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DOCTORAL THESIS

Transfer of knowledge from the lab to the market: The idiosyncrasy of academic entrepreneurs

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Summary of the contents

Although Technology Transfer Offices (TTO) only have been working for approximately ten years in Spain or twenty in US, this figure is receiving a growing interest from academics. In fact, the commercial innovation generated in the universities has increased dramatically after the introduction of this figure. Although the commercial innovation from universities typically has been represented by three outputs (Research contracts, Licenses and University Spin-offs) the current literature has been focused only on two of them, Licenses and University Spin-offs due to their relevance in TTO policies. In fact University Spin-offs is a very recent phenomenon (in Spain started with the 21st century). Their creation has been stimulated by policy makers given their role for (i) encouraging the economic development and stimulate the generation of local clusters, (ii) generating significant economic value and create jobs, (iii) enhance the commercialization of university technologies, especially the ones that are uncertain, (iv) some university spin-offs are very successful, hence they usually have an important growth rate and in some cases they become public (Initial Public Offering, IPO) and finally (v) they are an effective vehicle for encouraging investor involvement.

The goal of this dissertation is to provide knowledge about the reality of this phenomenon in Spain. For that purpose this dissertation is structured in four Chapters, the first one summarizing the theoretical literature around TTO policies and Spin-offs creation and the rest presenting empirical evidence about the phenomenon of University Spin-offs in Spain. Following it is a brief description of each one of them.

The first Chapter develops a general simple benchmark that permits the analysis of the different contributions made by the economic literature to the understanding of the TTO's role and how they produce and commercialize their outputs, Research contracts, Licenses and University Spin-offs. In particular, those contributions come from the new advances in the micro economic analysis of TTOs and focus on questions such as (i) the economic reasons for the existence of TTOs, (ii) the optimal incentive scheme for the scientist in order to provide projects to them and develop it to commercial products or services, (iii) the most appropriate output for each occasion, licensing or spinning-off, and (iv) the development problems of university spin-offs.

It is worth noting that while some empirical papers have started studying those lines of research, most of them still remain without analyzing and the existent evidence come basically from Anglo-Saxon countries, especially US. In this regard the first Chapter also presents 14 empirical implications for further research in order to advance in the theoretical field and hence improve the knowledge of the economic impact of these institutions. Some of them are focused on university spin-offs development.

The existent literature stresses two problems: the asymmetry of information (Moral Hazard problems) between academic entrepreneurs and the different sources of capital (especially venture capitalists) and the lack of managerial skills of the academic entrepreneurs. In this regard, according to the research conducted by Vohora et al. (2004), those problems are important for overcoming the 5 key stages of the development of university spin-offs: (i) the research phase; (ii) the opportunity framing phase; (iii) pre-organization phase; (iv) the re-orientation phase; and (v) the sustainability phase. In more detail Vohora et al. (2004) stress that those problems, among others, explain the challenges a university spin-off has to face in moving from phase to phase. These difficulties are what they call "critical junctures". In fact they argue that if the critical junctures remain unresolved for a prolonged period of time, the venture will eventually fail. The critical junctures identified in the development of university spin-offs are: (i) Opportunity recognition; (ii) Entrepreneurial commitment; (iii) Threshold of credibility, and (iv) Threshold of sustainability.

In order to study the aforementioned implications and the critical junctures it was necessary to construct a primary Spanish sample of university spin-offs and a comparison sample of high-technology independent start-ups. In the case of University Spin-offs we were able to list 495 firms from 30 Spanish TTOs and for the case of independent start-ups we listed 167 firms. In fact we were able to build a primary dataset with complete information of 71 firms (43 of those are university spin-offs). In the Chapter 2 it is illustrated how the survey has been conducted. Moreover, some features of the university spin-offs are described. It is worth noting that while academic entrepreneurs have higher formal education than independent entrepreneurs, they have less managerial skills, probably due to their bureaucratic background. Indeed, there is no corporate spin-off without at least one founder with managerial skills.

In the Chapter 3 we analyze how the characteristics of the university spin-offs' founders affect overcoming the critical junctures through the database aforementioned. In particular, we present evidence on the fact that university spin-offs receive more facilities at the founding (through public consulting advices and parent institution support) and this initial advantages seem to be maintained at the moment of receiving public or venture capital funds. Among these results we emphasize the importance on the lack of managerial skills for growing. There is consistent evidence on the fact that the university spin-offs without founders with managerial skills have a lower growth rate than university spin-offs which their founders have those skills and the corporate spin-offs. Besides, they do not solve these problems through hiring policy since teams composed by technical members tend to hire workers with technical skills.

Although the academic entrepreneurs have growth limitations because of their lack of managerial skills, organizational learning literature postulates that they will learn fast as they are familiar to the scientific method. So it is worth questioning empirically whether they are able to learn fast along time. In the Chapter 4 we conduct this analysis. In fact, an unbalanced panel from 1994 to 2005 has been constructed, using SABI, what allows analyzing the learning capacity of academic entrepreneurs. The data contains 104 university spin-offs and 73 independent start-ups. A longitudinal productivity analysis has been performed what allows explaining the output growth in two components: the growth of the inputs and the growth of the Total Factor Productivity which for the case of academic entrepreneurs can be interpreted as learning.

The results clearly determine that academic entrepreneurs have lower productivity than their counterparts at the outset but they are able to reduce such differences over time, and after a period of two or three years academic and independent entrepreneurs have the same productivity. Besides, this is the first test in the literature that shed light to the fact that the scientific method is a powerful tool for generating organizational learning.

To sum up the story is as follows. The phenomenon of university spin-off is becoming an important tool for commercializing university innovation by TTOs. For definition they are lead by academic entrepreneurs who in most of the cases have a lower degree of managerial skills than non-academic entrepreneurs. Although this endowment limitation affects negatively the performance at the outset (i.e. employee growth, productivity) it has positive consequences: they learn fast. So the differences in productivity are reduced along time because, following organizational learning predictions (Argyris, 1990), academic entrepreneurs are more familiar to the scientific method which allows them to learn fast.

CHAPTER 1:

Technological Transfer Offices Challenges: The reduction of informational asymmetries between inventors and firms

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I. - INTRODUCTION:

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 chapter 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 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

[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).

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).

[Insert Figure 1 about here]

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.

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 chapter are a summary of the implications of the existing models for the management of universities and TTO's and a research agenda with the theoretical and empirical issues most needed in research.

II. – 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_I. 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 Є $[0,1]$ 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 $U_F = P [\Pi^*(1-r)] - K$.

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.

[Insert Table 1 about here]

III. THE ORGANIZATION OF THE UNIVERSITY TECHNOLOGY TRANSFERENCE.

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 TTO's 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 TTO's 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, $R=0$.

[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.

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.

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.

[Insert Table 2 about here]

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.

Implication 1: 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, $e^* > K/(\Pi - R) < 1$.

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 research projects rather

[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 ($e^* = 1$) = $\beta R - c/2$.

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.

IV. - 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. 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) 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[4].

Implication 10: 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, (VT >VTSO). According to restriction ii), in Section 3.2, those projects that VT/αR >e*> VTSO/αR <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.

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

[4] 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.

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 > KSO), 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.

V. 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.

[Insert Table 2 about here]

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.

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.

VI. – 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.

VII. – RESEARCH AGENDA.

The incipient literature on the economic role of university TTO's has recently developed a set of propositions summarized in this chapter with little empirical research. 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 licensee 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 chapter, 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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Figure 1: Decisions related with technological transfers

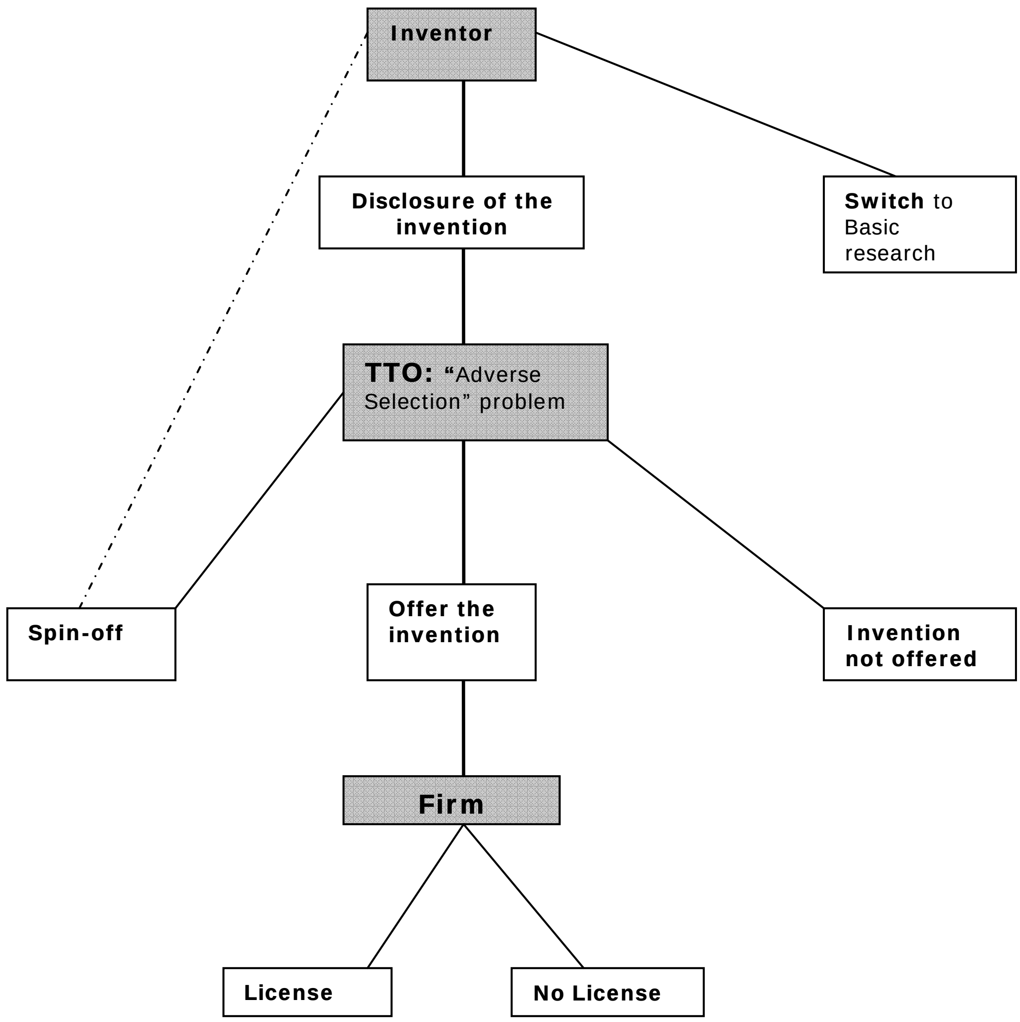


Table 1: Agents of innovation transfer from universities

	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

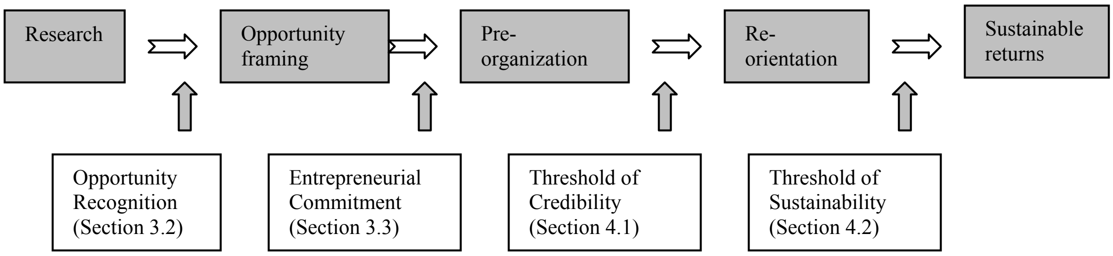
Source: Readapted from Siegel, Waldman and Link (2003)

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 π 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

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



CHAPTER 2:

Main features of the university spin-offs created by Spanish TTO's.

Index

I. INTRODUCTION.

The creation of TTO's in Spanish Universities (Oficina de Tranferencia de Resultados de Investigación, OTRI) was impelled by the Government in the First National Plan of R&D in 1988 developed by the Secretary General of R&D. The TTO assumes the role of the dynamist that the National Plan needed in order to integrate industry in an innovating dynamic. The main tasks of the TTO recognized in that plan are listed below.

- Contact with experts that have the knowledge that the firms require in order to advise them.
- Establish contracts and forms of collaboration between universities and firms.
- Look for public financial aid for the collaboration activities established.
- Promote the catalogue of knowledge and technologies available in order to transfer it to firms.
- Manage the patents that belong to the university and control the exploitation of the interested firms.

Although there is some degree of legal emptiness, there seem to be three important laws that most affect their activities, the Spanish Patent Law, the Universities Law (Ley Orgánica de Universidades, L.O.U.) and the Law of incompatibilities of the personnel of public administrations such as Universities.

The Spanish Patent Law establishes the property and decision rights to inventions developed by employees. In general, the inventions made by the employee during the contract period, which are part of the implicit or explicit activity of research that is the object of the contract, will belong to the employer. In addition, the employee making the invention will not have the right to any supplementary remuneration unless the importance of the invention clearly exceeds the object of the contract (Article 15). In particular, in relation to the property and decision rights to the inventions made in Public institutions such as universities, the owner of the inventions made by university professors as a consequence of the standard functioning in the university is the university (Article 20). Moreover, even though all these inventions must be immediately communicated by the professor to the university through the Figure of the TTO (Article 20.3), the professor has the right to participate in the profits that the university makes from exploiting the rights to the invention, and this participation will be published in the statutes of each university (Article 20.6). For example, according to the statutes of the Autonomous University of Barcelona (2003), 33% of the profits from technology transfer go to the professor, the TTO gets 33% and the rest goes to general university expenses.

Technology transfer can be achieved in different ways to licenses. One of the ways is through the creation of firms (Spin-off) which is explicitly recognized by Spanish legislation (in article 41.2.g of L.O.U.). Spin-off is understood to mean the creation of technology based companies linked to the university. These links with the University can be diverse in nature; some examples are legal and financial advice, introduction of academic entrepreneurs to the correct networks, offering work places to set up the initial phases of the firm (normally in technological parks) and so on. It is important to note that universities do not have the obligation to financially support the creation of the Spin-off, in some cases the university even charges for the services offered to the new ventures.

In some cases the success of the Spin-off is linked with the invention developer's participation in the project. Although in those activities, university employees (professors, researchers) can participate in accordance with university statutes, the "Law of incompatibilities of the personnel of public administrations" makes it difficult (article 12.1.b) for them to participate in the social capital and in the management of the Spin-offs, especially those university employees that work full time. The only option for the academic entrepreneur would be to take voluntary leave from the faculty. If the Spin-off wishes to participate with public administrations, university employees can own a maximum of 10% of the social capital.

Furthermore, collaboration between firms and universities is facilitated by access to financial support and fiscal incentives. In particular some public institutions stimulate the creation and future growth of these firms through subventions and other financial aid. Finally, in concordance with the National Plan of R&D 2000-2003 there are fiscal incentives for R&D activities. In particular, the deduction of the complete quota is 30%, the deduction of the expenses in R&D that exceed the average of the expenses in R&D

for the last 3 years is 50%, the deduction for R&D personnel of is 10%, other concepts that can be deducted are R&D projects that are subcontracted to universities or public institutions and the acquisition of advanced technology. In this sense, a Spin-off can avoid a maximum of 45% of the total taxes depending on the expenses on R&D.

Despite the large number of activities developed by the TTO's, our empirical work is going to focus on presenting empirical evidence regarding one of these activities: the creation of new firms by persons related with the university, Spin-offs. From the theoretical point of view[5] it is especially important to compare the main traits of university spin-offs with those of other new technological firms coming from the private sector. For this purpose, we basically use two sources of information, a public one, SABI[6], and a private one generated in the development of a study financed by the Direccion General de Política para la Pequeña y Mediana Empresa and the Fundación ICO. Although the document 'El spin-off universitario en España como modelo de creación de empresas intensivas en tecnología'[7] presents a summary of this database, we dedicate this chapter to summarizing the way in which the database has been constructed, Section 2, and the most relevant descriptive statistics, Section 3. This chapter closes with a summary of the main problems detected for the development of University Spin-offs.

II. UNIVERSE OF SPANISH SPIN-OFFS AND DESCRIPTION OF THE QUESTIONNAIRE.

The primary information for this study is taken from the replies obtained from a questionnaire that was issued to Spanish technology based companies belonging to two collectives, Spanish university spin-offs and companies appearing in the CDTI catalogue. The information collected refers to the current characteristics of the company (size, financing, public aid received, employee training, the company's capacity for innovation, and others) and of its founders (previous knowledge and experience, motivations, problems in the development of the project and personal evaluation of the experience of the same). Special emphasis was put on the analysis of the effects of the characteristics of the founding team (size, technical and management capacity,

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[5] For more details see chapter 1, section 5.

[6] For more information see Bureau Van Dijk web page: http://Sabi.bvdep.com. This webpage contains financial and accounting information for Spanish and Portuguese firms.

[7] It can be downloaded from the web page: http://www.ipyme.org/IPYME/es-ES/Publicaciones/estudios/

dispersion of capacities among the members of said team) and the decisions made by the company in relation to contracting and training employees, and on the results that were finally obtained.

General features of university spin-offs in Spain

According to a study made by the Spanish Oficinas de Transferencia de Resultados de Investigación (OTRI[8]) association, until 2005 an approximate total of 390 spin-offs were created in Spanish public universities (See Table 1). Prior to 2001 there were only 18 spin-offs, so practically all of the university spin offs in Spain were established after 2001. Table 1 also shows that between 2001 and 2005 the number of spin-offs created has maintained a very similar development to the number of licenses for the exploitation of patents, which gives us an idea of the importance that has been acquired by the creation of spin-offs as a mechanism for the commercial exploitation of knowledge accumulated in Spanish public universities.

[Insert Table 1 about here]

This being the only previous reference found for our study population, in March 2006 we started contacting the OTRI of the 58 universities that form part of the Spanish RedOTRI association. The specific request for collaboration involved asking them for the names and contact addresses of the companies created as part of the spin-off programmes of the respective universities. 39 OTRI's responded to this request for information (a 65% response rate). Of those that responded, 9 universities stated that they had not created any technological companies but did express their interest in creating them in the forthcoming years. At a later moment, February 2007, the OTRI's were contacted once again to ask for information about the criteria used to consider a company for a Spin-off, and the only requisite is that it should be mainly linked to the creation of the university's personal company, and to evaluate the mortality rate of these companies, which in accordance with the data obtained was situated at around 8.5%. Complementarily, we possess occasional information that appears on the web pages of the Innova programme[9] and the Catalan and Valencian Instituto Idea de las Universidades Politécnicas respectively on the mortality rates in said universities. The

[8] RedOtri (2006) www.redotriuniversidades.net
[9] http://pinnova.upc.es/

former states that of the 119 companies created between 1999 and 2004 only 12 are currently inactive. The latter comments that of the more than 200 companies created, 166 are still currently active. All of this confirms that we are dealing with companies with low mortality rates compared with Spanish companies as a whole, where the rate is around 40%[10].

Of the OTRI that responded there was an even degree of collaboration. Some OTRI, in general those that have a lower number of spin-offs, sent complete information about the names and contact addresses of the companies. Polytechnic Universities, possibly because they are closer to technology, are more active in the promotion of companies as an instrument for technology transfer. Thus, the OTRI of the Universidad Politécnica de Cataluña sent a list of 129 companies of which e-mail addresses could only be identified for 47. Via the website of the OTRI of the Universidad Politécnica de Madrid we identified the e-mail addresses of 17 spin-offs. The Universidad Politécnica de Valencia (UPV), through the Instituto Ideas de Creación y Desarrollo Empresarial[11], recognises the creation of 166 companies. The OTRI of said University declined to send contact addresses but did offer to send the questionnaires to the companies itself[12].

Table 2 summarises the number of university spin-offs that responded to our request for information grouped by geographical regions. Table 2 shows that the Universidad Politécnica de Cataluña and that of Valencia agglutinate more than half of the spin-off companies identified for the whole of Spain. Leaving aside the two aforementioned universities, Catalan universities are the most active in the promotion of spin offs (58); followed by Madrid (44), the Basque Country and Navarra (38).

[Insert Table 2 about here]

Table 3 complements the previous information by identifying the sector of activity to which the different spin-offs belong. The groupings by sector are broad because they have been accommodated to the system used by the CDTI itself[13] (Centro para el

[10] According to the executive report by the Global Entrepreneurship Monitor of 2004, for Spain, new companies represent 3.4% of the active population, while closures are 1.4%, i.e. a mortality rate of slightly more than 40%.
[11] http://ideas.upv.es/
[12] Which we know was done because we have received the questionnaire from some of the companies listed on the Instituto Ideas website.
[13] An institution that depends on the Ministerio de Industria, Turismo y Comercio, which promotes technological innovation in Spanish companies. For more information see www.cdti.es

Desarrollo Tecnológico Industrial). We can observe that the computer science sector (hardware and software) is the most represented (54% of the companies), followed by R+D (20%), chemicals (17%) and biotechnology (9%). The distribution by sectors of Spanish university spin-offs is similar to that which can be observed for the United States where 70% of the new technological companies between 1986 and 1999 belonged to the computer science sector, while Biotechnology was the least represented sector (Gompers, 2005).

[Insert Table 3 about here]

It is worth mention that in the literature there are different definitions of university spin-offs that go from more restrictive (Shane, 2004) to wider definitions (Roberts, 1991). Shane (2004) defines university spin-off as a new company founded to exploit a piece of intellectual property created in an academic institution. Roberts (1991) considers that all the firms founded by anyone that worked or studied in a university are university spin-offs. According with the answers of the TTO's, the Roberts' definition was the criteria used by most of the Spanish universities for identifying their spin-offs and the one used in the further analysis.

Having identified, defined and located the companies belonging to the universities that responded to the request for collaboration with the study, the following step was to approach them to ask for the information that could be used to reach the more specific proposals sought by this study. This information was gathered in the form of responses to a questionnaire that was specially made for this project. The companies received an e-mail communication from the authors of the study (the UPV directly approached its OTRI) asking them to answer a questionnaire made accessible to them using the Survey-monkey electronic survey system[14]. The questionnaire was made available on the web in order for companies to answer it at any time between July and October 2006, both inclusive. Every week all the companies that had not yet filled it in were sent reminders. Eventually, 62 companies responded, although not all of them filled in the questionnaire completely.

[14] www.surveymonkey.com.

The design of the study also includes a comparison between the results of the sample of university spin-offs with those resulting from administering the questionnaire to a reference population, in this case technologically based companies created outside of universities. The control sample of companies was taken from a list of companies that appear on the CDTI website as companies that at some time have requested and received aid from the CDTI in order to develop technological innovation projects. The public information that appears on the CDTI website does not include the e-mail address of these companies but does include a postal address, contact person and telephone number. We initially identified 167 recently created companies in different sectors. The distribution by sector and regions of these companies is shown in Table 4.

[Insert Table 4 about here]

In the lists of companies published by the CDTI there is a predominance of companies with their headquarters in Madrid and there is relatively less representation of companies in the computer science sector, which explains how the initially selected control population is slightly different from the sample of spin-off companies (Table 3). From October 18, 2006 work began on collecting information about these companies by contracting the services of TNS-Demoscopia. Thus, a questionnaire was sent by mail to a total of 210 companies, those companies selected from the CDTI catalogue for which a correct postal address and telephone was available, as well as those spin-offs for which we had postal information and that had not yet answered the questionnaire electronically. Approximately every ten days, TNS-Demoscopia phoned to remind the companies about the questionnaire. On January 8, 2007 the postal data collection ended with 31 new questionnaires, 8 from university spin-offs and 23 from CDTI companies. TNS-Dermoscopia also provided us with a list of e-mail addresses of companies that had not answered the postal questionnaire but had answered their calls. These mails were used for a final attempt by e-mailed questionnaire and obtained 8 further observations[15] in March 2007 (2 university spin-offs and 6 CDTI companies). In total 101 questionnaires were received, 72 with information related to the spin-offs and 29

[15] The descriptive results shown in the following section were made without the information about these 8 companies. These companies were used in the article titled: "Determinants Of Spanish University Spin-Offs Development: A Comparison With Other Technological Spin-Offs". Therefore, in this first description of the data, 93 observations are used in which 70 relate to university spin-offs and 23 to CDTI companies.

with information about the companies listed in the CDTI catalogue, although not all of these answered the questionnaire completely.

III. DESCRIPTIVE STATISTICS.

We shall now proceed with a summary of the main characteristics of the spin-offs proceeding from Spanish public universities on the basis of the descriptive statistics for the main variables collected from the questionnaires returned.

As can be seen in Table 1 and Graph 1, the phenomenon of university spin-offs is increasing in Spain and the support and commitment of universities is shown throughout the survey.

[Insert Graph 1 about here]

According to the results shown in Table 5, said support seems far superior to that which private companies offer their ex-workers when they venture to form new companies.

[Insert Table 5 about here]

Table 6 describes the profile of the founders. This tends to be a person aged between 30 and 40 years, in most cases a university professor or researcher in their different forms of contract (functionary, contracted employee or scholarship holder) and therefore many of them are doctors. The main cause for the creation of the spin-off is the detection of a business opportunity linked to their technical knowledge and one that is very difficult to exploit within universities. The implication of the founders is very high, constituting a major part of the workforce. The union links between the founders, prior to the creation of the company, mainly come from the work environment.

[Insert Table 6 about here]

As shown in Table 7, the personal motivations of the founders of the spin-offs seem different to the rest of the population.

[Insert Table 7 about here]

In particular, they show less concern for money and value social status less than the businessperson from the general population and in particular the founders of other analysed technological companies.

As already shown in Graph 1, the operative spin-offs have a short life, 75% of those that answered the questionnaire were less than five years old, are small, half have less than five employees, their activities are developed mainly around the computer science and research and development sectors, and they were constituted as limited companies with very little capital, many of which start up with the minimum legal amount, and almost half were founded with less than €5,000 (see Table 8).

[Insert Table 8 about here]

As for financial resources, the main contributions to the capital were the founders' own savings. Almost forty per cent of the Spin-offs received public aid for financing, an issue that most consider important or crucial for their company. However, half of the spin-offs consider the process of accessing said aid to be complicated or very complicated.

Spin-offs are highly innovative forms, mostly in terms of the product and, like the other analysed technological firms; the links with universities play a preponderant role in this innovation process. The person in charge of innovation actively participates in the management of the company, only 4.2 % have been unlinked to the company and 6.4% did so as an advisor. The immense majority of the remainder had management roles within the company.

It is worth noting that 79.2% of the university spin-offs have introduced significant innovations since their creation, while the CDTI firms introduced them in 91.3% of cases. Although this difference is not significant it is worthy of close attention because one would expect spin-offs to introduce innovations more assiduously. This difference is because university spin-offs are created on the basis of an innovation, and as they have been recently created they have not had enough time to introduce new innovations.

Table 9 shows how access to financial resources and advice in creating and managing the company can be considered key elements in the later development of the same.

[Insert Table 9 about here]

Specifically, the difficulty of becoming a business owner seems greater for this collective than for the general population or than for the founders of the other analysed technological companies. In fact, while in the control sample only half of the companies received advice, almost 90% of the spin-offs did (see last column Table 8).

As for knowledge of management (see last column Table 6), it is detected that although there are cases of companies founded by entrepreneurs with experience of having founded other companies before, more than half had no practical experience of management. Said percentage is very high if it is compared with the 7% for other technological companies.

As for the results of the experience for the founders of spin-offs this seems less positive than for the other technological companies used as control sample. Most of the founders of spin-offs positively value the experience as a form of personal enrichment but not as much in terms of improving their economic level (see Table 10).

[Insert Table 10 about here]

In the case of the founding teams behind Spin-offs it is detected that the number of doctors holds particular weight. The high opportunity cost of these people, in terms of their salaries from previous jobs, could justify the fact that they are relatively less satisfied with the financial returns that their entrepreneurial experiences have brought them.

IV. CONCLUSIONS

Although somewhat late, the exposed data shows that Spanish public universities have joined a process of creating and stimulating university Spin-offs. In this sense, the present chapter has supplied empirical evidence for the case of Spain in an environment predominated by Anglo Saxon literature. Although the phenomenon is very recent and notably increasing, creating around 90 firms a year, it would appear that there is room for improvement. The low mortality rate of the same if compared with the general population seems to be an indicator that business projects can be developed. On the other hand, despite the small size of the firms created and the lack of collaboration with other universities, there is the potential to develop more ambitious projects.

Public authorities should find ways to stimulate this process of developing and consolidating newly created companies. The existing evidence from the Anglo Saxon world (Vohora et al., 2004) highlights two basic developments in the development of university spin-offs. First, the inconveniences for being able to get external financing and secondly their low experience of management activities

The empirical evidence presented in this chapter reveals the cited problems as well as those that are most relevant for the founders of university spin-offs in Spain, that practically 90% of the financing is provided by the company founders and that little more than half of the founders of university spin-offs have previous experience of management clearly show such difficulties.

Academic debate has been focused on the specificities of university spin-offs and therefore discussion has been to transferred to whether specific public policies should be made for these companies and what they should be (Mustar et al., 2006). Whestead (1997), Colombo and Delmastro (2002), George et al. (2002) and Ensley and Hmieleski (2005) are examples of studies in this sense, in which an attempt is made to compare the characteristics of university Spin-offs with other recently created firms. In this sense, our objective is to contribute to this literature and therefore help with the development of said policies by comparing the difficulties than one and other form of firm have in overcoming the different stages of development identified by Vohora (2004)[16] and the transfer that this has on the financial magnitudes of said firms.

[16] For more details see section 5 of chapter 1.

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Table 1: Number of Spin-offs and Licenses in Spain

	Number of Spin-offs	Number of Licenses
Before December 2000	18	—
2001	39	50
2002	65	53
2003	87	78
2004	90	143
2005	88	106
Total	387	430

Source: Estudio RedOtri Universidades 2006.

Table 2: Number of Spin-offs by universities

REGION/S	Universities (number of Spin-offs identified)
ANDALUSIA, EXTREMADURA AND MURCIA	*U de Almería* (1), *U de Cádiz* (2), *U de Córdoba* (1), *U de Extremadura* (2), *U de Granada* (10), *U de Murcia* (2), *U de Sevilla* (4)
ARAGON	*U de Zaragoza* (4)
BALEARICS	*U de les Illes Balears* (7)
CATALONIA*	*UAB* (18), *U de Barcelona* (23), *UdG* (10), *UPC* (129), *U Ramon LLull* (6), *U Rovira I Virgili* (1)
GALICIA AND CANTABRIA	*U de Cantabria* (5), *U de La Coruña* (7), *U de Vigo* (2), *U Santiago de Compostela* (11)
MADRID AND CASTILE	*UAM* (3) , *U Carlos III* (18), *U Complutense de Madrid* (1), *U de León* (2), *UPM* (17), *U Pontificia Comillas de Madrid* (2)
BASQUE COUNTRY	*Universidad Publica de Navarra* (12), *U del País Vasco* (26)
VALENCIA*	*U Miguel Hernández de Elche* (2), *U Jaume I* (1), *UPV* (166)
TOTAL	*30 Universities*

Table 3: Descriptive by region and sector.

	COMPUTER SCIENCE	R & D	CHEMICAL	BIOTECHNOLOGY	TOTAL
ANDALUSIA, EXTREMADURA and MURCIA	12	3	4	3	22
ARAGON	2	1	1	0	4
BALEARICS	3	2	1	1	7
CATALONIA	99	28	38	22	187
GALICIA and CANTABRIA	11	6	5	3	25
MADRID and CASTILE	24	11	7	2	44
BASQUE COUNTRY and NAVARRA	20	11	6	1	38
VALENCIA	99	30	25	15	169
TOTAL	270	92	87	47	496

By way of simplification it is believed that a company belongs to the software industry if it works in Software (design, applications, programming,…) or hardware. R & D includes all companies that perform applied technological research projects. The chemical sector includes both chemical companies and pharmaceutical companies.

Table 4: Distribution by sector and region of the firms obtained from CDTI

	COMPUTER SCIENCE	R & D	CHEMICAL	BIOTECHNOLOGY	TOTAL
ANDALUSIA, EXTREMADURA and MURCIA	11	2	17	6	36
ARAGON	5	0	3	1	9
BALEARICS	5	0	1	2	8
CATALONIA	10	6	10	3	29
GALICIA and CANTABRIA	5	2	3	2	12
MADRID and CASTILE	20	9	9	7	45
BASQUE COUNTRY and NAVARRA	8	4	2	2	16
VALENCIA	5	3	2	2	12
TOTAL	69	26	47	25	167

By way of simplification it is believed that a company belongs to the software industry if it works in Software (design, applications, programming,…) or hardware. R & D includes all companies that perform applied technological research projects. The chemical sector includes both chemical companies and pharmaceutical companies.

Graph 1. Spin-off created by year.

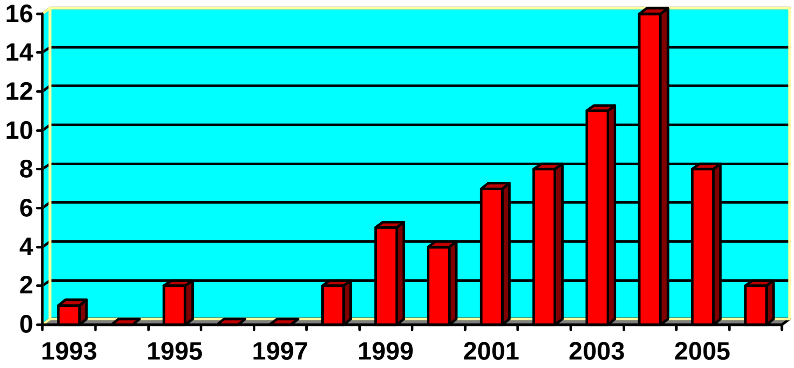

Table 5: Factors that affect the creation of the firm

	Mean (1=" Minimal importance"; 5="Maximum importance")	
Importance of factors in deciding that the current business project could not be developed at the company or institution where the founders worked previously		
ITEM	Spin-off	Control sample
Insufficient support from the institution.	2.43**	3.77**
The institution itself helped us to go ahead with the project	2.47***	1.23***

*, ** , *** , The difference in means between samples is significant at 0.1; 0.05 and 0.01 respectively. (Information from Question F35).

Table 6: Characteristics of the founders.

ITEM	Spin-off		Control sample
Mean age of the youngest founder	33.78		36.13
Mean age of the oldest founder	44.72*		49.78*
% founders contractually associated with the university. (In the control sample high technology firms)	60%*		38%*
% founders with a Master or PhD at the moment of foundation	38.49%**		24.92%**
Number of hours per week devoted to working for the company.	40.44		44.5
Average number of founders.	2.81*		3.65*
% Founders that met each other at work	51%		36.3%
% Founders with previous experience in Management.	41.7%**		95.9%**

*, ** , *** , The difference in means between samples is significant at 0.1; 0.05 and 0.01 respectively. (Information from Question E28, E29, E30, E31, F33).

Table 7: The relevant factors for creating the firm.

	Mean (1=" Minimal importance"; 5="Maximum importance")		
ITEM	Spin-off		Control Sample
Detection of a business opportunity (an uncovered need)	4.26		4.55
Putting into practice previously acquired technical knowledge.	3.53		3.67
Desire to earn more money than working for a salary.	2.22*		2.85*
Prestige or status of the business person	1.92**		2.65**
Advantages of working for yourself.	2.92		3.45
The company you worked for suggested it or encouraged you.	2.03*		1.45*
Difficulties perceived in the previous professional career.	2.09		1.60

*, ** , *** , The difference in means between samples is significant at 0.1; 0.05 y 0.01 respectively. (Information from Question F34).

Table 8: Characteristics of the firms created

ITEM	Spin-off		Control Sample
Mean of current employees	8.34***		18.39***
% Computer science	35.3%		26.1%
% R&D	36.8%		26.1%
% Limited liability company	89.7%*		73.9%*
% Total assets of the company lower than €5000	46.2%**		21.7%**
% Assets financed by the founders	90%		87.7%
% Firms that have received financial public aid	37.7%		34.3%
% Firms that introduced significant innovation	79.2%		91.3%
% Firms that developed alliances in the innovation process	61.5%**		85.7%**
% Alliances made with a university	78.1%		74%
% Firms that received advice	88.5%***		50%***

*. ** . *** . The difference in means between samples is significant at 0.1; 0.05 and 0.01 respectively. (Information from Question A3. A4. B7. B8. C11. D20. D22. and H41).

Table 9: Relevant factors on set-up of the firms

	Mean (1=" Minimal importance"; 5="Maximum importance"	
ITEMS	Spin- offs	Control sample
Access to financial resources	3.98	4.30
Advice in the creation and Management of the company	3.44**	2.70**
Lack of own experience in Management activities	2.76	2.44

*. ** . *** . The difference in means between samples is significant at 0,1; 0,05 and 0,01 respectively. (Information from Question I42).

Table 10: Personal value of creating a Spin-off

	Mean (1=" Minimal importance"; 5="Maximum importance"		
ITEMS	Spin- offs		Control Sample
"The experience has been worthwhile in terms of personal development"	4.60*		4.91*
"The experience has allowed me to improve my economic situation"	2.38**		3.35**
"The experience has helped me to learn to work as part of a team"	2.98*		3.57*
"The experience has helped me to understand better the relationship between technology innovation and the needs of the market"	3.76**		4.36**
"The experience has allowed me to revalue my technical know-how"	3.39**		4.09**
"All in all. having created this company. I am living better than if I hadn't done so"	3.11*		3.80*

*. ** . *** . The difference in means between samples is significant at 0.1; 0.05 and 0.01 respectively. (Information from Question I45).

APPENDIX I: QUESTIONNAIRE ON TECHNOLOGY-BASED COMPANIES:
(A1-D26, Current situation; E27-I46, Initial situation)

NAME OF THE COMPANY: ___________________________________

A. CURRENT COMPANY SITUATION
A1. In what year was the company founded? ______

A2. What is the company's legal status?

A3. Which economic activity sector does your company belong to? (R&D, 1; Computer science., 2; Chemicals, 3; Pharmaceuticals, 4; Biotechnology, 5; Other: Specify)

A4. How many people currently work in the company (including you)?

A5. What was the company turnover (sales volume) for the last financial year (2005)?

A6. Which of the following sentences best describes your company's current situation? GIVE A SINGLE ANSWER (Strong business volume growth, 1; Mild business volume growth, 2; Inactive business volume growth, 3; Negative business volume growth, 4)

B. INFORMATION ABOUT THE COMPANY'S FINANCING:
B7. Please indicate approximately the total assets on the company balance sheet at this moment.

B8. Please indicate approximately the proportion of the company assets that the following sources of financing represent.

	Percentage of financing
Founders / Promoters.	
Family circle and friends (of the founders).	
Financial entity. (shares)	
Financial entity (debt).	
Venture Capital.	
University (shares)	
University (debt)	
Suppliers (debt).	
Others. What? ______________________	

B9. Do you consider that since its creation the company has had to turn down investment projects important for its activity due to lack of adequate financing? (Yes, 1; No, 2)

B10. Do you believe that access to financing by the company in the last one or two years, in comparison with previous years. (Has Improved, 1; Has remained the same, 2; Has worsened, 3)

C. INFORMATION ABOUT PUBLIC AID:
C11. Please indicate the kind of aid that you have received since the company's foundation, from the following institutions:

Institution	Information	Carrying out set-up procedures	Training	Developing a business plan	Use of facilities	None
Industrial Technology	1	2	3	4	5	6
OTRI network	1	2	3	4	5	6
University	1	2	3	4	5	6
Chamber of Commerce	1	2	3	4	5	6
Technology Park	1	2	3	4	5	6
Technology centres	1	2	3	4	5	6
Autonomous community	1	2	3	4	5	6
Others. Specify.	1	2	3	4	5	6
Others. Specify.	1	2	3	4	5	6

C12. Could you evaluate the importance that the aid received has had for the survival and growth of the company? (Very little relevance, 1; Little relevance, 2; Correct, 3; Important, 4; Crucial, 5)

C13. Do you consider that the process of obtaining public aid is: (ONLY ONE ANSWER) (Quick and easy, 1; Some difficulties, but the process was fairly smooth, 2; Moderately complicated, 3; Quite complicated, 4; Very complicated and slow, 5)

D. INFORMATION ABOUT THE COMPANY'S MANAGEMENT:
D14. Please indicate the number of people in the company who have direct knowledge, as a result of studies or professional experience prior to their incorporation in the company, in the following matters: (Management, ___People; Innovation and Engineering, ___People; Administration, ___ People; Commercial or sales, ____People)

D15. Please indicate the number of people in the company with the highest of the levels of educational training listed: (Doctors, ____People; Degree graduates, ____People; Engineers, ____People; Others: Specify ____People)

D16. Which of the following services or tasks are contracted with people or professional services from outside of the organisation (outsourcing): (Accounting and Tax management, 1; Payrolls and personnel management, 2; Distribution and logistics, 3; Strategic business and marketing consulting, 4; Technological consulting, 5; None of these, 6)

D17. Do your employees make an effort to participate in training courses? (Yes, 1 (continue with D18); No, 2 (Skip to D20))

D18. Approximately how many hours a year are devoted on average to employee training? (Hours, ___)

D19. What kind of training predominates? (Technical, 1; Management, 2)

D20. Has any significant innovation (product/service/process) been introduced since the company was created? (Yes, 1 (continue with D21); No, 2 (Skip to D24))

D21. Indicate the degree of novelty of the innovation. (New for this company, 1; New in its geographic sphere of influence, 2; Totally new in the sector, 3)

D22. In the process of developing these products, has the company formed alliances with any of the agents that are indicated below? Please indicate each of them. (Universities, 1; Technology Parks, 2; Customers, 3; Other companies, 4; Other (specify), 5; None of them, 9)

D23. Indicate which have been the main key factors in the success of the aforementioned innovation. You can mark several answers. (The technological capacity of the companies' workers, 1; The good coordination between the company's different areas, 2; Commercial vision and adapting well to costumer's preferences, 3; Other (specify), 4)

D24. Has the company implemented a quality management system? (Yes, 1; No, 2)

D25. Are the products or services that the company offers the result of exploiting a patent, licence or trademark registered by the company? (Yes, 1 (continue with D26); No, 2 (Skip to D27))

D26. Indicate the number of the company's own patents or other patents that the company works with. (Own patents, ___; Own Brands, ___; Licenses with universities; ___, Licenses with Founders, ___; Licenses with other companies, ___; Other (Specify) ____)

E. CHARACTERISTICS OF THE FOUNDERS.

E27. Please indicate the company founder or founders' occupation at the moment that he/she/they decided to create the company (immediately prior to the creation of the company). (In the case of several founders, indicate their number). (Employee in a high tech company, 1; Employee in a company unrelated to the current activity, 2; Lecturer or civil servant researcher, 3; Lecturer or contracted researcher, Doctoral or post-doctoral researcher student, 5; Student, 6; Other (Specify), 7)

E28. The founding partners knew each other because of (mark one or several of the answers with a cross if appropriate): (Work, 1; Studies, 2; Childhood friends, neighbours, 3; They met during the process of setting up the company, 4; The company has only one founder, 5; Other (Specify), 6)

E29. Please indicate the company founders' age. (In case of a single founder, make a note of this in the youngest founder section). (Current age of the youngest founder, ___; Current age of the oldest founder, ____)

E30. Indicate the association with the company of the person or group of people that developed the products or the technology used by the company at the time of its foundation, and at the present moment.

	Moment of Foundation	Current time
a. Managing Director or highest executive position.	1	1
b. Occupying management posts.	2	2
c. Full-time employee without management post.	3	3
d. Part-time employee.	4	4
e. Technical assessor.	5	5
f. Not associated with the company.	6	6
g. Others. Please describe ______________________________	7	7

E31. How many hours per week, on average, do the founders (or founder) devote to working in the company?

E32. How many equivalent full-time staff members did the company have when it began its activity?

F. MOTIVATION OF THE FOUNDERS.

F33. Could you please reply to the following aspects concerning the experience of the company founders/promoters at the moment of the company's creation?

	Previous experience in management activities?			Number of companies founded previously.	Educational Level at the moment of founding			
	Practical	Theoretical	None		Diploma or technician	Graduated or Engineer	Master or PhD.	Other (Specify)
Founder/Promoter 1	1	2	3		1	2	3	
Founder/Promoter 2	1	2	3		1	2	3	
Founder/Promoter 3	1	2	3		1	2	3	
Founder/Promoter 4	1	2	3		1	2	3	
Founder/Promoter 5	1	2	3		1	2	3	

F34. Of the factors shown below, indicate which were the most relevant in the creation of the company. Please indicate their importance using a scale of 1 to 5, where 1 signifies "minimal importance" and 5 "maximum importance".

	Score (1 to 5)
a. Detection of a business opportunity (an uncovered need)	
b. Putting into practice previously acquired technical knowledge.	
c. Desire to earn more money than working for a salary.	
d. Prestige or status of the business person	
e. Advantages of working for yourself.	
f. The company you worked for suggested it or encouraged you.	
g. Difficulties perceived in the previous professional career.	
h. Others. Please describe	

F35. Indicate the importance that the following factors had in deciding that the current business project could not be developed at the company or institution where you worked previously. Please indicate the importance of the various reasons using a scale of 1 to 5, where 1 signifies "minimal importance" and 5 "maximum importance".

	Founder 1	Founder 2	Founder 3	Founder 4	Founder 5
a. It was not part of the institution's main strategies.					
b. Insufficient support from the institution.					
c. The institution itself helped you to go ahead with the project					
d. Studies just completed.					
e. Preference for undertaking the project individually.					
f. As it was a university or research centre, it was difficult to carry out commercial activities within this structure					
g. Others. Please describe					

G. CHARACTERISTICS OF THE COMPANY.

G36. The company was created to: (Develop a new product or service, 1; Develop a new production process, 2; Improve an already existing product or process significantly, 3; Market an existing product or process, 4)

G37. Together with the possibility of creating a company, was the alternative of licensing the invention out to other companies considered? (Yes, 1; No, 2) (Explain the answer briefly)

H. FINANCING AT THE MOMENT OF FOUNDATION.

H38. With how much capital was the company set up? (Capital, _______€)

H39. What proportion of this was put up by the founders? (___%)

H40. Where was the capital provided obtained from? (ALLOW SEVERAL ANSWERS) (Own Savings, 1; Bank loan with personal guarantee, 2; Personal loan from friend or family member, 3)

H41. What other sources of financing did the company obtain at the moment of set up? (ALLOW SEVERAL ANSWERS) (Family, 1; Friends or neighbours, 2; Work colleagues, 3; Company or university where you worked, 4; Banks or saving banks, 5; Venture capitalists, 6; Business Angels, 7; Public Aid, 8; Industrial Technology Development Centre (CDTI), 9; Suppliers and customers, 10; Other, 11; no other, 19)

I. ASSESSMENT OF THE COMPANY SET-UP:

I42. Of the factors listed below, indicate the most relevant for the company or for its founder(s) in the creation and first years of activity. Please indicate their importance using a scale of 1 to 5, where 1 signifies "minimal importance" and 5 "maximum importance".

	Score (1 to 5)
a. Access to financial resources	
b. Advice in the creation and management of the company	
c. Disassociation from the previous institution.	
d. Seeking and communicating with customers.	
e. Seeking and contracting qualified personnel.	
f. Lack of own experience in management activities.	
g. Renouncing the professional career that was already under way.	
h. Others. Please describe	

I43. At the moment of creating the company and starting it up, priority was given to (make a note of the two that are closest to what took place in reality): (Having people with suitable technical training, 1; Having a good management and sales team, 2; Being able to draw on the founder's management know-how, 3; Putting together a trustworthy and properly qualified team for sharing management and technical tasks, 4)

I44. Before setting up the company, from which of the following institutions did you receive advice?
(Industrial Technology Development Centre (CDTI), 1; Chamber of commerce, 2; Technology Park, 3; Technology Centre, 4; Autonomous Community organism, 5; University, 6; TTO university network, 7; Other (Specify), 8; No advice was received, 19)

I45. Based on personal experience during the time that you have been with the company, indicate the degree of agreement (5) or disagreement (1) with the following affirmations regarding your satisfaction with the results achieved.

	Score (1 to 5)
a. The experience has been worthwhile in terms of personal development	
b. The experience has allowed me to improve my economic situation	
c. The experience has helped me to learn to work as part of a team	
d. The experience has helped me to understand better the relationship between technology	
e. The experience has allowed me to revalue my technical know-how	
f. All in all, having created this company, I am living better than if I hadn't done so	

I46 How many years did the company take to make its first positive profits? (If they have still to be obtained, indicate this and estimate how many years from its foundation do you expect to go by until this moment arrives): (Years, ___)

CHAPTER 3:

University spin-offs idiosyncrasy: Is it conditioning their development?

Index

I. INTRODUCTION

Schumpeter (1939) identified the figure of the innovative entrepreneur emphasizing its positive impact on society wealth and welfare since their innovations generate positive business cycles. Moreover, while those new firms appear to be a vital part of the economy (Birch, 1987), the prospects for any particular new venture are uncertain. In that regard, the failure rate of new firms is high (Shapero and Giglierano, 1982) and many survivors achieve only marginal performance (Reynolds, 1987). Western economies dedicate a lot of public resources to encourage the creation of new firms and hence overcome innovation market failure (Martin and Scott, 2000). A better understanding of the factors relating to new firms' survival and growth can improve the decisions of policy makers and future entrepreneurs (Poyago-Theotoky, 2002). Empirical evidence shows that success factors are contingent on the firm's activities (Mustar et al., 2006). Thus, it seems especially interesting to focus on universities where potentially more new innovative entrepreneurs can appear given their task of new knowledge generation (Siegel et al., 2003; Locket et al., 2005).

Research based university spin-off have become an important issue in regard to universities' technology transfer processes (Di Gregorio and Shane, 2003; Wright et al., 2004a and 2004b) and an international phenomenon due to their growth (Clarysse et al., 2005). Some successful cases like Hewlett-Packard or Cisco System[17] have also helped to attract the attention of the academic world mostly on the development problems of such firms[18]. In addition, the higher education institutions other source of innovative entrepreneurs are well-established industrial firms (Oakey, 1995). So, for academics, policy makers and entrepreneurs it is of interest to know if the key elements for their development differ among university and corporate spin-offs.

The existent empirical literature on university spin-offs is dominated by qualitative analyses of case studies from Anglo-Saxon countries and has recognized gaps like: i) the analysis of the relevance in spin-off success of initial endowments such as the characteristics of the founders or the financial constraints (Mustar et al., 2006), ii) the

[17] Their market capitalization in 2002 was 34.855 billion and 123.953 billion dollars respectively. Some of the spin-offs in Oxford (UK) exceeded £100 million of market capitalization and 1000 employees in 2002 (Smith and Ho, 2006).

[18] For example, *see* Carayannis et al., (1998); Clarysse et al. (2005), Del Palacio et al. (2006), Fontes (2001, 2005), Steffensen et al. (2000), Upstill and Symington (2002), Wright et al. (2004a, 2004b), Vohora et al. (2004).

absence of a unifying framework (Mian, 1997) and iii) the comparison with spin-offs from other institutions: mainly corporations (Ensley and Hmieleski, 2005).

This chapter tries to fill these gaps by presenting empirical evidence from a sample of Spanish spin-offs about the differences in the development process between university and corporate ones. Whestead (1997), Colombo and Delmastro (2002), George et al. (2002) have compared samples of university and corporate spin-offs focusing on their features and performance differences. Ensley and Hmieleski (2005) have related both kinds of variables, by analyzing the role of top management team heterogeneity and dynamics as explanatory variables of performance differences. This present chapter focuses on the managerial experience of the foundational team and its influence on the development of firms.

Furthermore, the composition of the top management team is just a key element to overcoming one of the four critical junctures identified by Vohora et al. (2004) in the development of a spin-off: entrepreneurial commitment. Following the proposals of Lockett et al. (2005) or Mustar et al. (2006), we use the framework created by Vohora et al. (2004) in order to extend the analysis to identify other key elements for overcoming the remaining critical junctures: initial public and parent institutional support, founding team characteristics, financial access and human resources and R&D policies. In the next section, we present in detail the critical junctures identified by Vohora et al. (2004) by analyzing from the existing literature the key determinants for overcoming each one of the critical junctures. The chapter follows with a section describing the data sample and the variables used in the empirical analysis. The empirical results are presented in the fourth section; discussion is provided in section five and the last section summarizes the policy implications of the chapter.

II. UNIVERSITY SPIN-OFFS' SUCCESS: AN INTEGRATIVE MODEL AND DIFFERENTIAL ELEMENTS

It is posited that individuals choose an occupation or employment that maximizes the present value of economic and psychic benefits over their lifetime (Gimeno et al., 1997). Whether or not to undertake a particular opportunity or activity must be weighed up against the benefits from alternative courses of action (Shane and Venkataraman, 2000) or opportunity costs (Cassar, 2006). Although occupational decisions usually imply high sunk costs (Heath, 1995), they are reversible, as demonstrated by the decision of some academics to become entrepreneurs. From a case analysis study, Vohora et al. (2004) identify four critical junctures in the development of a university spin-off: Opportunity recognition, Entrepreneurial commitment, Threshold of credibility and the Threshold of sustainability. A direct test of that model is highly demanding of data, and requires information about successful firms and those that have not overcome each one of the junctures. An alternative is to develop hypotheses related with the key factors needed to overcome each of the critical junctures and test if they are present in existing firms: those that have overcome all the critical junctures. This section looks in-depth at the factors that contribute to overcoming such junctures and at the theoretical differences with other spin-offs: corporate technologically based spin-offs. These differences are mainly based on the literature that emphasizes the lack of previous managerial experience of university entrepreneurs (Shane and Stuart, 2002; Rajah and Tarka, 2005; Lasch, Le Roy and Yami, 2007).

1. Opportunity recognition.

In the development of academic activities, university researchers gather new information that can alter the present value of their current activity: academia. A decrease in this present value motivates the first step in the development of a university spin-off according to Vohora et al. (2004): the Research Phase for collecting information about the consequences and possibilities of the entrepreneurial activity. Those academics more undecided at the beginning[19], those with a less successful academic career or those doing research with more commercial capabilities[20] seem to be the main candidates for being new entrepreneurs.

Following Vohora et al. (2004), when this information finishes with the recognition of an opportunity, that opportunity has to be framed. Lazear (2004, 2005) presents evidence on the fact that an entrepreneur must have generalist skills. Future entrepreneurs have to be able to evaluate the technological and economic viability of the project. So, in this case, knowledge and time are needed. The knowledge is based on

[19] Storey (1994) or Delmar (1997) summarize academic investigation focused on which psychological factors are predominant in entrepreneurs. So, it is expected that those academics with such characteristics would be the more undecided at the beginning of their careers.

[20] Jensen, Thursby and Thursby (2003) present evidence that those scientists with good records in basic research tend to renounce becoming entrepreneurs.

previous activities and experiences of the researchers, and the support of the actual institution is one of the main determinants of the time devoted to this new venture.

Related with previous experiences, researchers at universities carries with an ambiguous relationship to commercial innovation and a preference for basic research (Ndonzuau, Pirnay and Surlemont, 2002; Birley 2002; Siegel, Waldman and Link, 2003). Most of his career recognition, and consequently compensation, comes from his success in basic research. They usually have less managerial experience and entrepreneurial culture than other researchers coming from a less academic and bureaucratic culture (Siegel, Waldman and Link, 2003; Murray, 2004). Hence, they need greater consulting advice in order to cover such limitations.

> *Hypothesis 1.1:* The amount of public consulting advice prior to setting up the firm is higher in university spin-offs than in corporate ones.

Private and public institutional support and networks[21] are important for the development of new firms (Perez and Martinez; 2003). In this regard, the supporting role of the parent institution, for example letting new founders use part of their workday and parent institution resources, is crucial. Gompers et al. (2005) shed light on this issue when they identified that the support given by the parent institution will depend on whether the organisation is private or public. In more detail, the study is based on the comparison between spin-offs created from public companies located in the Silicon Valley and Massachusetts and spin-offs created from private industrial firms. They suggest that public institutions tend to be more prolific in aiding new firms than private institutions, aside of other institutional features, as the commitment to freedom of research in universities (Aghion et al. 2005; Lacetera 2005), that can help for such development. Thus, we expect that the support universities give in order to develop a new firm will be higher than the support given by well-established industrial firms.

> *Hypothesis 1.2:* The support of the parent institution is higher in university spin-offs than in corporate ones.

[21] In this regard, George et al. (2002) and Colombo and Delmastro (2002) analyze technological alliances. They pointed out that university spin-offs have significantly more technological alliances than their counterparts.

2. Entrepreneurial commitment.

After the entrepreneurial opportunity has been framed, it is needed a commitment of the responsible for being entrepreneur (Vohora et al. 2004). The founding team appears as a key element in this step. Hambrick and Mason (1984) introduced the "upper echelons" perspective, arguing that managers make choices based upon their idiosyncratic experiences, values and dispositions, which affect the firm's results. Since then, academics have focused on the effects of the characteristics of the board, team size and expertise of the board, on the quality of such decisions and, consequently, on the firm's performance. The best way for measuring a new firm's performance has led to a long debate in the literature[22]. The value of all the economic profits obtained over a firms' life is, from the point of view of economic theory, the optimal measure, but it is difficult to obtain. The opportunity cost of each entrepreneur is difficult to know, and the accounting profits of such firms normally are not audited and are low and bad predictors of future ones, given that they are small firms in the first years of existence. At this stage, a firm's capacity for growth seems to be a good predictor of its future economic profits. So as in previous studies (Storey, 1994 and Lasch et al., 2007), we are going to use the growth in number of the firm's employees as the measure for its performance.

Experimental economics using game theory foundations make it possible to have laboratory evidence on the impact of team size on their performance. In general, teams work better[23] than individuals, and in teams with less of five members, the team performance increases with size (Blinder and Morgan, 2005; Cooper and Kagel, 2005; Kocher and Sutter, 2005; Besides Sutter, 2006). Consistent with this evidence, some research findings about new venture teams to date is that team-founded ventures appear to achieve better performance than individually founded ventures (Cooper and Bruno, 1977; Teach et al. 1986; Weinzimmer, 1997). Consequently, they all support that teams perform better than individuals, but could not state whether large teams perform better than small ones. Other research evidence suggests that size has a negative effect on a

[22] Cooper, Gimeno and Woo, 1994; Storey, 1994; Wiklund, Davidson and Delmar, 2003; Chandler, Honig and Wiklund, 2005; Cassar, 2006; Tornhill, 2006; Parker and Van Praag, 2006.

[23] These analyses used are based on the Beauty-contest game where decision makers choose simultaneously a real number between zero and one hundred. The winner of the game is the one decision maker whose number is closest to two thirds of the average of chosen numbers. The advantage of this game in studying differences in the quality of decision making between individuals and teams is that it does not confound effects of rationality and learning with the effect of social preference, such as inequality aversion, fairness or reciprocity.

team's performance. For instance, Amason and Sapienza (1997) found that larger teams often produced high levels of affective conflict, which has been shown to have negative impacts on group cohesion (Jehn et al. 1997). Similarly, relationship building takes time (Smith et al., 1994), and previous arguments entail that there might be an optimal size of the founding team. So, two opposed theories seem to deal with team size. On one hand, according to *Load Theory* (Chalos and Pickard, 1985) teams have higher decision consistency and are able to process a high information load better than individuals. On the other hand, size has a negative effect on social integration, informal communication, and communication frequency of teams (Amason and Sapienza, 1997; Jehn et al. 1997; Smith et al., 1994).

> *Hypothesis 2.1:* Employee growth in technologically based firms increases with the size of the foundation team and there is an optimal size after which it begins to decrease.

Following the human capital theory (Becker, 1964), the level of expertise and formation has to be translated into greater levels of productivity. Human capital theory has been taken into consideration in order to examine the performance of new ventures. The results indicate that more years of schooling generate greater performance for entrepreneurs (Cooper et al., 1994; Parker and Van Praag, 2006). This premium can be measured following Mincer (1974). The annual rate of return for each year of schooling ranges between 6.1% (Van der Sluis et al., 2004) or 7.2% (Parker and Van Praag, 2006) in the case of new venture entrepreneurs. These results are particularly important for academic entrepreneurs as they have made a large investment in formal education.

> *Hypothesis 2.2:* Employee growth in technologically based firms increases with the level of human capital of the founding team.

Following Ashby's (1956) law of requisite variety or Lazear's (2004, 2005) arguments, complex strategies and multifaceted environments necessitate a cognitive-heterogeneous founding team. In technological spin-offs, basically two kinds of skills seem to be the most relevant: technical and managerial ones. Whereas in a corporate spin-off it is expected that founders will have both kind of skills, in the case of university spin-off founders, the lack of the latter (managerial skills) is more plausible (Bunderson and Sundcliffe, 2002). Therefore, it is expected that the managerial skills of the founding teams of spin-offs, especially university ones, will affect positively their performance.

> *Hypothesis 2.3:* Employee growth in technologically based firms increases with the management experience of the founding team.

3. Threshold of credibility.

The entrepreneurial commitment of the founders is not enough for developing the firm; the participation of other people is also needed who, to a greater or lesser degree, usually provide financial support to the business. In terms of Vohora et al. (2004), the threshold of project credibility is basic for obtaining such participation and, consequently, funds. Financial constraints have been documented extensively as one of the main restrictions for the growth of new firms[24].

In the case of new high-tech firms, financial constraint problems become more serious (Shane, 2004; Wright et al., 2006). In this regard, Macho, Veugelers and Perez (2008) provide a theoretical framework that supports the idea that start-ups have difficulties obtaining venture capital. They state that there exists a moral hazard problem between the venture capitalist and the entrepreneur. These problems appear because venture capitalists have difficulties observing or evaluating the quality and the development of the invention. This moral hazard problem reduces the collaboration between both parties and thereby the investment of venture capitalists in high-tech firms. The figure of the TTO can reduce the problems of information with venture capitalists or established firms (Macho, Veugelers and Perez, 2007); therefore, we expect that university spin-offs have more relationships with venture capitalists than corporate ones do.

> *Hypothesis 3.1:* The presence of venture capitalists is more likely in university spin-offs than in corporate ones.

Furthermore, according to the pecking order hypothesis (Myers and Majluf, 1984; Roberts, 1991; Watson and Wilson, 2002) those entrepreneurs prefer internal financing or even debt rather than venture capitalist financing because they tend to protect their intellectual property avoiding ownership dilution.

[24] Fazzari et al., 1988; Evans and Jovanovic, 1989; Bates, 1990; Cooper et al., 1994, Holtz-Eakin et al., 1994; Cressy, 1996; Taylor, 1996, 2001; Dunn and Holtz-Eakin, 2000, Johansson, 2000; and Parker and Van Praag, 2006.

Hypothesis 3.2: The presence of venture capitalists is more likely in those spin-offs where inventions have greater legal protection.

Moreover, given their limited operating history, start-ups or spin-offs have been identified by Cassar (2004) as the most opaque firms in the economy in terms of information. Berger and Udell (1998) argue that start-ups are heavily dependent on initial insider financing due to their potential difficulties in obtaining intermediate external financing. Thus, a positive correlation between the presence of venture capitalists and firms' leverage ratios is expected.

Hypothesis 3.3: The presence of venture capitalists is more likely in those spin-offs where the leverage ratio is higher.

Thereafter, as external finance is incorporated, spin-off reputation increases and information problems are reduced and the firms have easier access to funds in order to grow.

Hypothesis 3.4: Employee growth in technologically based firms increases with the leverage ratio of those firms.

Governments are interested in stimulating technological entrepreneurship because the costs and risks of introducing one innovation onto the market entail a suboptimal investment in new technologies unless public institutions stimulates it through subventions (Hausmann, Hwang and Rodrik, 2006; Acs and Audrescht, 2005; Audrescht, Aldridge and Oettl, 2006). In this regard, a way of solving financial constraints for new technological firms is to look for public aid (Hall, 2002) or sales contingent claim (SCC) backed finance (Kaivanto and Stoneman, 2007). Consequently, public programs can influence the fact of overcoming financial constraints and invest optimally. Additionally, the institutional support given by universities is given by experienced offices (Technology Transfer Office, TTO); therefore, we expect that a university spin-off, on average, will receive a greater amount of public funds than a corporate spin-off will.

Hypothesis 3.5: Public financial aid is more likely in university spin-offs than in corporate spin-offs.

4. Threshold of sustainability.

Finally, the consecution of sustainable returns, the last phase in Vohora et al. (2004), is given by the specific actions of the firm. In small technological firms, two seems to be the key elements of their business strategy, the human resources and innovation policies. Innovation is a factor that traditionally has been related to firm performance (Naman and Slevin, 1993; Miller, 1983; Zahra and Covin, 1995). Tornhill (2006) states that innovative firms are likely to enjoy revenue growth, irrespective of the industry in which they operate.

Hypothesis 4.1: Employee growth of technologically based firms increases with the level of innovation.

Furthermore, hiring policy also matters in explaining small firm performance and growth (Barney and Wright, 1998; Wright et al., 2001). In fact, employees are a source of strategic value and their development, deployment and organization all contribute to firm performance and sustainability (Wright et al., 1994). Recently, Van den Steen (2005) has pointed out that managers tend to replicate their organizational beliefs and managerial vision in the employees they hire.

Hypothesis 4.2: Entrepreneurs tend to replicate their skills in their hiring policy.

Table 1 summarizes all these theoretical arguments.

[Insert Table 1 about here]

III. METHODOLOGY

In order to test the hypotheses above, the first step is to identify a sample of university spin-offs, in this case those generated in Spain. Between March and April 2006, we contacted the Technological Transfer Office (TTO) of the 58 Spanish Public Universities currently in existence. Thirty-seven of those offices responded to our requirements, an answer rate of 64%. Nine of these TTOs communicated that they do not yet have spin-offs but they are interested in their creation. The rest of the TTOs sent a list with contact information of the spin-offs that was supplemented with information available at different web pages. In this way, we were able to contact electronically with 495 spin-offs from 30 Spanish universities.

The second step was to send a questionnaire (see Appendix A in the previous chapter) to those firms. Between June and September of 2006 the questionnaire was sent to the founders of the university spin-offs using Survey-Monkey[25] services. The questionnaire was previously tested with experts on these topics. The number of questionnaires finally answered was 72[26]. After removing incomplete answers our sample was reduced to 43 firms. On average, each firm has 2.6 founders, so we gathered information on 113 founders. On average, the youngest founders are 34 years old, while the oldest ones are 45. Forty-two percent have had previous experience in the creation of a firm and thirty-seven percent have a PhD. The founding team contributes 90% of the funds required to create the firm. In 46% of the cases, the amount was lower than €5,000. The average age of the firm itself was 5 years. On average, they started with 2.7 employees and currently they have 9.2 employees what produces an average employment growth of 24.5% per year.

In order to compare the development of university spin-offs with respect to other technological spin-offs, we constructed a control sample. The third step was then to look for technological firms created in 1993 or afterwards. A way used by Quintana-García and Benavides-Velasco (2005) for identifying Spanish technological firms is the web of the *Centro para el Desarrollo Tecnológico Industrial* (CDTI) [27]. In this case, the e-mail addresses were not available, so the questionnaire was sent by post[28] between October 2006 and January 2007; twenty-nine answers were obtained. We checked that none of the CDTI firms was a university spin-off. Accordingly, with the information collected by the questionnaire[29], all the other CDTI firms were spin-offs from corporations. After removing incomplete answers our sample was reduced to 28 firms.

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[25] See www.surveymonkey.com for more information.

[26] For a more detailed description of the sample construction and a descriptive statistical analysis of the questionnaire, see Ortín et al. (2007).

[27] It is an Enterprise, dependent Public Organization of the Spanish Ministry of Industry, Tourism and Commerce, that promotes the innovation and the technological development of Spanish companies. It grants financial aid to the company itself and facilitates the access to other sources of finance. For more information, see www.cdti.es

[28] We employed the services of TNS-Demoscopia, a Spanish firm specialized in surveys.

[29] Practically all the founding members have declared that they were working previously in other corporations.

On average, each firm has 3 founders, so we gathered information on 85 founders. On average, the youngest founders are 36 years old, while the oldest ones are 50. While almost all the founders (96%) have had previous experience in the creation of a firm, only twenty-two percent have a PhD. The founding team contributes with 88% of the funds required to create the firm. In 22% of the cases, the amount was lower than €5,000. The average firm age was 6.7 years. On average, they started with 3.1 employees and currently they have 19 employees what produces an average employment growth of 27% per year. So the main differences among university and corporate spin-offs are related to the founders' training; in the first case, they have more formal education and in the second more managerial experience. Furthermore, we have not detected significant biases between the firms' populations, and those firms that answered the questionnaire, at least in those variables available, economic sector and geographic origin.

From the answers given by the final sample composed of 71 firms, we extract information about the dependent variables needed for testing the hypotheses developed above (see Table 1 for a summary): The amount of public consulting advice at the time of founding (Hypothesis 1.1), the parent institution support (Hypothesis 1.2), employee growth (All the Hypotheses 2; 3.4. and 4.1), the presence of venture capitalists (Hypotheses 3.1 to 3.3) or public institutions (Hypothesis 3.5) and the number of employees hired with particular skills (Hypothesis 4.2.). Table 2 shows the descriptive statistics of the variables that are going to be described below.

[Insert Table 2 about here]

Dependent variables

The amount of public consulting advice prior to the firm's creation, *consulting advice*, is measured by the sum of services received[30] (information, Carrying out set-up procedures, training, developing a business plan or use of facilities) from the six public institutions considered (CDTI, RedOTRI, Chamber of Commerce[31], Technological Park, Technological Centre and Regional Organism). Therefore, this index allows having a minimum of 0 public services and a maximum of 30 public services. As seen

[30] Question 11 from the questionnaire.
[31] It is a regional institution that gives support to both new and existing firms.

in Table 2, some of the firms have not received any public service (15) and the highest number of public services received is 13. The average is 2.84 public services per firm.

The institutional support from the parent firm, *parent support*, is graded by the questionnaire respondent in an ordered index that ranges from "1" (the support of the parent institution was inexistent) to "5" (the main parent institution proposes developing the project independently)[32]. This variable has some missing values, so the number of observations is 65. There are 38 firms that consider institutional support as null, and 10 consider the parent institution important or very important. The average is 1.78.

The firm performance is measured by the *growth in number of employees*. The questionnaire provides information about the current number of employees and those who were present when the firm was founded. So the annual growth tax can be computed as [Ln (Current employees – Initial Employees)/Years of the firm].

In regard to the actual financial structure of the spin-offs, the questionnaire collects information about who have been the different providers of funds. It is possible, therefore, to identify for each firm whether it has received *public financial aid* and funds from *venture capitalists*[33]. Thus, we construct a binary variable for each case that takes value "1" when the firm has received that kind of funds and "0" otherwise. In the sample, 17 firms have received public financial aid (24%) and 9 firms financial support from venture capitalists (14%).

The main variable for measuring the technical skills of the employees gathered by the questionnaire is the level of education of the employees hired. In this regard, we work with the number [34] of *employees with a PhD* or other graduate degrees. Thirty-three out of 71 firms have not hired any PhD holders. Moreover, its average is 1.78.

Independent variables

As independent variables, we will use the origin of the firm, a dummy variable *university spin-off* that takes the value one for university spin-offs and zero for corporate ones, and three sets of variables: one describing other characteristics of the

[32] Question 34 from the questionnaire.
[33] Question 41.8 and 8 of the questionnaire respectively.
[34] Question 15.1 of the questionnaire.

firms before the foundation (1), the second describing the characteristics of the founding team (2) and the last set describing the current characteristics of the firm (3).

Other characteristics of the firm at the time of founding it (1) are its size, the economic sector activity and the financial contribution of the founders. The size of the firm is measured by the number of employees at the time of founding, the average of *Initial employees* in the sample is 2.79. The firms have self-classified[35] in five different sectors: Computer Science, Chemical, Pharmaceutics, Biotechnology and Research & Development. As a difference, Computer Science is the sector that accumulates the largest number of firms, 32% of the sample, and the only one that in the tests conducted presents some specifics with respect to the other sectors. Therefore, it is the only economic sector considered in the results presented in the chapter. The dummy variable *computer science* takes the value one if the firm belongs to this economic sector and zero otherwise. The present *leverage ratio* of the firms is measured by the difference between 1 and the present proportion of equity over the total liabilities[36]. Only 65 firms have answered this question. The average of external funds is 47.9%. It is important to note that in 15 firms the equity represents 100% of the total liabilities[37].

The composition of the founding team (2) is characterized by the formation and managerial skills of the members, team size and skills heterogeneity. Given that all the founders have an undergraduate or higher level degree, the *formal education* of the founding team is measured by the percentage of PhDs in the team, which, on average, is 32% of the team members. The *team size* is a variable that was previously used by Eisenhardt and Schoonhoven (1990), and indicates the number of team members; the average in the sample is 2.77. One interesting fact is that around 68% of the university spin-off founders do not have management experience[38] while this percentage is practically nil for the other spin-offs. Hence, heterogeneity in managerial experience only exists for the university spin-offs, and more specifically in 24% of the sample. This percentage corresponds to the university spin-offs in which there are people in the founding team with and without previous managerial experience and identified with the dummy variable U*niversity Spin-off x Heterogeneity*. In that university spin-offs

[35] See question 3 of the questionnaire
[36] See question 8 of the questionnaire.
[37] Most of the analyses have included a dummy variable for these cases, and the results are basically the same. All the tests cited and not reported in the test are available from the author upon request.
[38] Extracted from question 33 of the questionnaire.

represent 60.5% of the sample, in the rest of the university spin-offs all the founders have previous managerial experience, which represents 14% of the sample. They are identified by the dummy variable *university spin-off x managerial experience x homogeneity*) or, in the others, none of the founders have previous managerial experience (22.5%). To avoid multicolineality (60.5=24+14+22.5), we have not introduced a third dummy variable for this last group. In that regard, when the first two variables are used together with the dummy *university spin-off*, this last variable captures the effects of those university spin-offs where none of the founders have previous managerial experience. Take note that, in all the analyses, the reference group is that of corporate spin-offs.

In relation to the current characteristics of the firm (3), information is available about the number of *current employees*, which is, on average, 13.21, and the innovation policy of the firm. The innovation policy is measured by the variable *Licenses*, the sum of licenses, patents, and the firm's own brands. The mean is 1.74 licenses, the maximum 20, and 43 firms (60%) remain without licenses, patents or their own brands. As 20% of the firms do not have a response for the variable of licences, patents and their own brands, and in order to maintain the greatest number of observations as possible, we have considered the number of licences of such firms as zero and created a dummy variable, *Unknown licences*, with a value of one when the firm has not answered the questions about the number of licences, and zero otherwise. The results, when this last variable is omitted, are practically the same, but their statistical significance is lower given the reduction in the number of observations.

IV EMPIRICAL TESTS

The determinants of public consulting advice

The first kind of analysis is going to focus on the determinants of the public *consulting advice* received by technological spin-offs. As defined before, this is a counting variable with values between zero and thirteen. A Poisson regression (Greene; 1993, p. 880) seems the most appropriate methodology for analyzing the variable's determinants. It is of special interest to test whether university spin-offs have benefited more greatly from *consulting advice* than other spin-offs as postulated in Hypothesis 1.1. Table 3 shows the results of this analysis.

[Insert Table 3 about here]

From Model 1, university spin-offs receive more public services than other technological spin-offs, supporting Hypothesis 1.1. at the 1% level of significance. Moreover, computer science and larger spin-offs tend to receive significantly less public consulting advice. This last result could be due to the fact that large firms have less need for this kind of service. Model 2 looks in more detail at such arguments and tests for the existence of differences in public consulting advice depending on the characteristics of the founding team. Consistent with the arguments above, those founding teams with more formal education receive statistically significantly less public consulting advice. The founding team size does not affect the amount of consulting advice received, nor does the kind of the university spin-offs. The null hypothesis that public consulting advice depends on the managerial experience of the university spin-off founding team is rejected at the usual levels of significance. Thus, university spin-offs receive a statistically significant level of more public services than do other spin-offs, in accordance with the estimations of Model 2. They receive an average of 62.57% more public consulting advice than other technological spin-offs.

The parent institution support

The second point of interest is to analyze the determinants of the parent institution support received by the spin-offs. The variable *parent support* is ordered from 1 to 5 in accordance with the level of support received; so, we estimate an ordered probit (see Greene 1993, p. 875 for more details) for analyzing the determinants of the level of support given by the parent institution. It is especially interesting to test whether university spin-offs will receive stronger support from parent institutions, Hypothesis 1.2. Table 4 shows the results of our analysis.

[Insert Table 4 about here]

Model 3 presents evidence that universities offer significantly greater support to their spin-offs than other institutions do, mainly private firms, supporting at the ten percent level Hypothesis 1.2. Furthermore, Model 4 tests for the existence of selective support depending on the characteristics of a firm's founding team. We cannot reject at the usual levels of significance[39] that those characteristics influence the level of parent institution support. The results offer evidence that institutions favour those founding teams with greater probabilities for surviving. On average, more ambitious projects, *number of employees*, and those teams with greater *formal education* receive significantly more support. We cannot reject the hypothesis that a university spin-off in which none of the founding members have managerial experience receives the same support as spin-offs from other institutions (the coefficient 0.212 is statistically insignificant). Hence, differences in support between university and corporate spin-offs are due to the fact that universities make an extra effort to support those spin-offs where (all or at least some of) the founding members have managerial experience[40] practically without distinguishing between them.

The determinants of growth rate of employees

The third block of analysis is focused on the determinants of the annual employee growth rate. As this variable is a continuous one, we run an OLS estimation, the results of which are shown in Table 5. In particular, we are interested in the relationship of the characteristics of the founding team (Hypothesis 2), the firm's leverage ratio (Hypothesis 3.4) and the innovation level (Hypothesis 4.1) with the employee growth rate.

[Insert Table 5 about here]

Model 5 shows that firms that started with a larger number of employees and computer science firms have a growth rate smaller than the rest. To test Hypothesis 2, we include the characteristics of the founding teams in the regression, see Model 6. We cannot reject at the usual levels of significance[41] that those characteristics influence the growth rate of the number of employees. Hypothesis 2.1 suggests a concave relationship between team size and employee growth rate. In Model 7, the quadratic term is insignificant, so our data do not support such a concave relationship. Therefore, according to Model 6, increasing the founding team by one member implies an increment of employee growth rate of 3.5%. Consistent with Hypothesis 2.2, the

[39] LRChi2 (4) = 8.05; Prob>Chi2=0.0897

[40] The sum of the coefficient Spin-off x Heterogeneity and Spin-off (0.576+ 0.212) and the sum of the coefficient Spin-off x Managerial Experience x Homogeneity and Spin-off (0.700 + 0.212) are both statistically significant at ten percent, and its difference is statistically insignificant at the usual levels.

[41] LR Chi2 (7) = 26.51; Prob>Chi2 = 0.0004

performance of the firms analyzed increases with the formal education of the founding team members. In this regard, and according to Model 6, increasing the proportion of PhDs in the founding team by 10% entails an increase of 1.53% of the annual growth rate of number of employees. Model 6 also shows that spin-offs without managerial experience have an annual employee growth rate of 9.69%, which is smaller than corporate spin-offs, although it is statistically significant at just the 18 percent level. What is statistically significant, at the usual levels, is the difference between those university spin-offs in which none of the founders have managerial experience and those in which at least one of the founding team members have such experience. In fact, when some of the founding team members of a university spin-off have managerial experience, the employee growth rate is 13 percent points higher and 16.8 when all the members have managerial experience than when none of the members have managerial experience. Furthermore, in the cases that university spin-off founding teams have managerial experience, they also have greater rates of employee growth than corporate spin-offs, although the differences are not statistically significant. Therefore, these results support Hypothesis 2.3.

Following Hypotheses 3.4 and 4.1, increasing the proportion of external funds and innovation help spin-off growth. Model 6 presents some evidence about these statements. In particular, the results show that an increase of 1% in the leverage ratio implies an increase of 0.095% in the employee growth rate, although it is just statistically significant at 22.3%. Moreover, introducing an extra license entails an increment of 1.5% in employee growth, which is statistically significant at the ten percent level.

The determinants of the presence of venture capital

Venture capital is a binary variable and, therefore, a Probit is an appropriate technique[42] for testing such relations. It is of special interest to test whether university spin-offs have a greater presence of venture capital than corporate ones (Hypothesis 3.1) for the presence of *venture capitalists* when innovations are more protected (Hypothesis 3.2), and when the firms are more leveraged (Hypothesis 3.3). Table 6 shows the results of these analyses.

[42] We have also estimated a logit model. The results are basically the same, although the explanatory power of the model is slightly lower.

[Insert Table 6 about here]

From observing Model 8, we see that university spin-offs have a significantly higher probability of having a relationship with a venture capitalist, thereby supporting Hypothesis 3.2. In Model 9, the characteristics of the founders are included jointly with the degree of licensing and the leverage ratio. It cannot be rejected at the usual levels of significance[43] that those characteristics influence the probability of the presence of venture capitalists. From Model 9, we can observe that the characteristics of a founding team with a negative and statistically significant effect are: the size of the team and its managerial experience. Those university spin-offs without managerial experience are those in which there is a greater probability of venture capitalists being present. In regard to the degree of licensing, we observe that those spin-offs with a higher number of licences have a greater probability of venture capitalists being present. If the number of licenses is positively related with the legal protection capacity of innovations, the result above supports Hypothesis 3.1. Finally, large firms and firms with a high proportion of external funds tend to have higher probabilities that a venture capitalist will be present.

The determinants of public financial aid

Public financial aid is a binary variable and defines whether the firm has received public subventions or not. Therefore, again a Probit is an appropriate technique[44]. Our interest is to test if a university spin-off receives a greater amount of *public financial aid* than a corporate spin-off (Hypothesis 3.5). Table 7 presents the results.

[Insert Table 7 about here]

From observing Model 10, we observe that university spin-offs have a higher probability of receiving public financial aid than corporate ones do, but this difference is not statistically significant. According to Model 11, the probability of receiving public financial aid is related to the managerial experience of the founding team. Those university spin-offs with founding team members without managerial experience have significantly greater probability of receiving public support than corporate spin-offs.

[43] LRChi2 (7) = 23.73; Prob>Chi2=0.0013

[44] We also have estimated a logit model. The results are basically the same, although the explanatory power of the model is slightly lower.

When the university spin-off incorporates some members with managerial experience the spin-off has a greater probability of receiving public financial aid than corporate spin-offs (0.836-0.625) but this difference is not statistically significant. Otherwise, when all the members of the university spin-off team have managerial experience, the spin-off has a lower probability of receiving public financial aid than corporate spin-offs (0.836-1.111), but this difference is not statistically significant. No other effects are statistically significant.

Mimicry in hiring policies

The hiring policy of firms is characterized by the number of *employees with PhDs*. This variable takes value zero in 33 of the cases and in the rest of the cases it takes positive values. As the variable can have a truncated distribution and thus the OLS estimations can be inconsistent, a left censured Tobit[45] is also estimated for analyzing its determinants. It is especially interesting to test whether entrepreneurs tend to replicate their abilities in their hiring policy. As Hypothesis 4.2 postulates, those teams composed mostly of academics will tend to hire employees with a well-developed academic background. Table 8 shows the results of an OLS and the Tobit indicated above. Although some biases have been detected, the main conclusions of both models are the same.

[Insert Table 8 about here]

An increment in the size of the founding team implies a positive and statistically significant increment in the number of employees with PhDs. In particular, from Model 13, on average, when spin-offs hire employees with a PhD they hire 0.7 employees for each extra member in the founding team. The most statistically significant effect is, however, that in relation to the formal education of the founding team. In those firms that have hired employees with PhDs, if the percentage of PhDs in the founding team increases by twenty points, on average, the firm has hired one more PhD. Consequently, in terms of Hypothesis 4.2, we find evidence that entrepreneurs tend to replicate their skills in their hiring policy.

[45] The Tobit model can be considered as a regression model with sample selection and with certain restrictions on the coefficients of the models. We cannot reject the existence of such restrictions at the usual levels of significance (for more details see Greene 1983, p. 915).

V. DISCUSSION

Vohora et al. (2004) have identified the critical junctures in the growth of university spin-offs: opportunity recognition, entrepreneurial commitment, threshold of credibility and sustainability. The theoretical discussion of the chapter emphasizes that the difficulties in overcoming such junctures depends on a spin-off's characteristics, mainly its origin (university or corporate), and founding team characteristics. The empirical evidence supports the main predictions derived from such arguments and confirms that critical junctures are more or less critical depending on a spin-off's characteristics, as we describe below.

The first step is to think seriously about the possibility of becoming an entrepreneur; in the words of Vohora et al. (2004), "Overcome the opportunity recognition juncture". The lack of managerial experience has been recognized as one of the impediments for the creation of university spin-offs. The development of public consulting advice for a firm's establishment can be a way for reducing such limitations, especially in the case of university spin-offs. The evidence presented in the chapter shows that university spin-offs have access to a significantly greater amount of public consulting advice than corporate ones. But, when differences in the founding team are introduced, the level of formal education alone reduces the volume of consulting advice received. The fact that the amount of consulting advice received is independent of the managerial experience of the team seems to postulate that other reasons - besides the lack of managerial experience - could explain the differences in their use by university and corporate spin-offs. As we only have information about public consulting advice, one possible explanation is the preference of university spin-offs for public advice and corporate spin-offs for private advice. Although more information is needed to reject such an explanation, it seems to imply some kind of economic irrationality. A second alternative explanation is due to the TTO experience that allows university spin-offs to have more information than corporate ones and, consequently, more possibilities to get public consulting advice. This fact is related to the parent institution support for the creation of spin-offs. In fact, it is mentioned in the literature as an important factor especially for university spin-offs (O'Shea et al., 2005; Lockett et al., 2005). Consistent with this view is previous evidence suggesting that public institutions give higher support to their spin-offs than private ones do (Gompers et al.; 2005). Although the evidence presented in the chapter confirms higher support from universities, this support is only significantly greater for those university spin-offs where the managerial team has greater managerial experience. This appears to be efficient behaviour on the part of TTOs. Those institutions make an extra effort to differentiate between projects and give more institutional support to those entrepreneurs with higher probabilities of success. In other words, founding teams composed of members with a high level of technical and managerial skills will receive higher support from universities, while the rest receive that similar to other corporations. Obviously, this opens the debate as to whether this extra support is socially efficient, especially taking into account that university spin-offs do not have the significant employee growth that corporate ones do. This result is consistent with George et al. (2002) and Whestead (1997), which did not find significant differences between the performances of those groups. Furthermore, when differences are obtained the results are contradictory. While Colombo and Delmastro (2002) found that university spin-offs have higher performance than corporate spin-offs, Ensley and Hmieleski (2005) found a higher performance for corporate ones.

The analysis of employee growth rate has also helped to test the importance of the founding team's characteristics for overcoming the second critical juncture: entrepreneurial commitment. At this stage, the configuration of the founding team can influence the future success of high-tech firms. Consistent with *Load Theory* (Chalos and Pickard, 1985) and Ensley et al. (2005) evidence the chapter presents shows that bigger founding teams have higher growth rates but we do not find a concave relationship as could be expected by the difficulties of communication (Amason and Sapienza, 1997; Jehn et al. 1997; Smith et al., 1994). The fact that the biggest team has five persons could be a reason for this result, given that the negative effects obtained by the papers mentioned come from teams that range between 5 and 9 members. Additionally, human capital is a variable that has been taken into account to explain new venture performance (Cooper et al., 1994; Delmastro and Grilli, 2004; Parker and Van Praag, 2006). In this regard, well-educated entrepreneurs have a premium. The results obtained are consistent with these sources. We found that high-tech firms with more PhDs in the founding team have higher employee growth rates. Moreover, we find that those university spin-offs in which none of the founders have managerial experience have lower employee growth rates than those in which some of the founders have managerial experience; maximum growth is achieved when all the academic entrepreneurs have managerial skills. It is worth noting that these results are consistent with Bunderson and Sundcliffe (2002) for a general sample of US firms. They postulate that functional diversity has positive effects when the top management members have generalist skills. Overall, these results support the idea that the founding team's characteristics help to overcome entrepreneurial commitment, but also to improve a firm's capacity for growth. It is especially interesting to create founding teams in which individuals are highly qualified and combine managerial experience and technical skills (Rothaermel and Thursby, 2005; Rajah and Tarka, 2005).

This chapter also detects a positive effect of the leverage ratio on the growth capacity of spin-offs, but it is not statistically significant, which suggests that financial restrictions do not seem to be a major problem for growing. Thus, it can be argued that the majority of the firms analyzed have overcome the third critical juncture: the threshold of credibility. Hurst and Lusardi (2004) arrive at a similar conclusion for a general sample of US firms. But, as they argue, it does not mean that this juncture does not exist at all. At this stage, it is necessary for external agents, to a greater or lesser measure, to provide financial support to the venture. The degree of credibility seems then to be related to the presence of venture capitalists. Traditionally, venture capitalists have been considered in charge of providing financial resources (Wright et al., 2006). Although there has been little evidence about the impact of venture capitalists on performance, the empirical evidence available identifies a positive relation between venture capitalist networks and performance[46] (Shane and Stuart, 2002). The presence of those agents in our sample is very small, as only 14% of firms have a relationship with venture capitalists. This result is consistent with the evidence found by Wright et al. (2006). They observe a mismatch between supply and demand. In this regard, venture capitalists prefer to invest in new ventures after the seed stage, whereas spin-offs prefer receiving such funds early on. Another theoretical explanation for the reduced amount of venture capital relations is the so-called equity gap (Lockett et al., 2002). Following the agency theory, in situations of asymmetry of information, agents must make a prior investment for reducing such asymmetry. An institution that can reduce such asymmetries is the TTO (Macho et al., 2007). The evidence presented in this chapter is consistent with this view. University spin-offs have more probabilities of having a relationship with venture capitalists. The evidence also supports the pecking order

[46] Although not shown, in our case the effect on performance is positive but statistically insignificant.

hypothesis (Myers and Majluf, 1984; Roberts, 1991; Watson and Wilson, 2002). The number of licenses is affirmatively related with the presence of venture capitalists, thereby suggesting that those relationships are encouraged when inventions are more legally protected (Shane and Stuart, 2002). Finally, it is also detected that more leveraged firms tend to have more relationships with venture capitalists, which suggests that credibility is easier to obtain when others before has entrusted with the project. Overall, the results support the idea that credibility is easier to obtain when inventions are more difficult to protect and other institutions (TTOs or other financier) have believed in the project.

Finally, we have detected a great access of those university spin-offs with founding teams without managerial experience to public financial aid. We postulate that they are more likely to receive public financial aid than corporate ones due to the presence of TTOs. Landry et al. (2006) analyse 1554 university researchers funded by the Natural Sciences and Engineering Research Council (NSEC) of Canada. They observe that entrepreneurial behaviour increases as the researchers have access to more financial resources from operating grants and university-industry partnership grant programmes, have more intellectual property assets and come from bigger universities. Hence, although better access of university spin-offs to financial public aid has been identified before, the evidence presented suggests that financial public aid goes to university spin-offs with less growth perspectives, perhaps those with lower access to private funds.

After the firm has been created and financial funds obtained, the entrepreneurs can focus on the development of the firm's strategy in order to overcome the last critical juncture: the threshold of sustainability. We have analyzed if hiring policies tend to replicate the characteristics of the founding team, as argued by Van den Steen (2005), or otherwise tend to compensate team limitations over time. The evidence presented supports the first hypothesis: mimicry in hiring policies. Finally, the innovation policy has been analyzed. For each license, on average, the employee growth rate increases by 1.5 percent points. Tornhill (2006), in a US sample of technological firms, discovered that innovation is affirmatively associated with firm performance because it allows a competitive advantage to be maintained (Covin et al., 2000). So, an active innovation policy is compensated with higher growth rates.

VI. IMPLICATIONS AND LIMITATIONS

This chapter is not only of academic interest, it also has important implications for policy makers and entrepreneurs. For policy makers, the evidence suggests that, given the financial aid offered to create companies, financial restrictions are not the major problem for the creation of new technological firms, including university spin-offs. Furthermore, in the case of university spin-offs, researchers' lack of managerial experience seems to be an important limitation for their creation and development. Public consulting advice and the support of TTOs seem to help in such development; however, the evidence presented casts some doubts on the social efficiency of such extra support because the performance of university spin-offs - in terms of employee growth rate - is not significantly greater than corporate spin-offs, which have benefited significantly less from that aid. Policy makers have to make an effort to evaluate and improve such policies.

For entrepreneurs, and in some sense for those that advise them, (for example the TTOs in the case of university spin-offs) the make up of the founding team is an important decision that will affect the success or not of the new venture. To add more people to the venture, especially if they are well trained and can supply different knowledge, has been demonstrated as increasing performance activity in the firms analyzed, especially university spin-offs when they supply managerial experience. In this regard, the mimicry in hiring policies detected in the sample analyzed can be counter-productive. The chapter also shows that the access to new financial resources, especially venture capital, is improved when inventions are legally protected and other individuals have previously financed the firm. Furthermore, the chapter presents evidence that firms with a continual policy of innovation have higher employee growth rate.

Although the theoretical arguments developed in the chapter are not contextually dependent, the empirical evidence is. So, some of the results may not be applied generally to other countries or legal environments. As more evidence is generated in different contexts and data quantity increases, we will have better knowledge of the subject.

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Table 1: Summary of the integrative model

Critical Juncture	Key Factors	Hypotheses
Opportunity Recognition	Initial Support: ✓ Public advice ✓ Parent institution	*H1.1:* The amount of public consulting advice prior to setting up the firm is higher in university spin-offs than in corporate ones *H1.2:* The support of the parent institution is higher in university spin-offs than in corporate ones.
Entrepreneurial Commitment	Characteristics of the founding team: ✓ Size ✓ Formation ✓ Heterogeneity	*H2.1:* Employee growth of technologically based firms increases with the size of the founding team and there is an optimal size after which it begins to decrease. *H2.2:* Employee growth of technologically based firms increases with the level of human capital of the founding team. *H2.3:* Employee growth of university spin-offs increases with the management experience of the founding team.
Threshold of Credibility	Financial access: ✓ External finance ✓ Leverage ✓ Public financing	*H3.1:* The presence of venture capitalists is more likely in university spin-offs rather than in corporate ones. *H3.2:* The presence of venture capitalists is more likely in those spin-offs in which inventions are more legally protected. *H3.3:* The presence of venture capitalists is more likely in those spin-offs in which the leverage ratio is higher. *H3.4:* Employee growth of technologically based firms increases with the leverage ratio of those firms. *H3.5:* Public financial aid is more likely in university spin-offs than in corporate spin-offs.
Threshold of Sustainability	Firm strategy: ✓ Degree of innovation ✓ Hiring policy	*H4.1: Employee growth of technologically based firms increases with the level of innovation.* *H4.2:* Entrepreneurs tend to replicate their managerial skills in their hiring policy.

Table 2: Statistical Descriptive

Questionnaire	Observations	Mean	Standard Deviation	Min.	Max.
Dependent Variables					
Consulting advice	71	2.84	2.53	0	13
Parent institution support	56	1.78	1.30	1	5
Employee growth	71	0.25	0.22	-0.2	1.04
Public financial aid	71	0.24	0.43	0	1
Venture capitalist	64	0.14	0.35	0	1
Employees with PhD	71	1.67	2.65	0	12
Independent Variables					
Initial employees	71	2.79	2.23	1	12
Current employees	71	13.24	15.94	1	77.5
Computer science	71	0.32	0.47	0	1
Leverage ratio	65	0.48	0.331	0	1
Formal education	71	0.31	0.36	0	1
Team Size	71	2.77	1.24	1	5
University spin-off	71	0.605	0.49	0	1
University spin-off x heterogeneity	71	0.24	0.43	0	1
University spin-off x managerial experience x homogeneity	71	0.14	0.35	0	1
University spin-off x non-managerial experience x homogeneity	71	0.225	0.42	0	1
Licenses	71	1.74	3.62	0	20
Unknown licenses	71	0.20	0.40	0	1

Table 3: The determinants of public consulting advice.

Categories	**Variable**	**Model 1 (POISSON)**	**Model 2 (POISSON)**
Origin of the firm	*University spin-off*	0.499***	0.486**
Characteristics of the firm	*Number of employees*	-0.096**	-0.114***
	Computer science	-0.466***	-0.462***
Characteristics of the founding team	*Formal education*		-0.455**
	Team size		0.0109
	University spin-off x heterogeneity		0.054
	University spin-off x managerial experience x homogeneity		0.255
Constant	*Constant*	1.094***	1.196***
Pseudo-R^2		0,0752	0.0937
Log-likelihood		-156.255	-153.126
Number of observations		71	71

Level of Statistical significance: *** 1%, ** 5%, * 10%.

Table 4: The parent institution support

Categories	Variable	Model 3 (OPROBIT)	Model 4 (OPROBIT)
Origin of the firm	*University spin-off*	0.663*	0.212
Characteristics of the firm	*Number of employees*	0.102	0.169*
	Computer science	0.179	0.252
Characteristics of the founding team	*Formal education*		1.067*
	Team size		0.186
	University spin-off x heterogeneity		0.576
	University spin-off x managerial experience x homogeneity		0.700
Pseudo- R^2		0,0414	0.1098
Log_likelihood		-56.489	-52.463
Number of observations		56	56
Cut 1		1.23	2.28
Cut 2		1.51	2.59
Cut 3		1.71	2.82
Cut 4		2.47	3.72

Level of Statistical significance: *** 1%, ** 5%, * 10%

Table 5: The determinants of employee growth rate

Categories	Variable	Model 5 (OLS)	Model 6 (OLS)	Model 7 (OLS)
Origin of the firm	*University spin-off*	-0.009	-0.096	-0.086
Characteristics of the firm	*Number of employees*	-0.034**	-0.035***	-0.036***
	Computer science	-0.099*	-0.083*	-0.091*
Characteristics of the founding team	*Formal education*		0.153**	0.153**
	Team size		0.035*	-0.027
	Team size squared			0.0104
	University spin-off x heterogeneity		0.130*	0.124*
	University spin-off x managerial experience x homogeneity		0.168**	0.164**
Degree of licenses	*Licenses*		0.015*	0.016*
	Unknown licenses		0.072	0.081
Leverage ratio	*Leverage ratio*		0.095	0.107
Constant	*Constant*	0.370***	0.142	0.212
R^2		0.1490	0.4340	0.4377
Number of observations		65	65	65

Level of Statistical significance: *** 1%, ** 5%, * 10%

Table 6: The determinants of the presence of venture capitalists

Categories	Variable	Model 8 (PROBIT)	Model 9 (PROBIT)
Origin of the firm	*University spin-off*	0.984**	5.537***
Characteristics of the firm	*Number of employees*	0.109	0.469**
	Computer science	-0.473	-1.198
Characteristics of the founding team	*Formal education*		0.39
	Team size		-2.57**
	University spin-off x heterogeneity		-3.803**
	University spin-off x managerial experience x homogeneity		-4.696**
Degree of licenses	*Licenses*		0.363**
	Unknown licenses		1.04
Leverage ratio	*Leverage ratio*		4.99**
Constant	*Constant*	-1.977***	-2.42
Pseudo-R^2		0.1153	0.5718
Log-likelihood		-22.993	-11.129
Number of observations		64	64

Level of Statistical significance: *** 1%, ** 5%, * 10%

Table 7: The determinants of public financial aid

Categories	Variable	Model 10 (PROBIT)	Model 11 (PROBIT)
Origin of the firm	*University spin-off*	0.307	0.836*
Characteristics of the firm	*Number of employees*	-0.053	-0.039
	Computer science	0.044	-0.066
Characteristics of the founding team	*Formal education*		0.113
	Team size		0.182
	University spin-off x heterogeneity		-0.625
	University spin-off x managerial experience x homogeneity		-1.111*
Constant	*Constant*	-0.776**	-1.391**
Pseudo-R^2		0.0178	0.0882
Log-likelihood		-38.386	-35.63
Number of observations		71	71

Level of Statistical significance: *** 1%, ** 5%, * 10%

Table 8: Mimicry in hiring policies

Categories	Variable	Model 12 (OLS)	Model 13 (TOBIT)
Origin of the firm	*University spin-off*	0.752	0.892
Characteristics of the firm	*Number of current employees*	0.027	0.045
	Computer science	-0.569	-0.804
Characteristics of the founding team	*Formal education*	3.569***	5.516***
	Team size	0.403*	0.706**
	University spin-off x heterogeneity	-0.979	-0.698
	University spin-off x managerial experience x homogeneity	-1.320	-0.650
Constant	*Constant*	-0.788	-4.022***
Sigma	*Sigma*		3.097***
R^2		0.3937	
Pseudo-R^2			0.1220
Log-likelihood			-115.844
Number of observations		71	71

Level of Statistical significance: *** 1%, ** 5%, * 10%

CHAPTER 4:

Do Academic Entrepreneurs Learn Faster than non Academics?

Index

I. INTRODUCTION

Research-based university spin-offs have become an important issue within the university technology transfer process (Di Gregorio and Shane, 2003; Wright et al., 2004a) and 2004b). The existing literature cites many reasons for studying university spin-offs in depth, including the following: (i) University spin-offs encourage economic development and stimulate the generation of local clusters (Lowe, 2002; Shane, 2004); (ii) They generate significant economic value and create jobs (Cohen, 2000); (iii) They facilitate the marketing of university technologies, especially those whose prospects may be uncertain (Thursby et al., 2001); (iv) Some university spin-offs are very successful, hence they usually have a significant growth rate and, in some cases, may issue an initial public offering (IPO) (Shane, 2004; Clarysse et al., 2005; Smith and Ho, 2006); and finally (v) They are an effective vehicle for encouraging investor involvement (Lowe, 2002; Jensen and Thursby, 2001).

Some authors (Siegel, Waldman and Link, 2003; Ndonzuau, Pirnay and Surlemont, 2002) stress that the founders' academic background might complicate the creation of university spin-offs and consequently jeopardize the aforementioned economic benefits. The available empirical evidence (Shane and Khurana, 2003; Colombo and Delmastro, 2002; Ensley and Hmielski, 2005) suggests that academic entrepreneurs have less extensive managerial skills, more extensive formal education and usually come from a more bureaucratic environment. Moreover, Shane (2004, p. 273) predicts that a lack of managerial skills may adversely affect performance and hence the growth rates of these firms. Even though there is little evidence thereof, some empirical studies (Chrisman et al., 1995; Ensley and Hmieleski, 2005) have reported lower performance among university spin-offs than among independent start-ups.

On the other hand, the organizational learning literature (Levitt and March, 1988; Argyris, 1990; March, 1991) suggests that the scientific method is the most appropriate learning method, even in entrepreneurial contexts. Consequently, one would expect that academic entrepreneurs' higher levels of formal education and more extensive scientific experience would enable them to learn faster than other entrepreneurs; consequently, any initial disadvantages should disappear over time.

As Mustar et al. (2006, p. 304) point out, previous studies that focused on university spin-offs did not use longitudinal data; these authors stress that longitudinal data analysis will provide a better understanding about how university spin-offs evolve. With a view to bridging this gap and testing whether academic entrepreneurs have an initial disadvantage that decreases over time, we compiled a secondary unbalanced data panel of 104 Spanish university spin-offs and a control sample of 73 Spanish independent start-ups using available financial data from 1994 to 2005.

The advantages of such an approach are numerous. First, to the best of our knowledge, we can provide primary evidence that academic entrepreneurs are less productive than independent entrepreneurs. The performance of university spin-offs and independent start-ups has been compared in terms of differences in total sales (Ensley and Hmielski, 2005), which is the most widely used measure of small firms' performance (Delmar, 1997; Weinzimmer et al., 1998). Following Mahadevan (2002), the available data enabled us to break down differences in total sales into those produced by differences in the level of contractual inputs or by differences in total factor productivity (TFP), i.e., how efficiently all inputs were used (Lieberman and Dhawan, 2005).

Second, and perhaps more important, the available data enabled us to test whether academic entrepreneurs (who are more familiar with the scientific method) can increase the productivity of the inputs used (Total Factor Productivity) more quickly than other entrepreneurs can over time. As far as we know, in a managerial context this is the most direct test available of the idea that the scientific method (Argyris, 1990) is the most appropriate learning method. The little empirical literature on the subject of organizational learning has been focused on analysing whether organizational characteristics such as size (Almeida et al., 2003), human resources techniques (Lee et al., 2000; Arthur and Aiman-Smith, 2001) or entry delays in a given sector (Mathews, 1999) affect the organizational learning process.

In the next section of this chapter, we will build on these theoretical arguments. We will then present the data construction process, together with the empirical tests and their robustness checks. Finally, we will discuss our findings and their implications and summarize the conclusions.

II. THEORETICAL FRAMEWORK

According to the upper echelons theory (Hambrick and Masson, 1984), firms are a reflection of their senior management teams. Indeed, there is extensive literature focusing on the characteristics of senior management teams and their impact on firm performance.[47] In that regard, Bunderson and Sutcliffe (2002) and Lazear (2004, 2005) stress the importance of having managers with general rather than specialized skills. In situations where certain team members lack managerial skills, they must acquire them if they wish to adapt to the industry and thus increase their performance (Van der Vegt and Bunderson, 2005).

There is evidence that academic entrepreneurs often lack managerial skills. For example, Shane and Khurana (2003) show that in 1,397 MIT-assigned inventions between 1980 and 1996, only 21% of the research teams had at least one founder with previous industry experience. Colombo and Delmastro (2002) present evidence that the founders of start-ups created in Italian science parks have higher levels of formal education (as measured by the proportion of founders with PhDs). Ensley and Hmielski (2005) present evidence from the US indicating that university-based teams that found spin-offs tend to be more homogenous and have less well-developed dynamics (shared strategic cognition, potency, cohesion and conflict) than those of independent technology start-ups. The existing evidence suggests that there are significant differences in managerial and industry knowledge among founders of university spin-offs and independent start-ups.

A lack of managerial skills may directly influence the behaviour of academic entrepreneurs (Landry et al., 2006) and thus the performance of university spin-offs (Roberts, 1991; Vohora et al., 2004; Shane, 2004). Furthermore, previous empirical studies have found a negative correlation between a lack of managerial skills and firm performance as measured by number of employees (Chrisman et al., 1995) or net cash flow and revenue growth (Ensley and Hmieleski, 2005). One concern with revenue growth is that sales levels can be increased merely by purchasing more inputs and consequently increasing expenditures, or improving the productivity of inputs what is free of monetary costs. To test the lack of managerial skills hypothesis, we will need to

[47] See Bunderson and Sutcliffe (2002) for discussion of this issue.

provide evidence of differences in productivity between university spin-offs and independent start-ups.

On the other hand, the organizational learning literature also suggests that academic entrepreneurs are fast learners. Levitt and March (1988, p.335) posit that "[Learning] does not always lead to intelligent behaviour. The same processes that yield experiential wisdom produce superstitious learning, competency traps and erroneous inferences. Problems in learning from experience stem partly from inadequacies of human cognitive habits, partly from features of organizations, partly from characteristics of the structure of experience. There are strategies for ameliorating some of those problems, but ordinary organizational practices do not always generate behaviour that conforms to such strategies." This view is consistent with the existing X inefficiency theory (Leibenstein, 1966). X inefficiency is defined as the failure of a productive unit to fully utilize the resources at its disposal and thus to attain its efficiency frontier, i.e., the maximum level of output possible with existing resources and under prevailing conditions.

Argyris (1990) defines two different modes of behaviour, referred to as Model I and Model II. Model I behaviour perpetuates X inefficiency while Model II behaviour reduces it. Individuals displaying Model I behaviour seek to gain unilateral control, to win and not to upset people. Under Model I, the recommended action strategies are primarily selling and persuading and, if necessary, saving face, both for oneself and for others. In contrast, Model II behaviour reduces X-inefficiency over time; it applies the same approach to organizational learning that scholars use in the scientific method, i.e., framing hypotheses in a manner that enables them to be disproved. Leibenstein and Maital (1994) formalized these arguments using a game theory approach.

The empirical evidence supporting the organizational learning theory is scarce. For example, Almeida et al. (2003) analyzed external learning (measured through patent citations) and found that it increases with start-up size; while this positive effect remains constant in situations involving alliance agreements, it is reduced in situations involving informal mechanisms of mobility and geographic co-location. Arthur and Aiman-Smith (2001) found a positive relation between internal learning (as measured through employee suggestions) and the introduction of employee profit-sharing plans. Lee et al. (2000) found that reduced load work is beneficial to organizational learning, as measured through changes in management attitudes. Mathews (1999) conducted a case study and found that latecomers to the Korean semiconductor industry have a greater facility for acquiring knowledge; in other words, they are fast learners.

Although there is some empirical literature on the subject of organizational learning, we are unaware of the existence of a direct test of the learning-related advantages of the scientific method (Argyris, 1990) in entrepreneurial contexts. Academic entrepreneurs have more extensive scientific experience and less extensive managerial skills. Although university spin-offs may be less efficient than independent start-ups at the outset, based on Argyris's findings, one would expect that the academic background of university spin-off founders would enable them to learn more quickly; consequently, any differences in efficiency would tend to disappear over time. In the following section, we describe how this hypothesis will be tested.

Formal testing

Firms can increase output by increasing the quantity of inputs or by increasing the amount of productive (or managerial) knowledge; this happens as the firm learns from experience and from experimentation (research and development). Often, increases in productive knowledge are not observed (especially if such knowledge is tacit and stems from experience and new production or organizational methods). Following Solow (1958), we assume that the production function of firm *i* in its year *y* of operations can be expressed as follows:

$$Q_{iy}= A_{iy} f\,(X_{1iy},\ldots,X_{jiy},\ \ldots\ X_{Jiy}) \qquad (1)$$

This function provides the maximum level of output Q that can be achieved with the quantity X_j of input j, $(j=1,\ldots,J)$. The parameter A_{iy} captures differences in total factor productivity (TFP) among firms and over time (output growth not explained by input growth), which is usually interpreted in the existing literature (Aigner et al., 1977; Meeusen et al., 1977) as one measure of the differences in the level of productive knowledge among firms and over time.

The abovementioned theoretical arguments assert that the level of productive or managerial knowledge is lower for university spin-offs at the outset of operations, although these differences fade over time. To test this hypothesis, we postulate that the

TFP of the firm *i* at year *y* can be written as $A_{iy} = e^{a+\lambda_1 USO_i + \lambda_2 y + \lambda_3 USO_i y}$ where *a* is a constant and *USO* has one of two values (1 for university spin-offs and 0 otherwise). Based on these theoretical arguments, we would thus expect the following:

i) In recently created firms ($y = 0$), the TFP of university spin-offs ($USO_i = 1$) would be lower than in corporate contexts ($USO_i = 0$); in other words, $\lambda_1 < 0$.

ii) Over time, managers can improve their knowledge and thus increase their firm's TFP ($\lambda_2 > 0$). Furthermore, managers of university spin-offs would be expected to learn faster than their non-academic counterparts, so the increase in their TFP would be greater ($\lambda_3 > 0$).

III. DATA

Data construction

To test whether the level of managerial learning in university spin-offs is higher than in non-academic start-ups, we constructed a longitudinal design database (Davidsson, Achtenhagen and Naldi, 2005) of new high-technology firms (Stiroh, 2003), including university spin-offs and a comparison sample of independent start-ups. Based on these data requirements, we constructed a secondary unbalanced data panel of 177 Spanish high-technology firms using financial data from 1994 to 2005 obtained from SABI (a database containing financial information on Spanish firms[48]). Subsequently, a dynamic analysis of the learning process was carried out.

To identify the spin-offs created in Spain, we contacted the Technology Transfer Offices (TTOs) of all 58 Spanish public universities in March and April 2006. We obtained information from 37 of these TTOs, for a response rate of 64%. Nine TTOs informed us that they had no spin-offs but were interested in creating them. The rest of the TTOs sent us lists of contact information for their spin-offs; this was complemented by information available on various other websites.[49] The existing literature contains various definitions of university spin-offs, ranging from more restrictive (Shane, 2004) to less restrictive (Roberts, 1991). Shane (2004) defines a university spin-off as a new

[48] More information can be found on Bureau Van Dijk's website (http://sabi.bvdep.com).
[49] http://pinnova.upc.es/ and http://ideas.upv.es/

company founded to exploit a piece of intellectual property created in an academic institution. Roberts (1991) maintains that any firm founded by anyone that worked or studied at a university is a university spin-off. Based on the TTOs' responses, Roberts's definition was determined to be the most widely used criterion by Spanish universities for identifying spin-offs.

We thus compiled a list of 496 spin-offs from 30 Spanish universities. We searched SABI for spin-offs and found 104 firms; all of these spin-offs were created in 1993 or later. We subsequently constructed an unbalanced data panel for the 1994-2005 period using financial information obtained from SABI. In specific terms, we obtained detailed data on the firms' balance sheets and income statements.

Our research model required a comparison sample of new independent high-technology start-ups as similar as possible to the university spin-off sample. Using the method described by Quintana-García and Benavides-Velasco (2005), we identified Spanish technology firms that received support for innovation and technology development activities from the Centro para el Desarrollo Tecnológico Industrial (CDTI).[50] In this way, we identified 167 technology firms created after 1993 outside of the university context; the geographic and economic-sector distributions of these firms were similar to those of the university spin-offs. As with the university spin-offs, we searched SABI for information on these non-university firms and compiled financial information for 73 technology firms for the 1994-2005 period.

In summary, we constructed an unbalanced data panel containing financial information on 177 technology firms obtained from SABI for twelve different years (104 of these firms were university spin-offs). The university spin-offs had a total of 347 observations (3.33 observations per firm per year) and the independent start-ups had 333 observations (4.56 observations per firm per year).

Definitions of variables

Since the data panel was unbalanced, we created a variable to calculate the operating period of the firm (*y*), thereby allowing us to better approximate the time trend.

[50]CDTI, an agency of the Spanish Ministry of Industry, Tourism and Commerce, promotes innovation and technology development among Spanish companies. It also provides firms with financial aid and facilitates access to other funding sources. For further information, see www.cdti.es.

Moreover, the quantitative variables were constructed using the balance sheet and income statement information obtained from SABI. We actually used accounting data (monetary values) for economic purposes (physical units); to avoid bias, it was necessary to deflate the monetary variables using accurate deflator price indexes (Salas, 1991). Production is measured by:

Net Sales (Q): Total sales as reported on SABI, deflated by two-digit industry level deflators (Wakelin, 2001; Brynjolfsson and Hitt, 2003) (1994 € equivalent). The sectors included computer science, R&D, engineering, chemicals, biotechnology and telecommunications.[51] The deflator indexes were constructed using information obtained from the INE (Spanish Statistics Institute).[52]

We used the following as production function inputs:

Fixed Assets (*KF*): This variable was computed using the book value of total fixed assets in SABI. Consistent with Wakelin (2001), it was deflated based on the capital investment price index (INE) (1994 € equivalent). It should be noted that this figure had to be deflated using the price index for the year of acquisition (Hall, 1990; Hernando and Nuñez, 2004), where the year of acquisition equals the current year (*t*) minus the age of the fixed assets (*Age*). To estimate the age, we divided accumulated amortization by current amortization. Using the method first proposed by Hall (1990), we then divided the book value of the total fixed assets (KF_{BV}) by the price on the date of acquisition ($KF = KF_{BV}/[Price\ index\ (t\text{-}Age)]$).

Intermediate inputs (*KC*): This variable was calculated based on the consumption of intermediate goods. Following Hernando and Nuñez (2004, p. 342), it was deflated to 1994 € equivalents using the industrial intermediate goods price index (IPRI from INE)

Labour expenses (*LE*): This variable was obtained directly from SABI and was deflated to 1994 € equivalents using the INE's labour cost index (harmonized and corrected).

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[51] The general price index was used for other sectors.

[52] INE (www.ine.es) only provides data on the gross and net aggregate values for each sector. The increase in the gross aggregate value may be expressed as $\Delta GAV = \Delta NAV + \Delta P + \Delta NAV * \Delta P$, where ΔNAV is the increase in the net aggregate value; ΔP is the increase in prices, which may be expressed as $\Delta P = (\Delta GAV - \Delta NAV)/(1 + \Delta NAV)$.

In the estimates, we also used a dummy variable representing university spin-offs *(USO)*. Table 1 shows the descriptive statistics for the variables presented for the first year in which the firms operated; it also differentiates between groups (university spin-offs and other technology firms). Although the initial project size was very small for both samples (only four employees on average), it should be noted that the non-university technology firms were somewhat larger at the outset. While the value of fixed assets for the university spin-offs was 50% of that for other technology firms (€50,000 as against €100,000), the intermediate inputs consumed were quite similar for both sample groups (approximately €40,000 in both cases). Moreover, the university spin-offs had lower labour costs (€49,000) than did the other technology firms (€83,000). These contractual inputs generated total sales of approximately €135,000 in the case of the university spin-offs and €200,000 in the case of their non-university counterparts.

As regards geographical distribution, the university spin-offs tended to be created in Catalonia and Valencia (47.1 + 30.8 = 72.5%), while the rest of the firms were under-represented in those regions (19.3 + 6.8 = 26.1%). This is because most of the university spin-offs came from two polytechnic universities located in those regions, UPC and UPV.[53] As in other similar studies (Gompers, 2005), the most common economic sector was computer science (40.7%), followed by R&D (13.6%), engineering (13%), chemicals (5.6%), biotechnology (5.1%), telecommunications (3.5%) and other sectors (18.6%). The relative proportion of the various sectors is quite similar among university spin-offs and independent start-ups.

[Insert Table 1 here]

For research purposes, it is important for the specific university spin-off features to pertain mainly to the academic background of their founders. In this regard, it is instructive to check whether there are significant differences in the relevant variables between the university spin-offs and the control sample. In this regard, we ran a LOGIT analysis where the dependent variable was the fact of being a university spin-off and the independent variables measured when the firms were founded. Table 2 shows the results

[53] Ortin et al. (2008) point out that the Universitat Politècnica de Catalunya (UPC) accounts for 129 university spin-offs and the Universitat Politècnica de Valencia (UPV) accounts for 166 university spin-offs. Consequently, they account for 295 of the 496 spin-offs created by Spanish TTOs prior to 2006 (59.5%).

of this analysis. Only the two regional variables previously mentioned (Catalonia and Valencia) were statistically significant.

[Insert Table 2 here]

IV. RESULTS

Initially and for estimation purposes, we assumed that the production function (1) would conform to a Cobb-Douglas production function (1928):

$$Q_{iy}= A_{iy} f\,(X_{1iy} ,\ldots,X_{jiy}, \ldots X_{Jiy}) = A_{iy}\prod_{j=1}^{J} X_{jiy}^{\;\beta_j} = e^{a+\lambda_1 USO_i+\lambda_2 y+\lambda_3 USO_i y}\prod_{j=1}^{J} X_{jiy}^{\;\beta_j} \qquad (2)$$

where β_j is the elasticity of production with respect to the input j.

The empirical approach to Equation (2) is to estimate the production function parameters using the following equation:

$$Ln\,Q_{it} = \alpha_i FIRM_i + \lambda_1 USO_i + \lambda_2 y_{it} + \lambda_3 USO_i y_{it} + \beta_1 LnKF_{it} + \beta_2 LnKC_{it} + \beta_3 LnLE_{it} + \varepsilon_{it} \, (3)$$

where t is the year of the observation, beginning in 1994 (t = 1) and ending in 2005 (t = 12). The variables $FIRM_i$ are dummies identifying each firm;[54] ε_{it} is a set of independent random variables following a normal distribution with a mean of zero and equal variance.

If we strictly compare Equation (2) and (3), the error term is expressed as ε_{it} = $\sum_{j=4}^{J}\beta_j Ln(X_{jit} / \overline{X_{ji}})$, where $Ln\overline{X_{ji}}$ = $\sum_{t=1}^{12} LnX_{jit} / 12$. Therefore, the assumption of independence and equal variance between the error terms will not hold if some firms systematically use unobserved inputs in excess of the average during certain periods. This may lead to potential misspecifications of coefficient values (Huber, 1967; White, 1982). To avoid such misspecifications, the coefficients presented in Table 3 are the Huber-White estimators.

Model 1 presents the results of estimating Equation (3). The parameter λ_1 is estimated at minus 0.175 and is statistically significant at 1%. Consequently, among recently created

[54] The possibility that the fixed-effects estimator may outperform the random-effects generator can be determined using the Hausman (1978) specification test. The Hausman test statistic for our model was 18.20 (p = 0.0027) with five degrees of freedom. Consequently, the fixed-effects specification outperformed the random-effects model.

firms, the university spin-offs will be 17.5% less productive than their non-university counterparts. In addition, Model 1 also provides the TFP growth of academic entrepreneurs ($\lambda_2 + \lambda_3 = 0.069$, statistically significant at 1%) and independent entrepreneurs ($\lambda_2 = -0.019$, statistically insignificant). The difference in growth λ_3 is estimated at 0.088, which is statistically significant at 1%. Therefore, university spin-offs increase their knowledge base at an annual rate of 6.9%. Based on these results, academic entrepreneurs need almost two years to reach the independent entrepreneurs' TFP level [$(-\lambda_1)/\lambda_3 = 0.175 / 0.088 = 1.98$ years].

It should be noted that previous studies using representative sample populations of Spanish manufacturing firms presented TFP growth estimates in line with the estimate for independent technology start-ups in our sample. Using a similar methodology, Mas-Ivars and Quesada-Ibañez (2006) estimated that TFP was -0.0171 for the 1995-2004 period. In addition, Fariñas and Martín-Marcos (2007) calculated a slightly higher TFP growth estimate (ranging from -0.01 to 0.02) for the 1990-1999 period. Therefore, the TFP growth rate of university spin-offs is higher than that of the other firms.

[Insert Table 3 here]

Model 1 in Table 3 was also used to estimate the elasticity of each of the various inputs with respect to output. The estimated elasticity of production with respect to fixed capital (β_1) is 0.0679. It should be noted that this value is not statistically significant; this production factor can thus be considered basically fixed over time. In addition, the estimated elasticity of production with respect to intermediate inputs (β_2) is 0.238 and is statistically significant at 1%. Increases of 1% in the intermediate inputs would be accompanied by an increase of 0.238% in production. Moreover, the estimated elasticity of production with respect to labour expenses (β_3) is 0.679 and is statistically significant at 1%. Increases of 1% in labour expenses would be accompanied by an increase of 0.679% in production. In this regard, based on these estimates and assuming the same quality of human capital, the technology also reports constant returns to scale. Therefore, the null hypothesis of constant return to scale with respect to inputs cannot be rejected ($\beta_1+\beta_2+\beta_3 = 1$).[55]

[55] Test for $\beta_1 + \beta_2 + \beta_3 = 1$: $F(1, 498) = 0.12$; $Prob > F = 0.7260$.

For comparative purposes, Fariñas and Martín-Marcos (2007) estimated an elasticity of production for fixed assets, intermediate inputs and labour of approximately 0.036, 0.58 and 0.23 respectively. Therefore, in technology firms, production is more sensitive to the labour factor than it is in more traditional firms. While Fariñas and Martín-Marcos (2007) did not find constant returns, Sanchez-Mangas (2007) found constant returns for a representative set of Spanish manufacturing firms for the 1990-2002 period. Unfortunately, Sanchez-Mangas did not specify the estimated production elasticity values.

It is also instructive to examine the factors contributing to annual sales growth for the university spin-offs and to compare them with the factors for the independent corporate start-ups. Based on Model 3 of Table 3, the average annual sales growth for all firms was 27% (λ_2 = 0.272). Based on Model 2 of Table 3, we can assume that the annual growth rate for university spin-offs (28.4%) (0.284 = $\lambda_2 + \lambda_3$) is virtually the same as that for other technology firms (26.7%) (0.267 = λ_2). In other words, the difference (λ_3 = 0.017) is not statistically significant.

Following Mahadevan (2002), annual production growth can be broken down into growth caused by increases in TFP and growth caused by increases in each input:

$$Ln(Q_{iy} / Q_{iy-1}) = \lambda_2 + \lambda_3 i + \sum_{j=1}^{J} \beta_j * Ln(X_{jiy} / X_{jiy-1})$$

Figure 1 summarizes this breakdown, taking into account the average annual growth of inputs for each type of firm (university spin-offs and independent start-ups).

[Insert Figure 1 here]

From Figure 1, we can see that in the comparison sample, annual production growth is entirely attributable to increases in inputs; in the case of university spin-offs, increases in inputs account for 75% of total growth (≈21.5/28.40), while the remaining 25% (≈6.9/28.4) stems from improvements in TFP. In both cases, the inputs that contributed significantly to total growth were increases in labour expenses, which were five points higher in the independent start-ups (18.5%) than in the university spin-offs (13.5%). In both types of firms, the contribution of increases in labour expenses was more than twice that of increases in intermediate inputs (5.73% in the case of university spin-offs) while the increase in intermediate inputs represents more than twice that of increases in fixed capital (2.29% in the case of university spin-offs). In summary, the university spin-offs and the independent start-ups in our sample had virtually the same rate of annual sales growth. However, in the university spin-offs, part of this increase was due to TFP improvements, while independent start-ups showed larger increases in labour expenses.

V. RESULT ROBUSTNESS

In this section we would like to check the robustness of the results related with the Total Factor Productivity presented in the section above. Our first concern relates to interpreting the results in terms of learning. In other words, the entrepreneurs had to remain with the firm during the period in question and thus there was no participation of external entrepreneurs in the firm or "surrogate entrepreneurs", to use the terminology of Franklin et al. (2001). Previous evidence for Spain suggests that this is the case: Ortín et al. (2007) analyzed 48 Spanish spin-offs in operation for an average of 3.8 years; in 86% of cases, the initial promoters were still the senior managers of the firm. To confirm this result, we contacted INFORMA,[56] which provided us with data on management appointments and resignations during the 2000-2005 period for the firms analyzed (information prior to 2000 were unavailable). Table 4 shows that only 11.5% of the spin-offs had changes in the management team (half of them have had appointments and resignations while the rest only appointments); those firms started out with an average of 2.83 individuals on their management teams (on average, the number of management team members for the rest of the spin-offs, the ones in which the management team remain unchanged, was 2.0) and moves up to an average of 5.33 members at their last period observed.

[Insert Table 4 here]

Column 1 of Table 5 presents the estimate from Equation (3) with respect to differences in initial TFP and in TFP growth among university spin-offs that underwent management team changes (*USO*CHANGES*) and the rest of population. It appears that this group of firms largely accounts for the initial productivity differences between university spin-offs and their non-university counterparts. We cannot reject the

[56] For further information, see http://www.informa.es.

hypothesis that university spin-offs without management team changes have the same productivity as other technology firms, while the productivity level of university spin-offs with management team changes is lower than in independent start-ups; this figure is statistically significant. These results are consistent with the hypothesis that the university spin-offs with the lowest productivity levels seek external support. However, the results do not support the hypothesis that such spin-offs learn more quickly than those without external management partners, even though the results contradict this. The annual TFP growth rate for university spin-offs with unchanged management teams was 8.5% (-0.021 + 0.0106), while the remaining spin-offs had a statistically significant lower TFP growth rate of -1.2% (0.085 - 0.097). In conclusion, we find no evidence that the higher TFP increase among university spin-offs is caused by the inclusion of external management partners.

[Insert Table 5 here]

Our second concern relates to the specific value of the TFP, A_{iy}. The estimated specific value in the above section assumes that the TFP of university spin-offs increases constantly over time, $\lambda_3 > 0$; therefore, at a certain point (λ_1/λ_3), the TFP of university spin-offs will be greater than that of their non-university counterparts. It would be instructive to verify whether university spin-offs are actually more productive. In other words, to test whether TFP differences decrease over time, the previous expression of A_{iy} must be modified:

$$A_{iy} = e^{a+\lambda_1 USO_i + \lambda_2 y + \lambda_3 USO_i y + \lambda_4 y^2 + \lambda_5 USO_i y^2}$$

The results of estimating Equation (3), taking into account the new expression of TFP, are shown in Column 2 of Table 5.

The increase in the explanatory power (R^2) of the model with respect to Equation (3) (Model 1, Table 3) is nearly zero and thus is not statistically significant; therefore, we cannot discard the possibility that the new parameters (λ_4 and λ_5) may equal 0. Even if this set of variables adds no information, the estimated coefficients apparently indicate that while initial productivity is lower for university spin-offs (λ_1 = -0.0169), their production capacity improves over time ($\lambda_3 + 2\ \lambda_5 = 0.081 + 0.0046\ y$). Therefore, we find no evidence that the knowledge generation advantage of university spin-offs begins to decline at some point.

Our third concern relates to the form of the estimated production function $f\,(X_{1iy}, \ldots, X_{jiy}, \ldots X_{Jiy})$ and its possible influence on the results. Cobb-Douglas (1928) production functions are among the most widely used in the existing literature. In addition, Brynjolfsson and Hitt (1995) postulate that the Cobb-Douglas function is the simplest way to calculate the relevant amounts without introducing an excessive number of terms that might lead to inaccurate estimates. Furthermore, Tybout (1990) explains that the Cobb-Douglas functional form allows maximum flexibility in dealing with secondary data. If we set aside these considerations, the estimates may be contingent on the functional form used in Equation (2). Therefore, we i) introduced physical inputs whenever possible (e.g., labour); ii) allowed differences in the elasticity of production with respect to the different inputs; and iii) used different production function specifications. The results of these robustness checks are shown in Table 6.

[Insert Table 6 here]

It should be noted that as regards labour, we obtained information about the number of employees (L); this figure was obtained directly from SABI. As usual (Brynjolfsson and Hitt, 2003, p. 807), we considered full-time employees only. To take full advantage of the available information, we defined the labour expense as the variable wage per employee ($W = LE/L$). Since firms may have employees with different skill levels, in a labour market with perfect competition, such differences are approximated by the wage per employee. Column 1 of Table 6 presents the results of estimating Equation (3); the inputs are the number of employees and the quality of labour (W) instead of labour expenses. We cannot reject the null hypothesis that the information is the same as that in Equation (3).[57] In other words, we can not reject that the elasticity of production with respect to labour (0.70) is equal to the elasticity of production with respect to wages (0.65). Consequently, based on this estimate, recently created university spin-offs will be 17.6% less productive (λ_1 = -0.176) than independent start-ups. The annual TFP growth of academic entrepreneurs was 9% (λ_3 = 0.09). This result supports the

[57] LR chi2(1) = 0.54; Prob > chi2 = 0.4621

hypothesis that academic entrepreneurs need an additional 1.95 years to reach the same TFP level as non-academic entrepreneurs.

Another assumption used in the estimates in the above section is that the only change that occurs in the production function over time is the TFP. In other words, the elasticity of output with respect to inputs remains constant over time regardless of the type of firm. This is an important point because if the TFP increase were due to an improvement in the elasticity of labour expenses, it could be construed that what we were measuring was that workers are those who learn. In fact, we are seeking to estimate a different elasticity value for each year and each type of firm (university spin-offs or other technology firms). To simplify the exposition and the estimates, we considered only two time frames: firms in operation for less than five years and firms in operation for more than five years;[58] these results are presented in the second column of Table 6. The increase in the explanatory capacity of the model (R^2) in relation to Equation (3) (Model 1, Table 3) is fairly low (0.0038) and is statistically insignificant. Therefore, we cannot reject the null hypothesis that the elasticity values remain constant over time, regardless of firm type (university spin-offs or independent start-ups). The main results relating to changes in TFP were maintained. In the first year, university spin-offs had a lower TFP (-0.224), which is statistically significant at 1%. University spin-offs were the only ones that increased their TFP, bridging the gap between the independent start-ups (λ_3 = 0.154) with each passing year.

The Cobb-Douglas function is the Taylor approximation using only the first-order derivatives of the function *h*, where $h\,(Ln\,X_{1iy}\,,\ldots,Ln\,X_{jiy},\,\ldots\,Ln\,X_{Jiy}) = f\,(X_{1iy}\,,\ldots,X_{jiy},\,\ldots\,X_{Jiy})$. Therefore, we postulate to estimate the Taylor approximation to *f* using only the first-order derivatives, Equation (3) where inputs are introduced without taking logarithms, and the Taylor approximation of *h* using its cross and second-order derivatives, i.e., the translog function.

Column 3 of Table 6 presents the estimate of Equation (3) where the inputs are introduced without logarithms. The R^2 value (0.829) is lower than that obtained for the Cobb-Douglas function (0.887; Model 1 of Table 3). Since the number of variables is

[58] We performed cross-section regressions for each year that the firms were in operation. This analysis enabled us to observe whether the elasticity values of the inputs vary over time. We observed clear differences only after the fifth year of operations. Results are available upon request.

the same, the Cobb-Douglas specification is preferable. The results without logarithms also provide a similar view of productivity changes. While the productivity of university spin-offs was 76.9% lower than that of independent start-ups, their TFP growth was significantly higher (λ_3 = 0.102). It should be noted that in this estimate, the TFP growth of independent spin-offs is positive and significant (λ_2 = 0.160).

The estimate of the translog function appears in the Column 4 of Table 6. The square of the various inputs and the possible interactions between them were added as independent variables in Equation (3). The increase in the explanatory capacity of the model (R^2) with respect to Equation (3) was quite small (0.0181), although statistically significant at 1%. The main results relating to changes in TFP were maintained and the elasticity values of the inputs with respect to output did not undergo any major changes. In the first year, university spin-offs have lower TFP (-0.329 less), which is statistically significant at 1%. University spin-offs are the only firms that increased their TFP, bridging the gap with independent start-ups (λ_3 =11.4%) with each passing year. Based on this calculation, the differences between these two groups will disappear in 2.88 years.

Our last concern is that all of the estimates thus far were calculated and interpreted without taking into account the fact that entrepreneurs seek to maximize profits. We can thus assume that in each period *t* management will contract the quantity of inputs in order to maximize the profits of the firm *i*, expressed algebraically as follows:

$$Max_{X_{jit}} : p_{qt}\, Q_{it} - p_{jt}\, X_{jit}$$

where p_{jt} is the price of the input *j* and p_{qt} is the price of the output at period *t*. If firms have market power, they can alter these prices. An inverse measure of the power of firm *i* in the output market is the output elasticity, $\eta_{q\,i,t} = \frac{\partial Q_{it}\, p_{qt}}{\partial p_{qt} Q_{it}}$, or in the case of the input market, the input elasticity with respect to price, $\eta_{j,i,t} = \frac{\partial X_{jit}\, p_{jit}}{\partial p_{jit}\, X_{jit}}$. In the event that the production function is described by Equation (2), $Q_{it} = A_{it} \prod_{j=1}^{J} X_{jit}^{\beta_j}$, the first-order conditions of the above maximization problem will be expressed as follows:

$$p_{jt} X_{jit} = \varphi_{jit} \beta_j \, p_{qt} Q_{it} \qquad\qquad j = 1,...J \qquad\qquad (4)$$

Where $\varphi_{j,i,t} = (1 + 1/\eta_{qit})/(1 + 1/\eta_{jit})$.

If we assume that these elasticity values are the same between firms and over time ($\varphi_{j,\,i\,t} = \varphi_j$), the estimation of the production function presented in Equation (3) has to take into account all of the first-order conditions (4). In other words, to estimate the next set of equations:

$$LnQ_{it} = \alpha_i FIRM_i + \lambda_1 USO_i + \lambda_2 y_{it} + \lambda_3 USO_i y_{it} + \beta_1 LnKF_{it} + \beta_2 LnKC_{it} + \beta_3 LnLE_{it} + \varepsilon_{it} \qquad (3)$$
$$pKF_{it} = \beta_4 pQ_{it} + v_{1it} \qquad (5)$$
$$pKC_{it} = \beta_5 pQ_{it} + v_{2it} \qquad (6)$$
$$pLE_{it} = \beta_6 pQ_{it} + v_{3it} \qquad (7)$$

where $\varphi_1 = \beta_4 / \beta_1; \varphi_2 = \beta_5 / \beta_2; \varphi_3 = \beta_6 / \beta_3$, *pKF* is the assigned cost of using[59] fixed capital, *pKC* is the undeflated intermediate inputs (*KC*), *pLE* is the undeflated labour expenses and *pQ* the undeflated net sales (*Q*). Given that the error terms of the equations (ε_{it},ν_{jit}) may be related, Table 7 presents the estimated parameters through seemingly unrelated regressions (Zellner, 1962).

[Insert Table 7 here]

The first column presents the results with no restrictions on the coefficients to be estimated; the second column assumes that the input and output markets are competitive[60] (φ_j =1 and $\beta_4 = \beta_1; \beta_5 = \beta_2; \beta_6 = \beta_3$). Comparing the estimates in the first and second columns of Table 7, we note that the null hypothesis that $\beta_4 = \beta_1; \beta_5 = \beta_2; \beta_6 = \beta_3$ is rejected at the usual levels of significance.[61] So according with these results, the firms have the greater power (less input elasticity) in the labor market and the lower one (greater input elasticity) in the intermediate input market (φ_3= β_6/β_3 = 0,110 < φ_1= β_4/β_1 = 0,183 <φ_2= β_5/β_2 = 1,194). The TFP-related results are quite consistent with those shown in Model 1 of Table 3. Even if we assume that the firms are

[59] This variable measures the incurred cost of fixed capital in the year *t*. This figure was calculated taking into account the amortization during the period *t* by firm *i*, and multiplying it by the cost of debt during the same period.
[60] This is also compatible with the fact that firms have the same market power in output markets and input markets, $\eta_{q,\,i,t} = \eta_{j,i,t}$
[61] Chi2(2) = 145.29; Prob > chi2 = 0.0000

in competitive markets (Column 2), the initial productivity was lower for university spin-offs (-0.585), although their productivity rate increased 5% faster than that of independent start-ups (0.050). It should be noted that in this case the TFP of all firms also grew at a statistically significant rate of 14.3%, while the elasticity of production with respect to labour expenses (β_3) fell dramatically with respect to the other estimates. Although labour is very productive in technology firms, the relative labour cost (with respect to sales) is quite low what can explain that the parameter gets an important reduction when it is constrained to be equal in equation (3) and (7).

VI. DISCUSSION

Based on a longitudinal sample of 177 Spanish high-technology firms, this chapter presents data on the comparative evolution of the university spin-offs' production function and that of the independent start-ups. The TFP of the university spin-offs in the first year is significantly lower than that of the independent start-ups. Over time, the TFP of the university spin-offs increases while in the rest of the firms it remains virtually constant, consistent with previous studies of representative samples of Spanish firms (Mas-Ivars and Quesada-Ibañez, 2006; Fariñas and Martín-Marcos, 2007; Sanchez-Mangas, 2007). All of these results are robust to different specifications of the production function. According to our estimates, during the first year, the TFP of the university spin-offs is lower than that of the independent start-ups. The difference ranges from 0.18 to 0.33 using Cobb-Douglas or Translog estimates, although each year the university spin-offs recover between 9 and 11.4 percentage points. Consequently, the academic entrepreneurs need approximately two or three years to achieve the same level of industry and managerial knowledge as their non-academic counterparts.

The first result – the TFP of the university spin-offs in the initial year – is significantly lower than that of the independent start-ups, reflecting the fact that independent entrepreneurs outperform academic ones during the first years after a firm is founded. Indeed, this result is consistent with the existing empirical literature (Chrisman et al., 1995; Ensley and Hmieleski, 2005), which measured performance in terms of workforce, net cash flow and revenue growth. Consistent with the literature concerning small firms (Delmar, 1997; Weinzimmer et al., 1998), the firms' performance was measured in terms of sales or growth. One problem with this measure is that the sales level can be increased simply by buying more inputs and thus increasing expenditures or otherwise increasing input productivity, which is free of costs. Therefore, the evidence presented goes a step further in relating performance difference to their common justification, i.e., academic entrepreneurs' lack of managerial skills when firms are founded (Shane and Khurana, 2003).

The second result indicates that the annual TFP growth rate is higher for university spin-offs than it is for independent start-ups. The managers of university spin-offs are scientists, for whom the scientific method is a working tool; therefore, they are more familiar with it than other entrepreneurs are. Based on the organizational learning literature, familiarity with the scientific method means that academic entrepreneurs have superior organizational learning capabilities. As far as we know, this is the first evidence in managerial contexts supporting the idea that the scientific method (Argyris, 1990) is the best way of generating organizational learning. Previous empirical studies focused exclusively on determining a direct correlation between firms' characteristics and the organizational learning process.

Obviously, this evidence comes from a specific dataset, i.e., our population of Spanish university spin-offs and independent high-technology start-ups. We strongly believe that these results could be reproduced in other contexts. In this sense, Spain does not seem to be a special case. Indeed, the Bayh-Dole Act (1980) and the Federal Technology Transfer Act (1986) transferred the right to own and license inventions stemming from federally funded research to US universities. Such legislation has been adopted in other countries, including Spain, France, Italy and the UK (Geuna et al., 2003). Furthermore, the previous evidence available for Spain (see Chapter 2) is consistent with the findings for other countries (Chrisman et al., 1995 for Canada; Shane and Khurana, 2003 and Ensley and Hmieleski, 2005 for the US; Colombo and Delmastro, 2002 for Italy). The founders of Spanish spin-offs also have more extensive formal education and less extensive managerial skills than do the founders of other independent technology start-ups, which reduces their growth capacity. Nevertheless, further evidence is needed to test if the aforementioned results are to be reproduced in other contexts.

VII. IMPLICATIONS

These results have direct implications for management. Firms can improve their productivity if they manage the organizational learning process more effectively and if they apply the scientific method during the process. How the scientific method is applied and adopted inside various organizations is an area for further research. In that regard, the scientific method may be viewed as a series of observations and experiments while operating in the market aimed at testing management's theories, intuition or hypotheses. Although managers must act according to certain theories or beliefs that make sense of reality, they must be open to alternative theories and adjust their assumptions in light of new evidence. In that regard, gathering observable and measurable information on the consequences of management's actions can facilitate this process. Furthermore, additional resources, in the form of managers' or specialists' time, must be devoted to analysing such information. Sharing the results of such analyses and processes with other members of the organization may help them learn more quickly.

These results also have indirect implications for policy makers. First, when setting priorities, they must compute the social value of the help being provided. In that regard, firms' productivity can be one of the measures used. As we have shown, the difference in firms' productivity during the first year of operations is not a good predictor of future productivity. This is especially relevant in the case of university spin-offs. Policy makers must take into account the fact that university spin-offs, on average, will be more productive in the long-term than they will be during their initial years of operations. Therefore, until now the advantages of stimulating the creation of university spin-offs may have be understated.

Second, our results have implications on the kind of policies needed for each type of firm. University spin-offs must accelerate the process of learning managerial skills. Policy makers and/or TTO officers must do their part by organizing courses, facilitating contacts with other persons possessing managerial skills or even facilitating the creation of founding teams that combine industry experience and managerial skills. For other firms, policy makers must stimulate organizational learning as a managerial practice. Understanding how scientists learn, compile and analyse information can help them learn more quickly and be more productive. Much of this transference in the method, not in the final results, has been little emphasized in the literature and by the universities involved until now.

VIII. CONCLUSIONS

This chapter emphasizes and presents evidence that the scientific background of the founders and managers of university spin-offs not only have disadvantages.

As highlighted in the existing literature (Siegel, Waldman and Link, 2003; Ndonzuau, Pirnay and Surlemont, 2002; Shane and Khurana, 2003; Colombo and Delmastro, 2002; Ensley and Hmielski, 2005), one negative aspect is that academic managers have less extensive managerial skills and underperform other technology entrepreneurs. The chapter adds evidence that they are also less productive at the first year of operations.

But this chapter also emphasizes certain advantages, e.g., academic entrepreneurs increase their productivity faster. Academic entrepreneurs are more familiar with the scientific method than their non-academic counterparts are. Consistent with the arguments of Argryis (1990) and with the organizational learning literature in general, academic entrepreneurs are more willing to learn. This chapter offers first evidence in this sense.

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Table 1: Descriptive statistics

CATEGORY		University spin-offs	Other technology firms	Total
INPUTS & OUTPUT	KF (€)	51,734 (83.694)	109,020 (153,971)	75,363 (120,820)
	KC (€)	37,006 (59.406)	46,441 (79,350)	40,487 (68,284)
	LE (€)	49,031 (65.572)	83,332 (107,163)	63,177 (86,608)
	Q (€)	135,227 (153,708)	203,100 (237,037)	163,218 (194,768)
REGION	Madrid	10.5% (0.3093)	38.3% (0.4896)	22.0% (0.4156)
	Catalonia	47.1% (0.5015)	19.3% (0.3964)	35.6% (0.4801)
	Basque Country	7.7% (0.2677)	13.7% (0.3462)	10.2% (0.3031)
	Valencia	30.8% (0.4637)	6.8% (0.2543)	20.9% (0.4077)
	Andalusia	3.9% (0.1932)	21.9% (0.416)	11.3% (0.3175)
SECTOR	Computer science	38.4% (0.4888)	43.8% (0.4996)	40.7% (0.4926)
	R&D	16.3% (0.3715)	9.6% (0.2965)	13.6% (0.3433)
	Engineering	13.6% (0.3429)	12.3% (0.3310)	13.0% (0.3371)
	Chemicals	5.8% (0.2342)	5.5% (0.2291)	5.6% (0.2315)
	Biotechnology	7.7% (0.2677)	1.4% (0.1170)	5.1% (0.2203)
	Telecommunications	3.8% (0.1932)	2.8% (0.1644)	3.4% (0.1814)
	Other sectors	14.4% (0.3530)	24.6% (0.4340)	18.6% (0.3905)

Standard deviation in parentheses.
The output and input data correspond to the first year of operations of each firm.

Table 2: Test for initial differences between university spin-offs and other technology firms

CATEGORY	VARIABLES	LOGIT SPIN-OFF
INPUTS & OUTPUT	**KF**	-0.0027 (0.0017)
	KC	-0.0038 (0.0044)
	LE	-0.00083 (0.0037)
	Q	-0.0009 (0.0023)
REGION	**Catalonia**	1.962* (0.495)
	Basque Country	0.679 (0.655)
	Valencia	2.625* (0.623)
	Andalusia	-0.719 (0.717)
SECTOR	**Computer science**	0.0612 (0.520)
	R&D	0.983 (0.696)
	Engineering	0.664 (0.678)
	Chemicals	1.090 (0.9507)
	Biotechnology	2.170 (1.337)
	Telecommunications	0.133 (1.170)
CONSTANT	**Constant**	-0.733 (0.559)
GENERAL INFORMATION	**Pseudo-R^2**	0.2687
	Observations	177
	Log-likelihood	-87.731

Level of significance: * 5%

Standard error in parentheses.

We omitted Madrid and Other sectors to avoid perfect multicolinearity.

Table 3: OLS with firms' fixed-effect models

CATEGORY	VARIABLES	PARAM.	MODEL 1	MODEL 2	MODEL 3
INITIAL PRODUCTIVITY	USO	λ_1	-0.175***	-0.763***	-0.713**
TFP & GROWTH RATES	*y*	λ_2	-0.019	0.267***	0.272***
	*y**USO	λ_3	0.088***	0.017	
PRODUCTION FUNCTION (INPUTS)	LNKF	β_1	0.0679		
	LNKC	β_2	0.238***		
	LNLE	β_3	0.679***		
GENERAL INFORMATION	R^2		0.887	0.753	0.753
	Observations		680	680	680
	Firms		177	177	177
	Within		0.666	0.273	0.272
	Between		0.661	0.199	0.221
	Overall		0.694	0.217	0.238

Level of statistical significance: *** 1%, ** 5%, * 10%
OLS misspecifications corrected through Huber-White sandwich estimator.

Figure 1: Determinants of annual sales growth[62]

Sales growth

USO	Rest
28.40%	26.70%
$0.284 = \lambda_2^{Model3} + \lambda_3^{Model\ 3}$	$0.267 = \lambda_2^{Model3}$

TFP Growth

USO	Rest
6.90%	-1.90%
$0.069 = \lambda_2^{Model1} + \lambda_3^{Model\ 1}$	$-0.0191 = \lambda_2^{Model1}$

Total input growth

Fixed capital growth (KF)		Intermediate input growth (KC)		Labour expense growth (LE)	
USO	Rest	USO	Rest	USO	Rest
2.29%	2.35%	5.73%	7.72%	13.43 %	18.53%
$0.0229 = \beta_1^{Model1}(\psi_{11}+\psi_{12})$	$0.0235 = \beta_1^{Model1}\psi_{11}$	$0.0573 = \beta_2^{Model1}(\psi_{21}+\psi_{22})$	$0.0772 = \beta_2^{Model1}\psi_{21}$	$0.1343 = \beta_3^{Model1}(\psi_{31}+\psi_{32})$	$0.1853 = \beta_3^{Model1}\psi_{31}$

[62] λ_2^{Model3} refers to the parameter λ_2 estimated in Model 3 of Table 3. The same applies to the rest of the parameters. Taking that into account, when dividing the total input growth by the growth of the various inputs, it is necessary to know the average growth of the various inputs for the spin-offs and for the control sample. This can be estimated for each input j, $LnX_{jit} = \psi_{j1}y_{it} + \psi_{j2}y_{it} * USO_i + \varepsilon_{it}$.

Table 4: Changes in academic team management

	FIRMS	INITIAL NUMBER OF MANAGERS	FINAL NUMBER OF MANAGERS
Academic founding teams that suffer modifications	12 (11.5%)	2.83	5.33
Only Appointments	6 (5.75)	3.16	4.66
Appointments and Resignations	6 (5.75%)	2.5	6
Academic founding teams that remained unchanged	92 (88.5%)	2	2

Source: Self constructed. The data were available from INFORMA.

Table 5: Robustness checks of the TFP specification

CATEGORY	VARIABLES	COLUMN 1	COLUMN 2
INITIAL PRODUCTIVITY	USO	-0.098	-0.169***
	USO*CHANGES	-0.546***	
TFP	*y*	-0.021	-0.050
	*y**USO	0.106***	0.081
	*y*USO*CHANGES*	-0.097*	
	y^2		0.0030
	y^2*USO*		0.0023
PRODUCTION FUNCTION (INPUTS)	LNKF	0.0701	0.069
	LNKC	0.240***	0.238***
	LNLE	0.682***	0.688***
GENERAL INFORMATION	R^2	0.887	0.887
	Observations	680	680
	Firms	177	177
	Within	0.667	0.666
	Between	0.671	0.663
	Overall	0.704	0.695

Level of statistical significance: *** 1%, ** 5%, * 10%
OLS misspecifications corrected through Huber-White sandwich estimator.

Table 6: Robustness checks of the production function specification

CATEGORY	VARIABLES	COLUMN 1	COLUMN 2	COLUMN 3	COLUMN 4
INITIAL PRODUCTIVITY	USO	-0.176***	-0.244***	-0.769***	-0.329***
TFP	*y*	-0.020	-0.027	0.160***	-0.027
	*y*USO*	0.090***	0.154***	0.102***	0.114***
PRODUCTION FUNCTION (INPUTS	LNKF	0.063			-0.064
	LNKC	0.237***			0.068
	LNLE				0.481***
	KF			$5.9*10^{-4}$	
	KC			$6.3*10^{-4}$***	
	LE			$6.5*10^{-3}$***	
	LNL	0.700***			
	LNW	0.653***			
	$(LNKF)^2/2$				-0.050*
	$(LNKC)^2/2$				0.122***
	$(LNLE)^2/2$				0.055
	LNKF*LNKC				0.037*
	LNKF*LNLE				0.036
	LNKC*LNLE				-0.085***
	LNKF*USO		-0.046		
	LNKC*USO		0.259***		
	LNLE*USO		0.673***		
	LNKF*independent		0.130*		
	LNKC*independent		0.192***		
	LNLE*independent		0.696***		
	LNKF*USO*Fifth		-0.024		
	LNKC*USO*Fifth		0.320***		
	LNLE*USO*Fifth		0.568***		
	LNKF*independent*Fifth		0.225**		
	LNKC*independent*Fifth		0.194***		
	LNLE*independent*Fifth		0.600***		
GENERAL INFORMATION	R^2	0.887	0.8908	0.823	0.9051
	Observations	680	680	680	680
	Firms	177	177	177	177
	Within	0.666	0.678	0.4782	0.720
	Between	0.664	0.666	0.2565	0.723
	Overall	0.695	0.702	0.3818	0.734

Level of statistical significance: *** 1%, ** 5%, * 10%
OLS misspecifications corrected through Huber-White sandwich estimator.

Table 7: Production function estimate with the first-order restriction

CATEGORY	VARIABLES	COLUMN 1	COLUMN 2
INITIAL PRODUCTIVITY	USO	-0.155**	-0.585***
TFP	*y*	-0.0145	0.143***
	*y*USO*	0.084***	0.050**
PRODUCTION FUNCTION (INPUTS)	LNKF	0.0713***	0.0147***
	LNKC	0.237***	0.291***
	LNLE	0.680***	0.080***
(F.O.C)	β_4	0.013***	0.0147***
	β_5	0.283***	0.291***
	β_6	0.075***	0.080***
GENERAL INFORMATION	R^2 (Eq.3)	0.886	0.836
	R^2 (Eq. 5)	0.114	0.111
	R^2 (Eq.6)	0.809	0.808
	R^2(Eq.7)	0.402	0.400
	Observations	680	680
	Firms	177	177

Level of statistical significance: *** 1%, ** 5%, * 10%