration and private firms. In order to achieve this, the intellectual property from discoveries obtained using public funds were transferred to universities, thereby allowing them to become patent holders, and at the same time stimulating them to ensure that their scientific discoveries were profitable in order to obtain financing. An important literature is beginning to emerge, covering both empirical and theoretical aspects, dedicated to the study of the effects of the Bayh-Dole Act. This literature has also been supported by the interest of the European Economic Community in promoting knowledge-based economies.

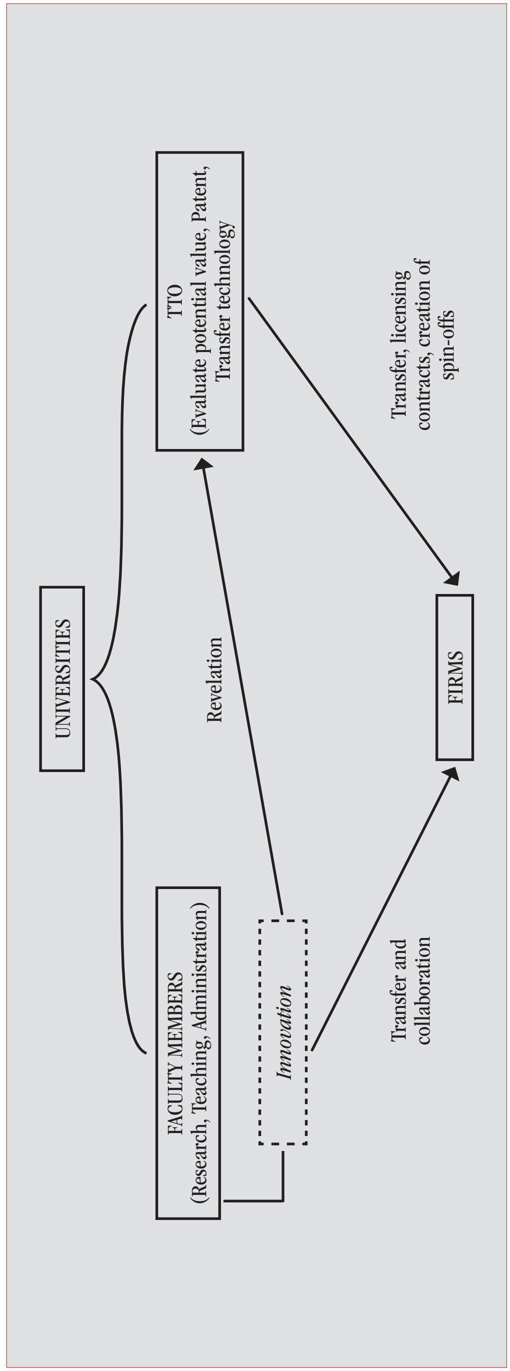
The present *opuscle* concentrates on a small part of this puzzle: the transmission of existing knowledge using university patent licensing contracts and contracts that also consider the creation of spin-offs, and the role of the TTOs in this process. The effects that we identify, and the conclusions that we arrive at in this study, will provide guidance as to how to handle other aspects of the transfer of the knowledge that is generated within universities to the wider economy. The arguments presented here are valid for any center that carries out basic research.

1. Universities

The framework that we shall be using for our analysis is one of a university that is comprised of faculty members who, besides other tasks, are responsible for carrying out research, and a TTO who's function is to receive the innovations, to analyze their potential value, to patent those discoveries that are worthwhile, and to transmit this new knowledge to firms (see Figure 1).

In what follows we shall apply the theory of incentives, which in essence recognizes that any

Figure 1:
Transfer of technology between universities and firms



form of remuneration is in practice an explicit or implicit incentive mechanism. Applied to the case at hand, this implies that it can affect the direction of research and the transmission of the results obtained, while at the same time inciting (or perhaps dissuading) agents to become interested in these activities. The absence of remuneration, therefore, is not neutral since it also affects the incentives facing agents when they take decisions.

In Figure 1, there are many decisions and interesting behaviors that can be analyzed from the point of view of incentives: the incentives to carry out research, the incentives to transfer the results obtained to the TTO or not to do so and to continue the research, to help the TTO in the transfer via licenses by collaborating with the firms that adopt the technology in order to better develop it, or to participate in a spin-off. As we have already mentioned above, we shall concentrate on the last of these aspects, although this should not be taken as an indication that the others are not equally important.[1]

In order to understand how the incentives work, or indeed if they do not work, it is useful to understand the decision-making power of each of the participants in the situation that we are interested in, and the interests that guide the behavior of academics, of universities, of TTOs, and also of firms when they take their decisions. Table 2 presents these aspects schematically.

Table 2 indicates the normal types of considerations concerning the objectives of the different agents and the decisions that they control, and these will be the objectives and decisions that we shall use in the analysis that follows. It shows that objectives are partially in conflict: what is a cost for the firm is the revenue of the TTO; the researcher may have a higher interest in conducting research than in transferring the discoveries obtained in the past.

Table 2:
Motivation and decisions of the agents

Agent	Decisions	Primary motivation	Secondary motivation	Organizational culture
Researcher	Research and transmit	Prestige	Remuneration	Scientific
TTO	Patent and license	Protection and profits from the innovation	Diffusion and prestige	Bureaucratic
Firms	Commercialize new technology, and produce	Profits	Control of property rights	Entrepreneurial

2. University licensing contracts

Research produces discoveries that can be useful to firms. When these discoveries identify an innovation that can be useful, or when the university believes that a firm might be interested in one of its discoveries, the transfer can be carried out under a ceding contract, or a patent or "know-how" licensing contract. This allows new products to be produced or commercialized, or perhaps it might allow improvements in the procedures under which existing products are produced by making use of the comparative advantage of both agents involved, since universities are more efficient in research but firms are more efficient in the development and commercialization of products. Besides, this avoids the unnecessary duplication of research effort and it allows the universities to obtain resources with which they can finance their activities. The difficulty lies in establishing the amount and form of the payment under the license.

According to studies based largely on data from USA, the licensing contracts that are used by universities include different types of payments (see Table 3, and for example, Jensen and Thursby, 2001).

2.1. Fixed versus variable payments

The first characteristic that differentiates the licensing payment mechanisms is whether or not they vary according to the use that the firm makes of the patent, and thus it is interesting to compare the advantages and inconveniences of using fixed and variable (also known as canons or royalties) payments in the contract. This *opuscle* considers the transfer of knowledge in the presence of informational problems. However, other arguments may influence the contract design of licensing agreements that we briefly mentioned for the sake of completeness.

Table 3:
Type of remuneration used in licensing contracts

Type of remuneration	% of licensing contracts that include them
Royalties	85 – 95 %
Fixed initial payment	approximately 90 %
Annual payments	approximately 90 %
Milestones	60 %
Participation in ownership	25 %

Royalties, or payments that vary according to the quantity produced and sold using the new technology, have the inconvenience (from the point of view of a firm that would like to incorporate the technology) of artificially increasing the marginal production cost, and so the advantage that is achieved by using the new technology is reduced and the firm will not be able to increase its production as much as it otherwise could. A fixed payment, independent of the activities of the licensee once the new technology is incorporated, does not have this distortionary effect, and outside of certain other considerations, it is in principle the better instrument for charging under a license.

However, there also exist convincing arguments in favor of payments that vary with the licensee's output. The most common of these is based upon the way that the parties share the risks that appear when the revenues that the licensee will earn by adopting the new technology are subject to uncertainty, either because it is difficult to anticipate how the demand will react or because it is difficult to predict the new production costs. If both the licensor (the university) and the licensee (the firm) are risk averse, then sharing the revenues that are derived from the adoption of the patent can be an efficient insurance mechanism. And if the revenues are to be shared, then the payment will have to depend upon revenues (that is, it must be a variable payment), which can only be achieved using a royalty rather than a fixed payment.

The other aspect to bear in mind when designing the contract is that of the incentives. Fixed payments and royalties have quite different effects upon the incentives of both the party that is transferring the technology and the party that is adopting it. In what follows we shall ignore the first aspect (risk sharing) in order to concentrate upon explaining the reasons why a variable payment might well be optimal from the point of view of incentives. This implies that we shall only consider situations in which, when incentives are not taken into account, it is efficient to license the patent under a fixed payment contract (which will be the case, for example, when both licensor and licensee are risk neutral).

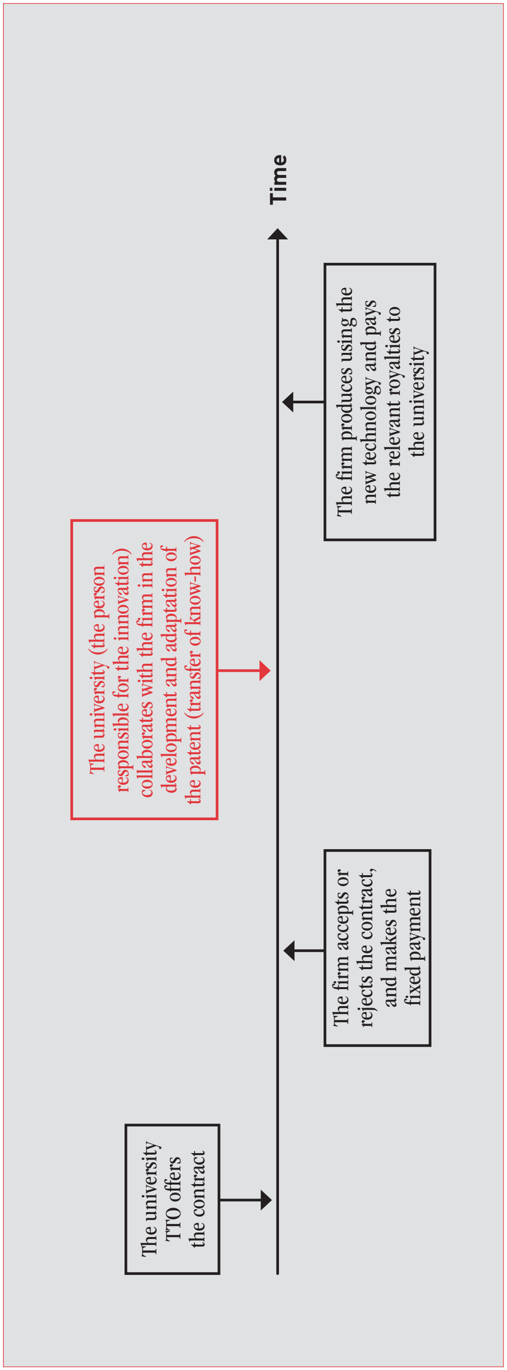
We will now go on to look at three different situations that are based principally on the work of Macho-Stadler and Pérez-Castrillo (1991) and Macho-Stadler, Martínez-Giralt and Pérez-Castrillo (1996).

Firstly, assume that the patent has generated some knowledge, or know-how, that is not included in the registry description of the patent itself but is still of great importance for the firm that adopts it and that would like to take full advantage of the new technology. In the case of university innovations, collaboration is more important because of the type of innovation that is often provided. In the description of north-American university licenses that is given by Jensen and Thursby (2001) we can see that about 75% were either in an embryonic stage ("proof of concept"), or only a laboratory prototype was actually available. Close to 71% of the licenses demanded a posterior relationship between the innovator and the licensee to adequately develop the product into a commercializable state. Only 12% of the innovations were actually ready to be commercialized.

In these cases, collaboration between the innovator and the firm is crucial for the latter to be able to take full advantage of, or to develop adequately, the new technology. But it is difficult to specifically include such a promise in the contract, because of the very nature of the information that is promised to be divulged. This situation is represented in Figure 2, and is known in the literature as a **moral hazard** problem. Moral hazard refers to situations of asymmetric information, and it occurs after a contract is signed. For example, it might refer to the work or effort that a contracted agent dedicates to his tasks (this is indicated in red in the time-line shown in Figure 2). If moral hazard is present, then one should design the payment mechanism with the objective that the agent be interested in his task; that is, we need to motivate the agent to exert the correct amount of effort.[2]

In the case shown in Figure 2, if the university (the innovator) cannot credibly commit to transmitting the know-how that is required to use the full potential of the patent, then the licensee will be in doubt and will be willing to pay only a small amount for the license.[3] If there is no risk, and if the contract is based on a fixed payment alone, then once the payment has been made the researcher will no longer have anything to gain, and yet would still be asked to suffer the costs associated with working with the firm. On the other hand, if the contract includes a royalty payment, then the remuneration under the license is variable and will depend upon the production of the firm, thereby offering the correct incentives to transfer the know-how. The argument is that the more the firm produces, which happens when costs of the firm are lower, the more the innovator earns. Given that at that point the royalties

Figure 2:
The problem of transfer of know-how



have already been set out in the initial contract, the only thing that the innovator can do to reduce the costs of production is to collaborate with the firm by transferring the relevant know-how and helping to adapt or develop the technology according to the firm's needs. Thus, we can see that royalties possess the property that they stimulate the innovator to become interested in the way in which the firm adapts the technology and he will be willing to help in the process.

Figure 3 shows a different moral hazard situation — one in which it is the firm that should take a decision after the contract has been signed. For example, the firm should allocate some funds and human resources to develop the innovation.

In this case, the problem is to design a licensing contract such that it stimulates the investment of the firm in the development stage. If the licensing contract is based on a fixed payment, the firm keeps everything that will earn, while a part of the earnings will go to the university if they are royalties. Therefore, the firm will have less interest in the success of the development stage when the payments are based on royalties. The appropriate incentives for the firm to invest in the development stage appear when the license is remunerated using an initial payment, in which case in order to recover this cost the firm will be interested in the success of the development and commercialization stage.

It is easy to see that we will face a dilemma if both types of moral hazard are present, and the decisions of both the innovator and the firm are crucial for the development of the innovation. This type of situation is more difficult to resolve because the incentives that are needed go in opposite directions. The person responsible for the design of the licensing contract will have to weigh the different incentive effects of both

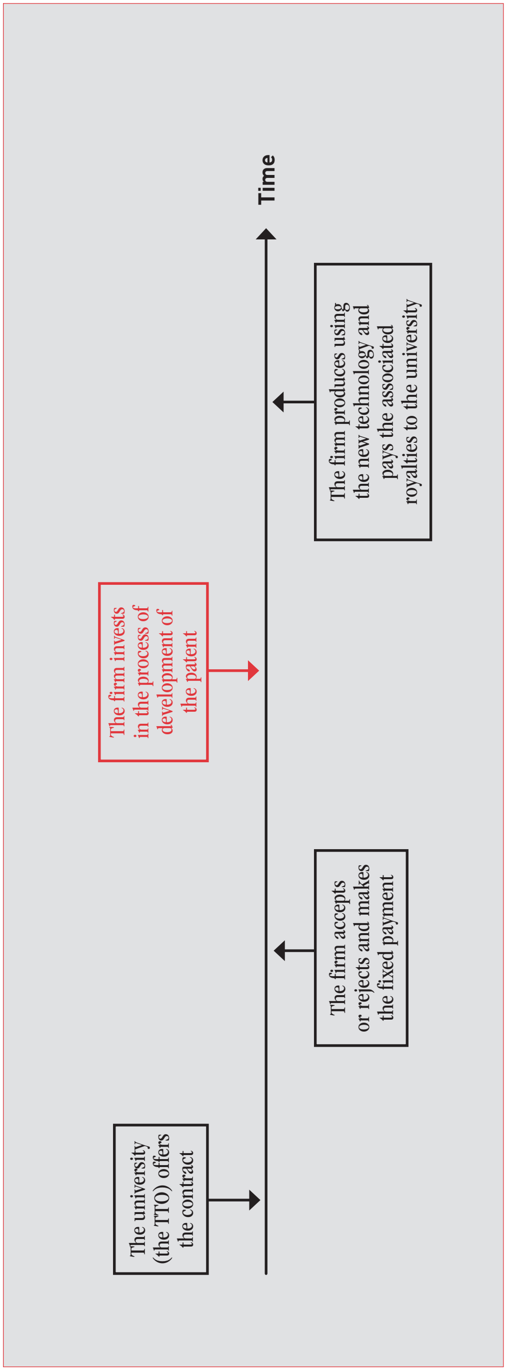


Figure 3:
The problem of investment in development

elements of the contract, and this often justifies the use of both.

Secondly, it could be the case that there is no patent that defines the technology that has been discovered. That is, we want to transfer an unpatented discovery (like a magic trick), or alternatively, what is most important to the firm is not the patent but rather the value of the new technology that it does not yet know. This situation is shown in Figure 4, where the university (or its representative in the bargaining with the firm) is better informed than the firm as to the type of innovation that is being offered.

The important aspects of this second type of situation are that the firm is willing to pay more for a more valuable innovation, and that the university is interested in suggesting that what it is proposing to transfer is a wonderful discovery. However, whatever is the true value of the discovery, all sellers will want to declare that it is of high value, and so the firm will wonder whether this is true or if it is only a trick to obtain a high price.

This type of situation is known as a **signalling** problem, in which the decisions and the terms of the contract can be used by the firm to attempt to get a better idea of the true value of the innovation. The informational asymmetry, as is shown in red in Figure 4, occurs before the contract is signed. Thus the contract itself can be used as a signal or message to the uninformed party in order that he revises his expectations.

For the case at hand, one obvious (although naive) option is to explain all the details of the discovery to the firm so that it may then decide how much it is willing to pay for the discovery. But this is not generally feasible since, once the firm has received all of the knowledge needed to evaluate its profitability, it no longer has an incentive to pay

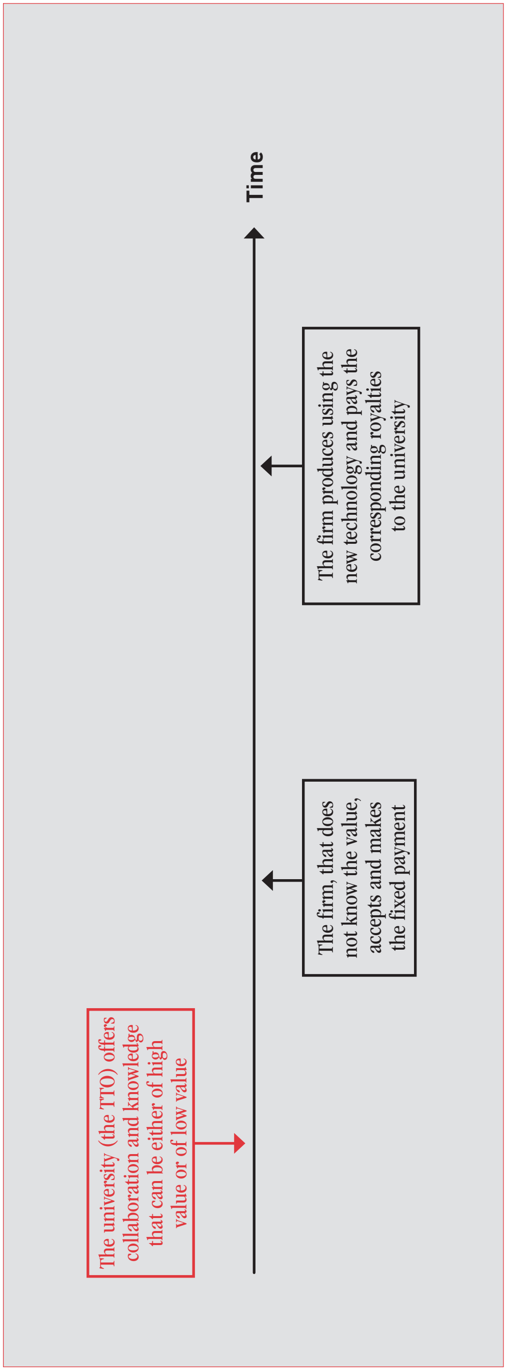


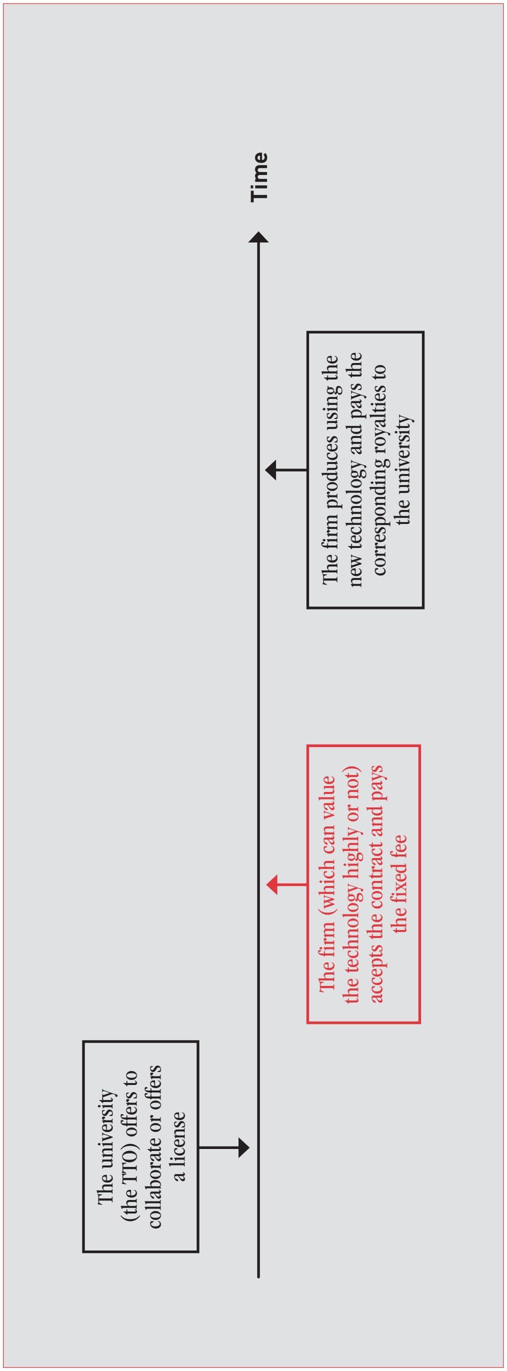
Figure 4:
The innovator possesses private information on the value of the innovation

for the knowledge (there is no need to pay to learn the secret since it is no longer secret). Can the clauses of a contract make it credible that the innovation is valuable? Imagine that the TTO claims that the innovation is very valuable, and that it proposes to use either a contract based only upon a fixed payment or another based only on royalty payments. If you were the firm, which of these two options would appear to be the best? In the case of a fixed payment contract the TTO will receive its money up front, independently of the use that the firm makes of the innovation, while under a variable payment contract the amount that the TTO receives depends upon what the firm manages to produce (that is, upon the value of the discovery). The second option then is the least suspicious, and so contracts based upon royalty payments can serve to signal valuable innovations.

Thirdly, there can exist other problems involving incentives and information that do not initiate with the university. Firms are in a much better position than the university to know their own market, to know the potential use of the new technologies, and to know the possible effects upon demand of a change in product. In fact, universities are typically poorly informed about firms in general. This situation is set out in Figure 5, and it corresponds to a problem of **adverse selection**.[4] In short, we have a situation of adverse selection when the informational advantage is held by the contracted party, and this advantage occurs before the contract is signed. In such a situation, the most common strategy is to use contract "menus", from which each type of agent chooses one (thereby revealing his characteristic).

If, when it negotiates the contract, the TTO knew that the value to the firm was high, then it would set a high fixed payment. On the other hand if it knew that the value was low, it would set a lower fixed payment. When the firm is the only

Figure 5:
The firm is better informed of the value of the patent in its production process



party who knows the value of using the patent, asking it what that value actually is would be quite useless since in all cases it would say that it has a low value in order to get a low fixed payment. Imagine now that we have two simple types of contract under which the patent can be licensed: one based entirely upon a fixed payment and the other on a royalty. We then ask the firm to choose between the two options. For a firm that places a high value on the patent the payment of a royalty to the TTO is costly, and so it would prefer the fixed payment contract. For a firm that places a low value on the patent the royalty scheme is better since if the firm produces and sells very little in the end it will not pay much for the right to use the technology. Therefore, firms that place a low value on the license will tend to sign contracts that include royalties.

Royalties are not the only way to structure a variable payment. Holding shares or “equity” in the firm is an alternative way to make the payments depend on the use that the firm makes of the new technology. The advantage of shareholding is that it does not distort the firm’s costs and so there is not the same negative effect as royalties. Further, shareholding also works as a risk sharing mechanism since what is received will depend upon whether the new technology is successful or not for the firm, and it also gives the right to some of the profits derived from new applications or improvements. On the other hand, shareholding also has an important disadvantage: it is not really believable that in order to use an innovation in some minor stage of its overall complex production process, the firm would be willing to hand over some of its shares to the patent holder. Thus, royalties are more likely to appear in the licensing of innovations to large firms. In any case, universities generally prefer funds than to possess a portfolio of shares.

2.2. The intertemporal structure of payments

The intuition above can be applied to the design of licensing contracts when there is more than one period involved, and it is necessary to determine the intertemporal structure of the payments. This is the case, for example, if milestones are used in the contract. The optimal design of a licensing contract depends upon the moments when the different actors take their decisions, and so it can be useful to us to apply some of the results explained above. In the interests of simplicity, we shall limit ourselves to contracts that use only fixed payments and we will consider their intertemporal structure.[5]

Consider a process of transfer of technology with two consecutive stages, development and commercialization, in which there are three actors: the university (i.e. the TTO), the innovator, and the firm (we assume them all to be risk neutral, which justifies the use of fixed payments).

The TTO designs the contract that will be offered to the firm, and the scientist who obtained the innovation will receive a percentage of the university's revenue. Once it is signed, there are two stages — one of development and another of commercialization — that could be successful or not (in other words, it is possible that commercialization does not occur). The intertemporal development of this type of situation is depicted in Figure 6.

At the development stage (in red in Figure 6), the innovator must participate using a certain level of effort. This effort and the investment that is made by the firm at the development stage will influence the success (or failure) of this stage. At the commercialization stage (in pink in the figure), the firm is the only party that should invest, and this investment determines whether or not the

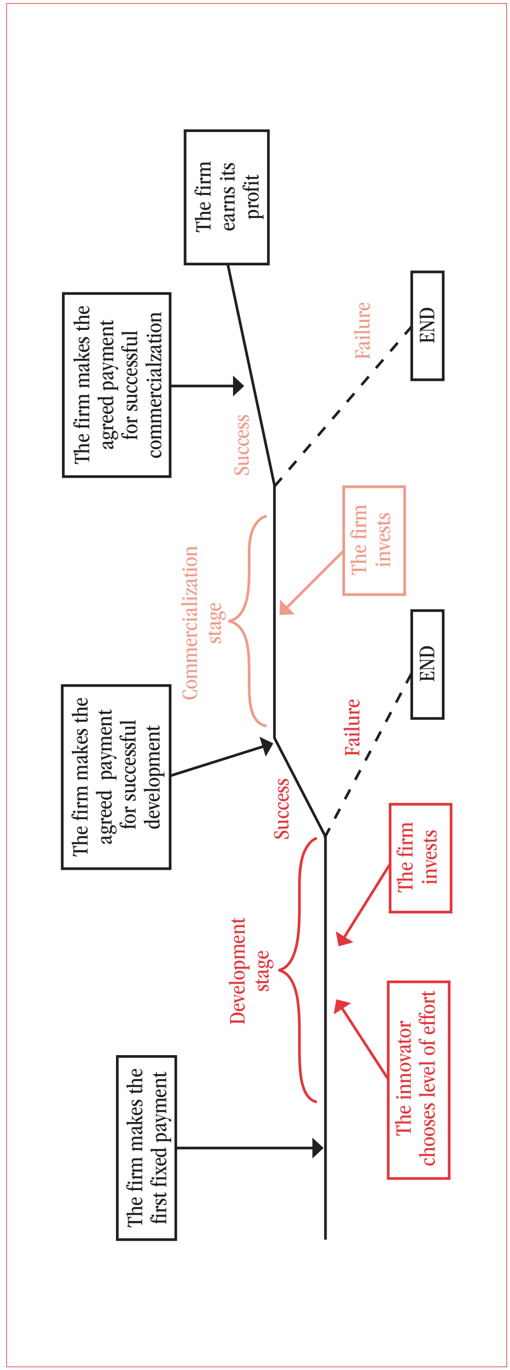


Figure 6:
Patent licensing with development and commercialization stages

commercialization is successful. It is only at this stage that money can be earned: if the stage is successful the revenue will be positive, and if it is a failure, the revenue will be zero.

All of the participants in these decisions are worried about the difference between their costs and their revenues. The firm will receive revenue only if both stages are successful, and the expected cost that it must suffer is that associated with the licensing contract which consists of an initial fixed payment plus, after the development stage, the payment that should be made at the end of that stage, and if the commercialization stage is also successful, the payment that must be made after that stage is finalized as well. The revenue for the university is an expected cost for the firm. On top of this, the firm must also cover the costs of the investment at the development stage, and if it gets there, the investment in commercialization. The innovator receives a percentage of the revenue of the university and suffers the costs of effort at the development stage.

When everything can be clearly specified in the contract, there are no incentive problems, and the TTO can design the contract in such a way that the expected payments extract all the surplus from the firm. In this case, the intertemporal structure of the payments is not important. There are many equivalent contracts that combine fixed initial payments with payments for the development and commercialization stages. The later a payment becomes due, the greater it will be because it will be paid with a lower probability.

If the innovating scientist's effort cannot be specified and controlled in the contract, then again we have a moral hazard problem. In order to motivate the scientist to work well, his payment should depend on the success of the development stage. If his payment were received at the start, then there would be absolutely nothing that depends on the innovator's effort. Therefore, to solve this problem of moral hazard it is best to base the contract on payments that are conditional upon the success of the development stage (and this can be thought of as a milestone), or perhaps even on the success of the commercialization stage. However, in order to motivate the firm during either the development or the commercialization stage, we require that the licensing payment be made at the outset, so that the firm has a greater interest in these stages being successful.

It is obvious that in reality all of the difficulties that we have mentioned above are present when a contract is designed. An initial payment gives incentives to the firm (but reduces those of the innovator to collaborate with the firm). A milestone at the development stage gives incentives to the innovator and to the firm to commercialize, but it does not provide an incentive to develop. A payment associated with the outcome of the commercialization stage gives incentives to the innovator but it will be counterproductive for those of the firm at the previous stages. Balancing these advantages and disadvantages in terms of the incentives (and therefore the outcomes) that are offered by different contractual clauses and payment structures requires a case by case analysis.

3. Creation of spin-offs

Sometimes innovators cannot, or will not, sign a licensing contract with an established firm for the development and commercialization of an innovation. Firstly, innovators may not be interested in using the patent system because their research can lead them to even more promising results and a patent might be a way in which competitors can become informed (above all when the innovation is in an embryonic stage), or alternatively, because the patent system is rather costly and slow. Secondly, many established firms prefer not to work with embryonic innovations (at least, not with embryonic innovations from external laboratories), which leads to some universities not being able to find an adequate purchaser. In these cases if the innovation looks as if it will be an important success, it is possible that a new firm is created with the specific objective of developing and commercializing the innovation at the right moment (or to sell the rights to the innovation once it has generated the desired value). Such firms are known as "spin-offs", or technology based firms (TBF).

Spin-offs are firms that are in the earliest phase of a new entrepreneurial adventure (they are also known as "start-ups"). They are created from existing organizations and they act as project incubators. In this way they contribute to the transfer of scientific findings, and a couple of notable examples are "Silicon Valley" and "Route 128" where spin-offs from Stanford and MIT can be found. We shall define a university spin-off as a firm that is created to commercialize the technology or scientific results that are developed within the university, and which fulfill two conditions: the individuals that are involved in them should be university staff (scientists or students); and the knowledge that is transferred to the new firm should come from within the university.

There are several problems faced when creating a university spin-off, some of which are common to all spin-offs and are due to the fact that they are high risk ventures. In the case of a university spin-off it is the TTO that should solve these problems. Firstly, it needs effective protection for the intellectual property involved, since the spin-off uses and generates knowledge. This aspect relies largely upon the existing institutional framework and on how it protects the initial discovery (without any unnecessary holding up of academic publications) as well as the inventions and innovations that the spin-off itself generates. Secondly, a crucial element for the success of the venture is that it is run by capable administrators, and this often turns out to be at least as important as the quality of the initial technology; it is worthwhile to add that, in general, researchers are not good administrators. Thirdly, it is necessary to resolve the issue of the gap that exists between the R&D project and the concrete proposal of a final development with sufficient potential market value that it is able to attract financing. Closing this gap may not be expensive, but if it is not done in an appropriate way the time-frame can change from being a matter of months to being a matter of years. Finally, it is necessary to have solid relationships with financiers who are willing to put up the venture capital.

Using a sample of 101 American universities and 530 spin-offs, Di Gregorio and Shane (2003) studied the roles played by the availability of venture capital, by whether the orientation was more academic or applied (measured in terms of who provides financing), by the scientific quality of the researchers, and by the policy of using equity instead of monetary payments as remuneration for the participating researchers. They concluded that, at least for their sample, all of these aspects are important, although the final two appear to be the most important.

We shall concentrate on the design of a contract for the creation of a spin-off in which the TTO (which administers the intellectual property of the discoveries of its researchers), the financier (who supplies the capital to create the spin-off) and the innovator (who should collaborate in the development of the discovery in order that it is successful) all come to an agreement on the way the equity shares in the new firm are distributed among themselves. The results that we report are from the paper Macho-Stadler, Pérez-Castrillo and Veugelers (2008). It is interesting to note that an important part of that paper was inspired by the experience of the Catholic University of Leuven (the KULeuven) concerning the spin-off contracts that it had signed. The KULeuven has a TTO that was set up in 1972, currently employing 34 professional staff. The activities of the TTO generate revenue that represents 25% of the total research budget of the KULeuven. It deals with the formalities of research contracts, patents, licensing contracts, and transfer of knowledge via spin-offs. In 2004, the TTO of the KULeuven had generated 61 spin-offs (approximately 33% of the projects) of which 52 are still active currently. These spin-off firms generate revenue of some 350 million euros, and employ about 2.000 people.

Spin-off contracts that involve the three agents mentioned above (TTO, innovator, and venture capitalist) take a special form. The design of the contracts takes into account the fact that the value of a spin-off is uncertain, since some are successful (perhaps very successful) while others are not. The probability of success depends on the quality of the initial innovation, the effort of the innovator in the development, the amount of capital available, and pure chance. The agreement should provide incentives for the innovator to be involved in the development of the discovery, it should reward the venture capital at a fair expected rate, and it should also remunerate the use of scientific innovations. The equity or shares in the new firm are distributed such that the TTO receives a proportion A_t, the financier receives A_f, and the innovator receives A_i, where $A_t + A_f + A_i = 1$. The shares remunerate the invested capital, the intellectual property, and labor. Denote by F the percentage of the total shares that go towards remunerating capital (financial shares) and by I the percentage of the total shares that go towards remunerating intellectual property and labor (non-financial shares). In Table 4 we show the resulting structure of the shareholding.

Table 4:
Distribution of equity under a contract for the creation of a spin-off

Agent	Percentage of total shares		% of financial shares		% of non-financial (intellectual) shares
TTO	A_t	=	F_t	+	$I_t > 0$
Innovator	A_i	=	F_i	+	$I_i > 0$
Financier	A_f	=	$F_f > 0$	+	$I_f = 0$
Total	1	=	F	+	I

Obviously, since the financier only puts up capital, as is shown in Table 4 we have $I_f = 0$. The fact that intellectual property (and the researcher's labor) are remunerated implies that $I_t > 0$ and $I_i > 0$. The financier receives $F_f > 0$ as compensation for his capital. It might be the case that $F_i = 0$ (and respectively that $F_t = 0$) if the innovator (respectively the TTO) do not participate with capital. Otherwise, it must be true that the remuneration of capital would be proportional to the amounts of capital that are put up. That is, for any two agents, for example the financier and the TTO, the financial shares that each receives should satisfy the relationship $F_f / F_t = C_f / C_t$, where C_f is the amount of capital put up by the financier, and C_t is the amount of capital put up by the TTO.

The objectives of the participants can be summarized as follows. The financier's income is the expected value of the firm's shares that he owns, and his costs are the alternative uses that he could have made of his funds. The innovator's income is the expected value of his shares less the costs of working in the spin-off and, as the case may be, the costs of putting up capital. Finally, the university receives the expected value of its shares and suffers the opportunity cost of investing in the firm, if it should do so. The results are unchanged if, besides the dependence on revenue, the university's objective function also depends on the researcher's welfare, which is a dimension that for example can act as a measure of its ability to attract good scientists.

We shall begin by considering the case in which there only exists an incentive problem of the moral hazard type, in which the researcher must be motivated to dedicate his energy to the spin-off. If the researcher's moral hazard problem is not too important (perhaps because the project is very promising or because he is very motivated to work in the firm) he could be motivated by payment in non-financial shares, but he would not be required to invest capital in the project. In this case, the only agent that should put up capital for the project is the financier. When the moral hazard problem is more severe, the number of shares that would be needed to motivate the innovator would be higher. If none of these shares were financial shares, what is left over could be insufficient to adequately remunerate the financier or the TTO. In such a case it is efficient that the innovator also provides some capital, even if the cost to him of doing this is greater, in order to be able to assign to him shares of both types, financial and non-financial — this fact can, in the end, mean that there is an over-investment in the spin-off if too much capital is invested. The TTO should not put up any capital and should only receive shares as remuneration for the intellectual property. As we expect, the proportion F of financial shares to the total number of shares grows if the cost of capital (which depends upon the other investment opportunities that are available) grows. Also, the more the TTO is interested in the welfare of its researcher, the more willing it is to give up a part of the financial shares in order to motivate him — therefore, even though the moral hazard problem of the researcher is important, he will not be required to provide so much financial investment to the project.

We now assume that the information on the expected value of the project is limited, because we do not know the generic value, or the specific value to the industry, of the innovations that are going to be used. In general, we can expect that a good TTO is well informed on both aspects, since it knows more than the researcher about the potential value of the project for the industry, and/or it knows more than the financier about the potential value of the discovery that forms the basis for the spin-off. In these cases, in order to signal the fact that it is convinced that the spin-off is potentially very profitable, and in order to convince, above all, the financier but also the innovator, the TTO should involve itself financially in the project. For example, the administrators of KULeuven's TTO possess 20% of the venture capital fund (the rest is put up by two banks) with which the spin-offs are financed, but sometimes the TTO individually invests even more capital, and it is precisely this action that generates confidence by signalling its faith in the quality of the project as an explanation of such investing behavior.

Finally, it is worthwhile to point out that the empirical literature on university spin-offs indicates that the option of creating a spin-off is, and indeed should be in practice, the exception rather than the rule. Whenever possible, it is normally better to use licensing contracts to channel the transfer of technology that is generated from within universities. However, successful TTOs should also have sufficient ability and know-how to generate the appropriate incentives to attract researchers to the adventure of creating spin-offs, as well as to be able to obtain sufficient initial capital, to anticipate the potential of converting technical ideas into market applications, to have good relationships with potential investors, and to collaborate in the running of the business and the administration of the spin-offs.

4. The role and the design of TTOs

Now that we have discussed the format of technology licensing contracts and the creation of spin-offs, we will go on to dedicate this section to explaining why it is necessary for a university to create a TTO, what the advantages of this are, and what characteristics should be satisfied for it to be efficient.

To start with, we should point out that TTOs are not research centers, but rather they are research administrators, and have the advantage of being specialized in the type of innovations that universities generate, or can generate, and should thus be created specifically with this in mind. TTOs are also specialists in the markets in which these discoveries can be sold, and they must possess good knowledge of the legal framework for the protection of intellectual property rights. Besides, the innovations that the TTOs patent should have an expectation of being commercially useful since patenting them is a tedious and expensive process. Thus, being able to identify which innovations are potentially commercializable is important, and for that reason the TTO must have first-hand knowledge of the industry and the markets. For all of these reasons, it is crucial for the success of the transfer of a university's technology to have a well designed TTO that can carry out these tasks adequately.

A good TTO allows the university to have access to services that, if supplied individually by each researcher, department or laboratory, would be quite expensive or hard to finance. Examples of such services are the search for potential business partners, market knowledge, and a good legal service for administering the intellectual property and to defend against the possibility of copying. In Macho-Stadler, Pérez-Castrillo and Veugelers (2007) we analyzed another advantage of having a good TTO, namely reputation.

Consider a dynamic situation in which different departments and researchers of a university are achieving discoveries, with greater or lesser frequency. Assume two possible alternatives: the individual sale of the discoveries by the researchers, and the existence of a TTO that knows the innovations well and that undertakes the task of transferring them all. We can compare these two alternatives in order to understand the advantages that can emerge when, instead of each researcher establishing a relationship with potential purchasers, this is done by the TTO. In order to avoid confusion, we shall ignore the sources of economies of scale or of specialization of the TTO mentioned above, and we shall concentrate exclusively on the fact that a patent does not cover all of the dimensions of a discovery (an important part of which lies in the know-how), which makes it difficult to evaluate the exact value of a discovery for a potential purchaser.

We can think of the above situation as a comparison between what many technology salesmen attempt to achieve with a small portfolio of discoveries (in the sense that they have a low frequency of technology to sell), or a technology seller with a large portfolio (including all of the innovations of the small salesmen, and therefore having a high frequency of discoveries). In a repeated model in which the market has little information on the value of the innovations, reputation can be of aid for transferring good innovations, and sometimes at a good price. If the technology seller has a large portfolio of innovations, he will be interested in leaving aside those of lower quality in order to concentrate on selling the better ones, thereby achieving that the market believes him when he states that he has a good innovation to sell. Using such a strategy, he will sell fewer innovations, but he will obtain more of them, or will find that more of them are developed, because the market is willing to pay more to invest in their development. If the seller only has a small portfolio, reputation will be irrelevant, and he will attempt to take full advantage of the innovation, at all costs. In the limit, he might have one discovery today, but he thinks that he will never get any more. The market will anticipate this behavior, and will not purchase, or at least will invest less in the development of these innovations.

This result is consistent with the conclusions of Siegel, Walkman and Link (2003), who find that the TTO will generate economies of scale with respect to the revenue from the transfer of technology but not with respect to the number of transfer contracts that are entered into. This combination of evidence is difficult to explain using the arguments of specialization or economies of scale mentioned above.

This argument leads us to some interesting conclusions, although we should be careful to take into account the differences between disciplines. Firstly, a TTO should be sufficiently large so that it can benefit from reputation effects, and so it might happen that small universities or those with few innovations do not manage to reach this critical size. This could lead to the establishment of TTOs that service more than one university, as long as the problems from doing so do not outweigh the benefits that it produces. Along the same lines, in some disciplines or markets the creation of a reputation can require specialization within that particular discipline or market. In this case, it is worthwhile to consider the possibility that a group of universities shares a TTO that is specialized within that specific discipline. A second interesting aspect is that a university's TTO will represent many research groups of diverse characteristics, only some of which obtain a frequency of innovation that would allow them to generate reputation alone. However, it might be the case that a TTO that only works with small departments is inadequate, and in order to reach the sufficient size it should include all the departments. In these cases, the departments, groups or researchers that generate many innovations contribute more to the TTO's reputation, and by doing so they produce a positive externality for the others. One could argue that the more active groups should be compensated, for example, with a larger part of the earnings that are generated.

5. Some final concluding thoughts

Public support for universities and other research centers is justified by the private sector's preference for more applied research, with short-term profitability. This preference implies a persistent under-investment in fundamental or basic research, which is characterized by being more difficult to appropriate and with scant immediate commercial value. It is important that we do not lose sight of the role of universities as generators of basic science, without the pre-condition of having to worry about the commercial results that are obtained from it.

At the same time, if the university generates knowledge but does not transfer it, society does not benefit from it. In the above discussion we have concentrated upon some of the basic instruments that are used to transfer technology directly to the market. However, universities transfer knowledge to society using several other mechanisms. It is worthwhile to mention that besides patent licensing and spin-offs, there also exist other mechanisms associated with the diffusion of innovations like research contracts, media publications, consultancies, informal meetings with institutions or firms, researcher exchange programs or continued education and training. However, the two primary activities of the university system are teaching, which directly transfers knowledge and contributes to the education of new generations of technicians and researchers, and research which transfers new discoveries via scientific publications and patents. Only looking at one of these activities in isolation can give an erroneous idea of the work of a university in the diffusion of its knowledge, and of its impact on the economy and on society.

Notes

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(1) In particular, as we have already mentioned, we shall ignore teaching as a mode of knowledge transfer to society and firms. Note that the quality of teaching, above all at postgraduate level, appears to be linked to the quality of research that is carried out in the university. For example, the analysis of Cohn, Rhine and Santos (1989) identifies economies of scale between teaching and research.

(2) This type of opportunistic behaviour appears because it is not possible for third parties, whose job is to ensure that the contract is not breached, to observe effort. It may also happen that there are many contingencies that are difficult to define, like for example all of the problems that can occur when the discovery is applied and how each particular case should be treated. This situation implies that the contract is incomplete since it does not set out all of the possible contingencies and requirements of the university.

(3) In situations involving many repetitions, reputation and the interest of the parties in maintaining it, can play an important role and can solve, at least partially, this problem. See section 4 below on TTOs.

(4) The difference between a case of adverse selection (when the firm is informed) and one of signalling (when the university is informed) is not in the part that is informed but rather who designs the contract (the informed or the uninformed party). When the informed party designs the contract it acts as a signal to the uninformed party.

(5) For more details, see Dechenaux, Thursby and Thursby (2009).

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