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The economic analysis of University Technology Transfer Offices: a theoretical review and empirical implications

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The economic analysis of University Technology Transfer Offices: a theoretical review and empirical implications

The Triple Helix model postulates that the university research commercialization is an important driver of the regional competitiveness. In this regard, the role of university Technological Transfer Offices (TTOs) is receiving a growing interest by university management and academics. This paper aims to facilitate the communication among both communities by reviewing the contributions made up to now by economists and by analyzing the implications for those running universities and TTOs. For that purpose, we develop a general, simple benchmark that permits analysis of the different contributions made by the economic literature to understanding the TTO's role. In this sense, we focus on the existence of the TTO, the incentives that scientists require in order to develop embryonic projects, the decision of whether to license or spin-off and the development problems of spin-offs. The main contributions of the existing literature are summarized in several empirical implications, and for each implication the empirical evidence available nowadays is described. Finally, the paper outlines future streams for theoretical and empirical research and general implications for university and TTO management.

El análisis económico de las Oficinas de Transferencia de Resultados de Investigación: una revisión de la teoría e implicaciones empíricas

El Modelo de Triple Hélice postula que la comercialización de los resultados de la investigación universitaria es un impulsor importante de la competitividad regional. En este sentido el papel de las Oficinas de Transferencia de Resultados de Investigación (OTRI) está siendo objeto de un creciente interés por parte de las administraciones universitarias y de los académicos. Esta investigación busca facilitar la comunicación entre ambas comunidades revisando las aportaciones hechas hasta ahora por los economistas y analizando las implicaciones para aquellos que dirigen universidades y OTRI. Con ese fin desarrollamos un sencillo benchmark general que permite analizar las distintas aportaciones hechas por la literatura económica para entender el papel que juegan las OTRI. En ese sentido nos enfocamos en la existencia de la OTRI, en los incentivos que necesitan los investigadores para desarrollar proyectos embrionarios, la decisión sobre si licenciar o crear una spin-off y los problemas de desarrollo de estas últimas. Las principales aportaciones de la literatura existente se resumen en varias implicaciones empíricas y, para cada una de ellas se describe la evidencia empírica existente hoy en día. Por último se esbozan futuras líneas de investigación teórica y empírica así como las implicaciones generales tanto para la universidad como para la administración de la OTRI.

Ikerketaren Emaitzak Transferitzeko Bulegoen analisi ekonomikoa: teoriaren azterketa eta ondorio enpirikoak

Helize Hirukoitzaren Ereduak adierazten du unibertsitateko ikerketaren emaitzak merkaturatzeak eskualdeko lehiakortasunari bultzada garrantzitsua ematen diola. Ildo horretatik, Ikerketaren Emaitzak Transferitzeko Bulegoen (IETB) egitekoa gero eta interes handiagoa sortzen ari da unibertsitateko administrazioen eta akademikoen artean. Gure ikerlanak bi erkidego horien arteko komunikazio zubi izan nahi du eta horretarako, ekonomialariek orain arte egindako ekarpenak aztertu ditu eta unibertsitateak eta IETBak zuzentzen dituztenentzat atera daitezkeen ondorioak azaldu. Xede horrekin, benchmark orokor bat prestatu dugu, IETBen egitekoa ulertzeko literatura ekonomikoak egin dituen ekarpenak aztertzeko aukera ematen duena. Hurrengo arloei jarri diegu arreta: IETBrik baden ala ez, ikertzaileek zein pizgarri behar dituzten hastapeneko proiektuak garatzeko, nola erabaki lizentzia saltzea edo spin-off bat sortzea, eta zein arazo dituzten spin-offek aurrera egiteko. Literaturaren ekarpen nagusiek hainbat ondorio enpiriko dituzte eta ondorio horietako bakoitzerako, gaur egungo ebidentzia enpirikoa azaldu dugu. Azkenik, etorkizuneko ikerlerro teoriko eta enpirikoak adierazi ditugu, baita unibertsitatearentzat eta IETBen kudeatzaileentzat ateratako ondorio nagusiak ere.

1. INTRODUCTION:

The rapid rate of technological change, shorter product life cycles and more intense global competition has radically transformed the current competitive position of many regional economies (O'Shea, 2007:170). Universities have been demonstrated as a potential tool for technology and knowledge creation. Some voices stress the relevance of university research commercialization in order to contribute to regional competitiveness. For example Etzkowitz (1998, 2003, 2004) coined the term "Entrepreneurial university" and highlighted the importance that universities contribute to regional economic development through technology transfer via licenses or spin-offs. To pursue this complex phenomenon, Etzkowitz stresses the need of governments, industry and universities to work together in the Triple Helix model.

The Bayh Dole Act (1980) and the 1986 Federal Technology Transfer Act (1986) moved the right to own and license inventions from federally funded research to the universities in the U.S. Since then, the amount of inventions commercialized from universities has increased dramatically (Nelson, 2001; Mowery et al., 2001), not only in the U.S., but also in other countries like Spain, Italy or the UK where universities have the same structure of ownership and decision rights about inventions, (Geuna et al., 2003). This commercial success and the commercialization of research as an important option to create wealth (Etzkowitz, 1998; Shane, 2002) have also been accompanied by an increasing interest of academics about the role of University Technology transfer offices (TTO). The purpose of this paper is to review this literature.

Most of the descriptive literature[1] (Ndonzuau, Pirnay and Surlemont, 2002; Birley 2002; Siegel, Waldman and Link, 2003) has analyzed the two ways of commercializing innovations from universities: selling licenses and spinning off companies. The analysis mainly focuses on the organizational contexts that

[1] Other questions recently analyzed by this kind of literature are the analysis of the organizational structure (Bercovitz et al., 2001; Siegel et al., 2003), the study of ownership structure (Godfarb and Henrekson, 2003; Locket et al., 2001, 2003), the development of networks (Perez and Martinez, 2003, Locket et al., 2003), the characteristics of the academic inventor (Locket et al., 2003; Murray, 2004), the strategy of the TTO or university administrator (Locket et al., 2003; Di Gregorio and Shane, 2003, Perez and Martínez, 2003; Hindle and Yencken, 2004; De Coster and Butler, 2005) and how resource endowments influence success (Shane and Stuart, 2002).

define the actions and decisions, and which shapes the motivations of the main agents of these processes: the university scientist, the TTO and the firm in the case of licensing.

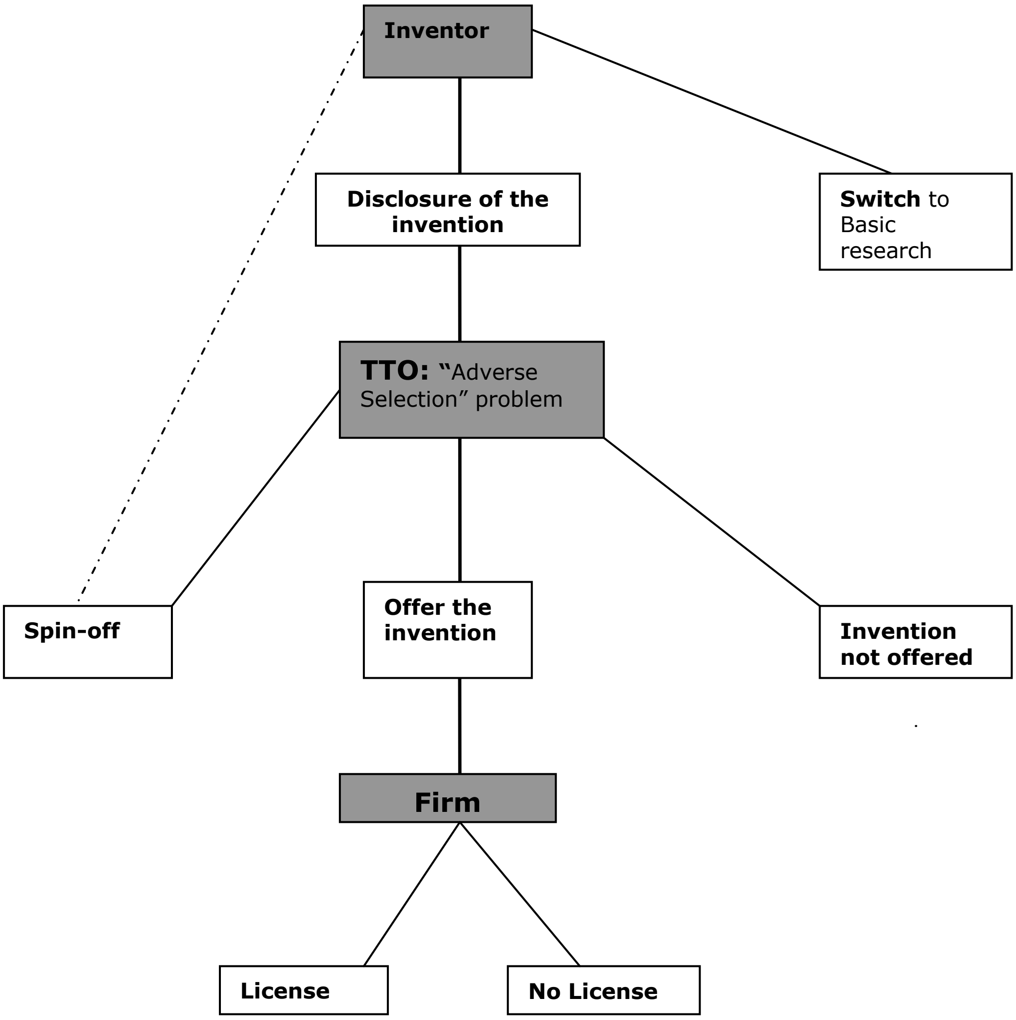
The university scientist or inventor has an academic culture, which carries with it an ambiguous relationship to commercial innovation and a preference for basic research. Most of his career recognition, and consequently compensation, comes from his success in basic research; therefore, it is a clear, and in some cases important, opportunity cost for the development of commercial innovation. Obviously, institutional arrangements can modify such interests. In addition to the personnel policy of scientific and academic staff, the university also has other vias to stimulate the development of commercial innovation. More specifically, the university has the intellectual property of those developments made by their scientists, so the university decides the internal distribution of the income that comes from patentable and non-patentable inventions, also called labor inventions, among general administration, TTO, and inventor or faculty.

University Technology transfer offices (TTO) are entities responsible for the protection and commercialization of a university's intellectual property and deals with researchers, in order to receive commercial innovations and firms in order to use this innovation in their production organization or development of new projects.

The TTO usually receive suggestions from scientists and they analyze if the project is commercializable and later decide how to commercialize it: by licensees or creating a spin-off, or ventures founded by employees (professors, researchers, students, etc.) from the university around a core technological innovation, which had initially been developed at the university (Birley, 2002). The TTO has a bureaucratic culture given that administrative tasks are carried out within the university. In spite of that, their budget comes in part from the income generated from these transactions (Siegel, Waldman and Link, 2003).

Finally, the entrepreneur or firm is an agent interested in investing in new projects. These projects tend to be a proof of concept or a prototype and at that point are in an embryonic stage, and need further development before commercialization; hence, the collaboration of university scientists is needed. In order to commercialize these projects, firms usually pay the university a fixed fee and sponsor research in the first stage; if successful, they also pay royalties or give equity. Figure 1 summarizes the different decisions made by the agents mentioned.

Figure 1: Decisions related with technological transfers



Theoretical models have focused on the problems of asymmetric information between agents. Ordering studies from the most general to the most concrete, previous works justifies the existence of the TTO's because they avoid the adverse selection problem between the inventor and the firm (Macho, Veugelers and Perez, 2007), the introduction of incentives for stimulating researchers in order to develop commercial innovation (Jensen, Thursby and

Thursby, 2001, 2003) and under which circumstances a TTO chooses between license and spin-off (Chukumba and Jensen, 2005).

Our purpose is to develop an as simple as possible benchmark model for analyzing the contributions of all of this literature. We shall do so in the following section. The models related with the organization of a TTO's activities are analyzed in Section 3, and Section 4 analyzes the models that discuss the best way of exploiting an invention, licensee or a spin-off. The problems of a spin-off development are analyzed in more detail in Section 5. Through all these sections, special stress has been placed on illustrating the main empirical implications and the existing evidence. The last two sections of the paper are a summary of the implications of the existing models for the management of universities and TTOs and a research agenda with the theoretical and empirical issues most needed in research.

2. A GENERAL FRAMEWORK OF THE PROCESS OF TECHNOLOGICAL TRANSFER.

The goal of this section is to set up the simplest model that allows us to discuss the main contributions of the formal incipient literature related with the tasks of TTO's. To do so, we develop a general benchmark, based on Jensen, Thursby and Thursby (2003), and Jensen and Thursby (2001), introducing some nomenclature in order to capture the main decisions and variables, most of which are described in the introduction.

In a first stage, the institutional context fixes how the university incomes are going to be distributed between the TTO (an α share) and the scientist (a β share). The remaining ($1-\alpha-\beta\geq 0$) income is going to support general expenses of the university. For the sake of simplicity, we assume that university incomes only come from royalties (R). At the end of this section, we discuss how to introduce fixed fees in the model.

The scientist has to decide what kind of research, commercial innovations or basic research is going to be done, thereby obtaining, in the last case, a utility of V_l. If he decides on commercial innovations the scientist chooses when the project can be commercialized, i.e. proof of concept stage or prototype, or in other words the level of effort (e) put into the project. For simplicity's sake, let us assume that the utility function of the scientist is defined by $U_I = w\text{-}C(e)$, where w is the income obtained by the scientist; in our case, $w = \beta R$ and $C(e)$ is the cost of effort, $C(e) = c\ e^2/2$ where $e \in [0,1]$ and c is a constant ($c = \partial^2 C(e) / \partial e^2 > 0$) , so $U_I = \beta R - c\ e^2/2$.

The TTO maximizes the differences between incomes ($Y= \alpha\ R$) and the costs, basically those of seeking a firm to license (V_T), which does not depend on the success of the project. Hence, the TTO objective function is: $U_T = \alpha\ R - V_T$. The TTO is going to accept all of those projects that generate profits, $\alpha\ R - V_T > 0$.

Finally, the firm takes care of its profits. For each project, the firm has a fixed cost of project commercialization (K), which is independent of the success of the project. The net income of one project is going to be Π if it is a success and 0 otherwise. The probability (P) of success increases with the quality of the idea of the scientist ($Q \in [0,1]$) and the stage of development of the project (e). Therefore, probability is defined as follows:

$$P(Q,e) = e^*Q \qquad (1)$$

Thus, the expected profits of the firm are going to be: $U_F = \Pi\, P - E(R) - K$.

Take note that R are the royalties paid to the university, which are going to be a share r of the profits obtained, so the expected amount of royalties is $E(R) = Pr\Pi$, so $U_F = P\ [\Pi^*(1\text{-}r)] - K$.

We have not considered explicitly the possibility of fixed fees paid by the firm to the university. In fact, the consideration of these fees just implies a redefinition of the variables K, V_T ,and V_I. The former, K, can be interpreted now as the sum of fixed fees and commercialization costs of one project. V_T is the difference among the costs of looking for a firm to license and the part of fixed fees received by the TTO and V_I the difference between the opportunity cost of making commercial innovations and the part of fixed fees received by the scientist. For large fixed fees, V_T and V_I could be negative. All the agents are risk neutral. Table 1 summarizes and relates the nomenclature defined with the actions and motivations identified in the introduction.

Table 1: Agents of innovation transfer from universities

	Actions	Primary motives	Secondary motives	Organizational cultures
University Scientist	New research projects or commercialize the current project (*e*)	Recognition within scientific community (V_I) Financial gain: Max: $\beta R - c\, e^2/2$	Financial gain and a desire to secure additional funding	Scientific
TTO	Sell the technology to licensee, create a spin-off, or even cancel it.	Protect and market the university's intellectual property $U_T = \alpha R - V_T > 0$	Facilitate technological diffusion and secure additional research funding	Bureaucratic
Firm/Entrepreneur	Commercializes new technology	Financial gain $U_F = \Pi P - E(R) - K > 0$	Maintain control of property technologies	Entrepreneurial

Source: Readapted from Siegel, Waldman and Link (2003)

3. THE ORGANIZATION OF THE UNIVERSITY TECHNOLOGY TRANSFER.

The academic research in this field has focused mainly on the reasons for the existence of University Technology transfer offices (TTO's) and the incentives provided by the fees and royalties charged by the universities to the firms and its distribution among the TTOs and researchers.

3.1. When is a TTO needed?

Although the TTO has some relevant occupations such as specialized services or intellectual property management that can justify its presence, Macho, Veugelers and Perez (2007) argue that TTOs exist mainly because building a reputation allows parties to reduce asymmetry of information, thereby avoiding adverse selection problems.

In order to consider the arguments of Macho, Veugelers and Perez (2007) in our benchmark, we now assume that the effort of the inventor is given (for simplicity $e = 1$) but we have projects with different quality levels. In order to simplify, we define only two possible qualities: λ being the percentage of high quality ($Q=1$) projects and $1-\lambda$ the percentage of low quality ($Q=0$) projects that the TTO receives every year. Let us assume that there is asymmetry of information, and thus the quality of one project is just known by the faculty members and the TTO but not by the firms. Take note that we are under a situation of adverse selection (see Figure 1). Assume also that each scientist can only create one commercial innovation, the TTO and the firm is infinitely lived and all the inventions are licensed to the same firm[2]. The firm can license a new project each period and already knows the results of the project from the year before. For the sake of simplicity, let us assume also that α and β are equal to *0,* and consequently, all the income received by the TTO and the inventor comes from the fixed fee (V_I and $V_T < 0$); therefore, the incomes of the TTO and scientist come from the number of projects licensed, independently of the quality of the project, $U_I - V_I = -c/2 - V_I > 0$ and $U_T = -V_T > 0$. The firms also pay a fixed fee included in K, $R=0$.

Prior to playing this game for infinite periods, the university and firms negotiate the fixed fees and the university establishes the decision about the creation of the TTO, or, in other words, two situations are analyzed: in the first, only the scientist can sell the license and consequently a TTO does not exist, and in the second, the university can license the inventions made by the researchers and as a result a TTO does exist. Table 2 synthesizes the timing of the game.

Situation 1: A TTO does not exist. In that case, after the firm has developed the project and it is a failure, i.e., a low quality project ($P=Q=0$), the firms cannot impose any punishment on the scientist because they will never meet again in the market. Hence, for the firms *a priori* all the projects are equal and the expected profits are going to be: $E(U_F)= \lambda \ \Pi - K$. The firm will buy all the projects if the expected profits are positive; therefore, if the percentage of good projects is high enough ($\lambda > K/\Pi$), all the projects will be commercialized. On the contrary, when $\lambda < K/\Pi$, no project will be negotiated. Consequently, the average income generated by the firm during each year in this situation is: $\lambda \ \Pi$ or 0. So, $\lambda \ \Pi$ is the maximum K, i.e., university fixed fees plus marketing expenses, which firms can support.

[2] Take note that for simplicity's sake we assume that there is only one firm. This assumption could be interpreted as we having many firms that have complete information about the behavior of the TTO, therefore all the firms know if the TTO honors or betrays each agreement.

Table 2: Timing of the game

Periods	Events
(0)	Fixed fee (*K*) is defined.
(0.1)	The university decides whether to create a TTO or not.
(i.1)	Firm receives a project (by the TTO or randomly selected).
(i.2)	If the project is developed, the firm obtains profits п or not and consequently knows the quality of the projects ($Q=1$ or $Q=0$).
i= 1…∞	The game is repeated infinitely in the last two steps.

Source: Self-elaborated

Situation 2: A TTO exists. The TTO interacts continuously in the market with the firm. In that case, after the firm has developed the project and it is a failure, i.e., a low quality project ($P=Q=0$), the firms can impose a punishment on the TTO by not buying any further projects (trigger strategies). Take note that this is a Subgame Perfect Nash Equilibrium. If one year, the TTO sells a low quality project and obtains a net income of $U_T > 0$, but the TTO is not going to sell any more projects in the future, the TTO is going to loose infinite future pay offs. Knowing that, the firm is going to accept all the projects because they are going to be of good quality. So the income generated each year by the firm is Π, which is the maximum *K* that firms can support.

The fact of joining the projects of a university in the same office of technology transfer allows the creation of a reputation that avoids the adverse selection problems consistent with the model of Macho, Veugelers and Perez (2007). In our simple version of the model, this allows firms to obtain greater incomes (Π versus $\lambda\ \Pi$) and as a result in a possible negotiation for the fixed fees between the firm and the university, the University could acquire part of these incomes through greater fixed fees.

<u>*Implication 1:*</u> Commercialization through TTO's generates greater incomes for Firms and universities.

Godfarb and Henrekson (2003) give partial proof of this implication. They compare the case of Sweden where the right to sell intellectual property belongs to the inventor (Situation 1), with the case of the U.S., where the right to commercialize intellectual property and exploit these resources through the figure of the TTO (Situation 2) belongs to the university. They conclude that Sweden has a higher relative amount of researchers than the U.S. but that the income generated by licenses is relatively larger in the U.S.; therefore, the ownership of the right of a university to make decisions and the presence of the TTO lead to a more efficient technology transfer process.

If we relax the assumption of a TTO with an infinite life, future payoffs can be lower than U_T and the TTO has no incentives to maintain a reputation. In such a case, Macho, Veugelers and Perez (2007) emphasize that the incentives to maintain a reputation increase with the size of the TTO.

Implication 2: The TTO needs to achieve a critical size in order to be able to build a reputation.

3.2. How to stimulate commercial innovation?

At the time that a scientist realizes that he has created a potential innovation, the invention usually is a proof of concept and needs further development. In order to ensure this development, institutional context, TTO's and firms must stimulate the scientist. This problem is contained in Jensen, Thursby and Thursby (2001 and 2003).

To summarize the main results of Jensen, Thursby and Thursby (2001 and 2003), we assume that the quality of the project is a given, for simplicity we assume Q=1, and consequently the effort is equal to the probability of the project being a success, P=e.

The socially optimal level of effort would be, in this case, $e_s = argmax \{U_I + U_T + U_F\} = \Pi/c$. We are going to assume that the effort is neither observable nor contractible; therefore, the effort exerted depends on the scientist's incentives. So the scientist, before developing a commercial innovation, analyzes the effort he wants to put into it. In our benchmark, the effort that maximizes his expected utility[3] is: $e^{*}= \arg\max\{U_I\}=\beta R/c$, *so* the expected utility in that case is $U_I\ (e^{*})= (\beta R)^2/2c$. He is going to develop the project if all the following restrictions are fulfilled:

i) The expected utility is higher than the participation constraint ($U_I\ (e^{*}) = (\beta R)^2/2c = P\beta R/2 > V_I$).

ii) The TTO is interested in commercializing the innovation when the probability of success is higher than the ratio between the fixed cost of looking for a firm over the TTO income, $e^{*}> V_T/\alpha R <1$.

iii) The firm is interested in acquiring the license if the probability of success is higher than the ratio between the fixed cost over the net margin is positive, $e^{*}> K/(\Pi\text{-}R)<1$.

The model above has several implications assuming that the effort cost (c) is equally distributed among the scientists of different universities:

<u>*Implication 3:*</u> No development and thus no commercialization will be done unless there are either royalties (R) or equity (β) in the compensation of the scientist.

Jensen, Thursby and Thursby (2001) provide survey evidence of the licensing practices of 62 U.S. universities. They found that only 12 percent of the projects were ready for commercial use at the time of license, and only 8 percent were feasible for manufacture. Moreover, 75 percent were no more than proof of concept or lab scale prototypes. So inventions tend to be in an embryonic stage at the time the firm which licenses the technology wants to commercialize them, and even if the invention is already a prototype it needs further development in order to be commercialized.

According to Jensen and Thursby (2001) since the development of the product (once the firm has licensed the technology) is made by the inventor, there is a moral hazard problem because the inventor usually prefers to work on new

[3] Take note that the maximum effort that the agent can do is one, so if $e^{*}=\beta R/c > 1$, the restriction above applies and the solution to the scientist's problem is to make an effort equal to 1, and consequently the expected utility in that case is UI ($e^{*}=1$) = $\beta R - c/2$.

research projects rather than develop projects that are already licensed, especially if they receive few incentives for development.

Implication 4: From the level of effort, $e^*=\beta R/c$. In those universities where the share of royalties (β) that go to the scientist (or his department) are higher, the quality of the projects increases.

Jensen, Thursby and Thursby (2003) find that universities with greater net income have less proportion of inventions in the initial phases, and so more prototypes. Moreover, from restrictions i to iii), these universities have a greater fraction of scientists dedicated to commercial innovations. Lach & Schankerman (2003) confirm the idea that higher royalties for the scientist increases the number of projects disclosed. They analyze panel data on U.S. universities and they find that universities with higher shares for the scientists have higher license incomes.

Implication 5: From the level of effort, $e^*=\beta R/c$. Those scientists with greater effort costs (c) are going to disclose less developed projects.

Implication 6: From restriction i), when the share of royalties (β) that go to the scientist increases, some of the scientists with greater effort costs (c) that before would not have been interested in commercial innovation will then be interested in those innovations.

Jensen, Thursby and Thursby (2003) for example argue that those scientists with the best results on basic research have a greater preference for their time, and as a result a greater cost for developing commercial projects (c). In particular, they found that the quality of the faculty affects positively and significantly the quantity of inventions disclosed in early stages and negatively the amount of prototypes. In other words, when the share of the scientist increases, the projects are disclosed more easily, but in a more embryonic stage.

Implication 7: From restriction i), those scientists with a more promising career in the basic research arena, higher V_I, need more incentives (βR) in order to develop commercial innovations.

Jensen, Thursby and Thursby (2003) find evidence that TTO directors feel that the quality of the inventions that are disclosed is low; therefore, high quality faculties have more incentives to continue with their research in new projects than disclose inventions.

Implication 8: From restriction ii), more efficient TTO's (less costs of seeking firms over royalties, $V_T/\alpha R$) help to increase the number of commercial innovations.

Take note that this restriction is applied only when firms are relatively more efficient ($K/(\Pi\text{-}R) < V_T/\alpha R$). The findings of Siegel, Waldman and Link (2003) support this result. The TTO's that bring the commercial innovation from the inventor to the market in a more competent way obtain, on average, more income in licenses.

Implication 9: From restriction iii), more efficient firms (less marketing costs over profit margin, $K/(\Pi\text{-}R)$) help to increase the number of commercial innovations. Take note that this restriction is applied only when TTO's are relatively more efficient ($K/(\Pi\text{-}R) > V_T/\alpha R$).

Notice that it is an unexplored issue since it is difficult to find evidence on the marketing costs of the different projects.

4. LICENSING OR SPIN-OFF?

The transfer of technology from universities to the commercial sector has historically been dominated by the practice of licensing (Siegel et al., 2003). But Locket et al (2003) indicate that more successful universities in the UK have developed more explicit and proactive strategies towards the development of spin-off companies[4]. Therefore, deciding whether to license or spin off has become in the last few years a relevant question for both academics and TTO's managers.

Chukumba and Jensen (2005) propose a model that is a reasonably straightforward compilation and extension of that of Jensen and Thursby (2001)

[4] Shane (2004) provides similar evidence for the case of US.

and Jensen, Thursby and Thursby (2003). In order to adapt their model to our benchmark, we assume that *Q* is constant (*Q=1*) and let us assume that some of the variables of the model have different values depending on the nature of the firm that commercializes the invention, and whether it is a spin-off (*SO*) or an existing firm.

Inventor effort: An inventor has a closer relationship with a spin-off, and may provide greater implication, rejecting easier basic research projects than if the invention is going to be commercialized by other firms ($V_I > V_I^{SO}$). In that case, according to restriction i) in Section 3.2, the projects that are going to be commercialized as spin-offs are those projects that $V_I > U_I(e^*) > V_I^{SO}$. Then, Spin-offs will therefore develop projects that would not otherwise be developed due to their low quality[5].

<u>*Implication 10:*</u> The decision (of the TTO) whether to commercialize using a license or a spin-off depends on the implication of the scientist. The fact that the scientist has less aversion to applied research when a spin-off is created entails that low quality projects with a low probability of success tend to be developed through spin-offs.

Search costs: Chukumba and Jensen (2005) consider that TTO's tend to focus their limited time on finding established firms as licensees for their most promising inventions, while essentially ignoring the others, which then typically are commercialized only if the inventor makes the effort of finding investors for the spin-off.

Hence, in this case, we can consider that the commercialization cost of licensees are greater than the cost of commercializing using spin-offs, ($V_T > V_T^{SO}$). According to restriction ii), in Section 3.2, those projects that $V_T/\alpha R > e^* > V_T^{SO}/\alpha R < 1$ are going to be commercialized as spin-offs. Then, Spin-offs will therefore develop projects that would not otherwise be developed due to their low quality.

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[5] In all of the argumentations of this section, we are assuming indifferent scientists and that TTO's prefer to license rather than create a spin-off. This is similar to assuming that creating a spin-off has a very small cost.

Implication 11: The decision (of the TTO) whether to commercialize by means of a license or a spin-off depends on the cost of searching for an established firm. The fact that seeking a licensee is more costly implies that low quality projects will be commercialized by means of spin-offs.

Chukumba and Jensen (2005) found evidence that gross licensing royalties have a positive and significant impact on licenses granted to established firms, but do not significantly affect the creation of spin-offs. In this regard, it appears that those universities that are able to generate many start-ups may not be the same universities that also have large royalty incomes, and therefore the majority of "royalty rich" TTO's obtain their revenue from established firms, and view spin-offs as a last resort.

Opportunity cost: expected profits depend on the firm's cost of development effort and the cost of commercialization. The opportunity cost of development and commercialization can be greater for established firms ($K > K^{SO}$), which typically have alternatives that are more closely related to their current product line, and so are more profitable. On the contrary, venture capitalists routinely deal with inventions that do not fit well in existing product lines, thus they may have a cost advantage from better access to information about the technological expertise needed to develop and commercialize embryonic inventions. Moreover, the inventor's superior knowledge of the technology can limit transactional and informational problems. Finally, when there is the possibility of receiving financial aid from public institutions for the creation of new firms, the incentives for creating a spin-off will be higher.

In that case, we find that restriction iii) in Section 3.2 is not fulfilled for existing firms but is fulfilled for spin-offs, $K/(\Pi\text{-}R) > e^* > K^{SO}/(\Pi\text{-}R) < 1$, which leads to developing low quality projects that otherwise would not be developed.

Implication 12: The decision (of the TTO) whether to commercialize by means of a license or a spin-off depends on the cost of commercialization and the cost of development. If these costs tend to be greater for licenses, low quality projects tend to be commercialized through spin-offs

Chukumba and Jensen (2005) found evidence that opportunity cost is an important variable at the time of choosing the optimal alternative. They focused on the opportunity cost of the venture capitalist, and found that the five-year rolling average of returns to venture capital negatively and significantly impacts the creation of a spin-off. That means that when the rate to venture capital is high, venture capitalists have many opportunities that are more lucrative, and so they pursue them instead. Alternatively, stated, given the embryonic nature of university inventions, the evidence of Chukumba and Jensen (2005) suggests that venture capitalists turn to university start-ups as a last resort.

Arrow (1962), Shane and Stuart (2002) and Locket et al. (2003) offer another justification for the existence of spin-offs in the case of projects that are protected with ineffective patents. In that case, the profits of the firm are unobservable for the TTO and they cannot make a contract on the basis of these profits. So the royalties are going to be null $R=0$, and consequently from Implication 3 the inventors have no incentive to provide commercial innovation. For these authors, the advantage of spin-offs is that they make profits observable for the TTO and the scientist and as a result incentives can be given to the inventor.

5. SPIN-OFF DEVELOPMENT.

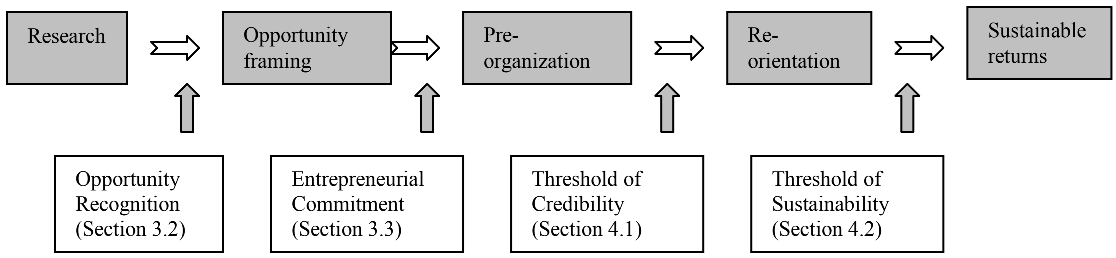
According to Vohora et al. (2004), after analyzing 9 case studies, a spin-off must overcome 5 phases of development in order to be a successful venture (*see* Figure 2). In particular, (1) Research Phase, (2) Opportunity framing phase, (3) Pre-organization phase, (4) Re-orientation phase, and finally, (5) Sustainable returns phase.

The authors define as critical junctures the processes and objectives that must be acquired in each phase in order to advance into the next one. In this regard, the authors define four critical junctures, (1) Opportunity recognition, (2) Entrepreneurial commitment, (3) Threshold of credibility, and (4) Threshold of Sustainability (*see* Figure 2).

Vohora et al. (2004) argue that opportunity recognition (1) is the match between an unfulfilled market need and a solution that satisfies the need. To make this possible, It is a need for the ability to synthesize scientific knowledge with an understanding of markets.

The critical juncture of entrepreneurial commitment (2) arises due to the conflict between the need for a committed venture champion to develop the spin-off and the inability to find an individual with the necessary entrepreneurial capabilities; these difficulties are caused by the academic culture of the inventor and his preference for basic research. Once these two critical junctures are achieved, finance is the key resource without which the entrepreneur is prevented from carrying out the transition to a fully operational business that is able to engage in productive activities. In addition, the finance issue entails a problem of information between the scientist and the external entrepreneur.

Figure 2: The 5 phases of development and the 4 critical junctures (Vohora et al., 2004)



Therefore, the main problems that appear in the threshold of credibility (3) are the need for financing and the relationship between the entrepreneur and the venture capitalist. Once the venture has received seed financing and embarks upon the process of commercially exploiting its technological assets, the entrepreneurial team must develop the ability to create value from the existing resources. Thus, the main issue for overcoming the threshold of sustainability (4) is the need for the management team to acquire the correct skills.

The first two phases, research and opportunity framing, are related to the researcher's focus on commercial innovation and decision to be an academic entrepreneur, which have been broadly analyzed in the previous section, 3.2. In the following sections we are going to analyze more deeply the problems of finance, particularly for the informational problems with the venture capitalist

(Section 5.1) and the problems linked to the skills of the management team of the spin-off (Section 5.2).

5.1. Threshold of Credibility: How are the problems of information solved?

Macho, Veugelers and Perez (2008) argue that part of the financing problem is due to moral hazard problems. Venture capitalists have difficulties observing or evaluating the development level (or effort) of the invention. So the problem is similar to that analyzed in Section 3.2, instead of having an established firm we have a venture capitalist and the use of royalties is not common in spin-offs. More formally, the optimal effort derived in the section cited is: $e^* = \beta R/c = \beta r\Pi/c$, where now βr plays the same role as the capital shares of the entrepreneur in the spin-off. From the result above, development will occur if and only if the inventor has a positive equity.

The socially optimal level of effort, $e_s = \Pi/c$ (*see* Section 3.2) can be obtained with the sufficient level of participation in the capital of the firm, $\beta r = 1$. Macho, Veugelers and Perez (2008) argue that, given wealth limitations, academic entrepreneurs could not obtain such participation, and therefore in this case the moral hazard problem with the venture capitalist will not be solved completely.

Implication 13: In order to develop projects into spin-offs, the inventor must be a shareholder of the new venture; in addition, the limited resources of the inventors could entail that the moral hazard with the venture capitalist is not solved completely, especially when the moral hazard problem is acute.

Macho, Veugelers and Perez (2008) find evidence from a case study, in particular: K.U. Leuven Research & Development (a Belgian TTO). This TTO has generated 60 spin-offs and one of the reasons for their success is their incentive system. In the case of a spin-off, individual researchers can receive up to 40% of the intellectual property shares; they can also invest financially in the spin-off and will hence obtain a *pro rata* share in the common stock of the company.

Lockett, Wright and Franklin (2003) compare two groups of universities in the UK. In the first group, they include the top ten universities in transferring technology and in the second group the rest of universities (47). Using surveys from all these TTO's, they identify that more successful universities tend to create new ventures where the equity is divided more equally between parties, particularly: the TTO, the venture capitalist and the academic entrepreneur.

5.2. Threshold of sustainability: Do academic entrepreneurs have skill limitations?

According to Lazear (2004, 2005) entrepreneurs perform many tasks. The founder of a spin-off needs to have many skills in order to be up to date on scientific and technological advances, hire workers, choose firm locations, obtain good materials from suppliers at a reasonable cost, and so on. In this regard, Lazear (2004, 2005) argues that entrepreneurs must be generalists, and in the event they do not have all the necessary skills they must acquire them.

As Lazear does (2004, 2005), let us assume that effort is a function of the skills developed by the entrepreneur. To simplify, we assume that the entrepreneur can develop two skills: technical (e_1) and management (e_2), and moreover his effort function is $e(e_1, e_2) = Min\{e_1, e_2\}$. The intuition of this effort function comes from the fact that in order to create a firm, both scientific and management skills are equally important.

As the entrepreneur comes from the university environment we assume that initially he is lacking in management skills, $e_1 > e_2$. Consequently, he may increase his skills in management (e_2) in order to acquire the optimal effort that maximizes his expected utility subject to his participation constraint ($e_2 = e^* = \beta R/c < e_1$).

<u>Implication 14</u>: The academic entrepreneur will invest in management skills in order to increase the probability of success of the firm created, or at least, he will join the running with a management expert. In other words, the director or direction team may have generalist skills.

Lazear (2005) finds two kinds of evidence. First, those who have more varied careers, as seen by having more roles as part of their work experience, are more likely to be entrepreneurs. Second, from Stanford MBA data, Lazear

(2005) concludes that those students who study a more varied curriculum are more likely to be entrepreneurs and to start a larger number of businesses over their careers.

6. IMPLICATIONS FOR UNIVERSITY AND TTO MANAGEMENT.

Macho, Veugelers and Perez (2008) argue that in contexts of adverse selection problems about the quality of the projects, TTO's can build a reputation more easily than individual researchers. To do so, firms need to consider the TTO, and not exclusively the individual researcher, as the signal of the quality of a certain project. In that regard, firms must know the records of the TTO commercial innovations and their successes to prevail. Firms can get this information just by continuous interactions with the TTO, but also by the proactive diffusion of this information through public media (annual reports, webs, etc.) or customers' meetings that let them share experiences. Obviously, the reputation is maintained if the TTO is able to distinguish between good and bad projects, getting as much information as possible from the individual researcher about the quality of the project and introducing control mechanisms for the selection of projects in order to establish and guarantee their reputation.

Although the assumptions of Macho, Veugelers and Perez's (2007) model are fulfilled (the TTO is considered as a signal and the TTO has access to all the information that the researchers have), the advantages of a TTO can differ from universities. These advantages grow as with the number of commercial inventions created in a university and its dispersion, the number of different researchers, departments or groups of researchers from where these inventions come. If practically all the commercial inventions are concentrated in one researcher, the existence of a TTO does not make sense in terms of generating a better reputation than the one the researcher has. In the case of small universities, with a low number of inventions in dispersed areas of knowledge, the TTO could have problems improving the reputation that individual researchers have by themselves. Hence, it is not clear whether it is necessary for all universities to have a TTO, at least for reasons of reputation.

But the success of the TTO does not just depend on the activities of their personnel, they need the collaboration of other agents, mainly that of researchers. Jensen, Thursby and Thursby (2001, 2003) help to focus the discussion. Researchers have to dedicate time to commercial innovation, mainly by reducing the time dedicated to basic research. Considering that it is very difficult to control the kind of inventions that a researcher is creating, no development and thus no commercialization will be done unless the scientist benefits from doing commercial innovation. The usual way that universities have to compensate such dedication are either the participation of the scientist in the royalties-equity or fees received by the university. At universities where the share of royalties that go to the scientist are higher, the number of researchers doing marketable research and the time devoted to their inventions increases, and consequently the quality of such inventions.

Take note that those scientists with a more promising career in the basic research arena need more incentives in order to develop commercial innovations, so they will be the last ones to switch basic research to commercial innovations. In that regard, Jensen, Thursby and Thursby (2003) find evidence that the TTO directors feel that the quality of the inventions that are disclosed is low; therefore, high quality faculties have more incentives to follow with their research in new academic projects than disclose inventions. So universities' managers have to be aware that commercial innovation, in most cases, is not free. Thus, the distribution of their budget is going to affect researchers' incentives, and consequently the mix of basic research and commercial innovations obtained in the end.

Jensen, Thursby and Thursby (2001, 2003) pointed out that the promises of greater compensations are not sufficient; researchers have to be confident that their invention is going to be marketable. This implies that the project has to overcome two hurdles: the TTO is one; it must be of interest to the TTO to make sufficient efforts of commercialization. The firm is the other; the firm has to be interested in developing the invention into commercial products. Hence, the reputation of the TTO is not just an external one. The capacity of the TTO to find possible firms and its criteria in the selection of those firms, is not just critical for the result of an invention, but is also going to affect the incentives of future scientists for producing commercial inventions.

When the TTO receives a marketable invention, one dilemma is how to commercialize it, i.e., by means of a license or a spin-off. Arrow (1962), Shane and Stuart (2002) and Locket et al. (2003) argue that spin-offs are a good solution for commercializing innovations in those cases where the patent system is less effective, so the experience and legal support of the TTO's in this field is very important in such decisions. Chukumba and Jensen (2005) offer other considerations to be taken into account. The first one is to check the inventor's implication. If he considers it as an important professional project and is proud to participate in it, perhaps the spin-off solution is a better way to make a profit from such voluntarism. The second is that the creation of a spin-off could be a cheap bet for those projects that the TTO believes would be difficult to commercialize or for which an interested firm could be found.

Obviously the creation of a spin-off is not problem-free. The usual problems of newborn firms (credibility and sustainability) seem to be made worse in that case by two factors: the fact that most of the projects are intensive in knowledge and that their sponsors have little experience in business management. The TTO, therefore, can have an important role here in reducing the informational asymmetries between venture capitalists and inventors, by means of central services of management consultants that can also help to overcome inventors' initial lack of knowledge on business management.

7. RESEARCH AGENDA.

There is a need of stimulating the technology transfer from universities and hence the Triple Helix model (Etzkowitz, 1998, 2003, 2004; O'Shea, 2007). Unfortunately there is an incipient theoretical literature about TTOs and a very scarce amount of empirical evidence.

Empirical evidence about which universities have TTO offices and not about the determinants of the efficiency of TTO's or direct tests of the consideration of the TTO as a signal by their customers will help to test and better understand what the profits are for universities in having a TTO. Although additional evidence already exists, which analyzes the effect of incentives on the behavior and decisions of scientists, further work is needed for refining such tests. The influence of the inventor's expectations about a TTO and firms' decisions on the kind of research that he is going to do (basic or marketable) is of special interest in the models analyzed. We are unaware of the existence of such tests.

The decision of license or creating a spin-off will be greatly improved with the existence of further evidence about the decision rules taken since now and the results of such decisions. It is of special interest to see whether university spin-offs have problems different than those of other newborn firms and what the causes may be.

The test of all such hypotheses and their robustness in the different institutional contexts that can offer international comparisons will help in the understanding and development of new theoretical arguments. Furthermore, from the general framework developed in this paper, some straightforward theoretical extensions also appear. For example, there is no integrative model where the quality and the effort of the inventor are unobservable that could affect the election of the optimal structure of fees and royalties. Other considerations, such as what is the optimal mix of basic and marketable research for a university or how the spin-off development costs influence the way that inventions are commercialized are extensions that could enrich current models.

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