Brokering knowledge from universities to the marketplace: the role of Knowledge Transfer Offices

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Abstract

Purpose – This study conceptualises the role of Knowledge Transfer Offices (KTOs) as Knowledge Brokers (KBs) and identifies which factors are most significantly related with their performance for supporting Public-private Research Organizations (PROs), testing our hypothesis for the Spanish case.

Design/methodology/approach – An empirical analysis is conducted based on data from RedOTRI 2008 annual report about 63 Spanish KTOs. A multiple lineal regression model is carried on each of the selected variables representative of KTOs' performance (number of priority patents, revenues from industry collaboration and number of spin-offs) in order to establish possible relationships with some factors related to the knowledge process that characterize KTOs' activity.

Findings – A theoretical framework conceptualizing the KTOs' role as knowledge brokers is suggested. Factors positively influencing KTOs' performance are PRO's total annual expenses, the type of PRO, the KTO age, the existence of a science park, the explicit regulation of intellectual property rights, the number of specialized full-time staff of the KTO and the availability of a patent stock.

Practical implications – The identification of those critical factors for the day-to-day operation of Spanish KTOs in their different ways of transferring knowledge, drawing managerial and organisational practices that may improve their performance.

Originality/value – This paper provides two original contributions for literature on knowledge transfer: a theoretical framework for the conceptualisation of KTOs as KBs, and the categorisation and further analysis of factors closely related to the performance of KTOs. A set of managerial implications for a better improvement of such institutions is presented.

Keywords – Knowledge broker, Knowledge transfer office, Public/Private Research Organizations, Patents, R&D Contracts, Spin-offs, Spain

Paper type – Research paper

1. Introduction

Knowledge has been widely recognised as a driving force for economic development. Nevertheless one of the main obstacles society is facing today is how it is transferred from knowledge-creators to knowledge-users, bridging the gap between those who produce it and those who exploit it (Ward et al. 2009).

In an attempt to find an appropriate solution able to close this "know-do gap", a new figure has emerged, namely knowledge brokers (KBs), individuals, institutions or organizations responsible for organizing the interactive process through which knowledge is transferred. The characterization of a KB can be easily understood if the term is split in its two words. While "knowledge transfer" entails a complex and messy process which goes beyond the one-way push of information from researchers to users, the word "broker" suggests the world of the stock exchange (Monasta, 1997), where goods, products and capital are traded and exchanged, prices established, and people divided into clients and salesmen.

Positioned in the interface between researchers and end users, KBs are seen as powerful bodies in charge of interpreting and delivering knowledge (previously acquired), assessing institutions in how to exploit it, and bringing people together by creating new relationships built in a trusting environment where ideas are shared and workers perform their jobs better (Hargadon, 2002; Johri, 2008). Therefore, an effective knowledge brokering activity involves a wide range of different practices, going further than simply *moving* knowledge, but transforming it (Meyer, 2010).

So important is the role of KBs, that literature on this topic has acquired a growing prominence in recent years (Bielak et al., 2008), being on the rise in a wide variety of areas and in both the public and private domain (Blondel 2006).

Within this ecology of knowledge creation and diffusion, public/private research organisations (PROs), mainly universities but also some R&D centres, are seen as strategic sources for the generation of such knowledge (Markman, et al., 2005). So much so, since the 1980s universities faced the need to formalize the establishment of Knowledge Transfer Offices (KTOs) that, acting as "technology intermediaries", facilitate this knowledge flow to the industry, capturing the economic rents associated with these commercial transactions of knowledge.

Regarding knowledge brokering as an important capability for KTOs, in this paper we present a conceptualization of KTOs acting as KBs. Thus, a conceptual framework is presented, based on the construct of knowledge and its different stages of development, and the potential relationships among the agents involved. Aware of the variety of factors influencing the performance of KTOs, we then propose an empirical approach to identify which factors stimulate or inhibit the quantity of knowledge commercialized, materialized in form of patents, licenses, R&D contracts and spin-offs. Three models are tested for the Spanish case, using data from the RedOTRI (the Spanish network of KTOs). Our main findings identify as positively influencing factors the performance of KTOs, the PRO's total annual expenses, the type of PRO (specialized or generalist), the KTO age, the existence of a science park, the explicit regulation of knowledge transfer issues as intellectual property rights (IPR), the number of specialized full-time staff of the KTO and the availability of a patent stock.

The paper is organized as follows. Section 2 reviews the literature on knowledge brokering and describes the similarities between the role carried by KTOs and KBs. A conceptual framework is then presented to facilitate the understanding of KTOs' functions. Section 3 provides an overview of the main factors conditioning the performance of KTOs. Section 4 describes the research design, including the sample, the variables and the models. In Section 5 the empirical results are presented. Finally, Section 6 discusses the results and suggests managerial implications for a better improvement of KTOs as KBs.

2. A conceptual framework for KTOs as KBs

A knowledge broker is an individual, organization or institution responsible for facilitating the creation, translation and use of knowledge between researchers (knowledge-creators) and end users (knowledge-users) (Sverrisson, 2001). Evidence of KBs' impact can be found in many different fields such as the business (Burnett et al., 2002; Hargadon, 1998; Verona et al. 2006) or the health sectors (van Kammen et al., 2006; Ward et al., 2009).

To study the role of KBs is to understand how the innovation process and its organizational design are delineated to foster the speed at which research findings are transferred or commercialized to the marketplace, linking know-how, know-why, and know-who (Blondel 2006). Typical roles for a KB may include (Michaels, 2009) collaborations with end users in identifying problems; access, assessment, interpretation, and transference of research results; contribution in the establishment of new partnerships and networks between users and researchers; identification of users' strengths and capacities; provision of specific training courses; or the promotion of an innovative culture.

Within the literature of KBs three different approaches can be identified, highlighting different ways in which KBs can act (Meyer, 2010): as managers, as linkage agents or as capacity builders. As managers, KBs enable, facilitate and manage the creation, diffusion and use of knowledge. Adopting a mediating role between knowledge-creators and knowledge-users KBs scan the horizon looking for who needs to be engaged, what expertise is needed, who can provide it and how, signalling opportunities in both directions that lead to the formulation of common goals. Finally, in the third approach KBs facilitate the development of specific skills and capacities of knowledge-users by carrying training activities or monitoring services.

There is no doubt that KBs are a natural response for systems where information, innovation and knowledge are in abundance. A clear example of such a system is the higher education one, where new organizational forms such as KTOs started to emerge aimed to fulfil academics' needs for spaces and a professional team devoted to brokering research at the margins of the university (Jacobson et al., 2004; Vogel and Kaghan, 2001). The interest for exploring how KTOs act as KBs seems then completely legitimate, as such entities traffic with huge amounts of knowledge, having naturally become professionalized centres for playing this role.

KTOs' role has been largely studied in the literature, being described as facilitators of the technological diffusion from universities to industry (Siegel et al. 2003); assisting researchers in the dissemination of research results for the public good (Carlsson and Fridh 2002); promoting and managing the value of the university's intellectual property (Meseri and Maital 2001); directing entrepreneurs to venture capitalists (Roberts and Malone, 1996); and assuming the role of principal decision makers in the evaluation of inventions (Roberts and Malone, 1996). Thus, KTOs accomplish with KBs' functions, providing both a strategic and a structural response towards embedding industry science links within academic institutions (Link and Siegel, 2005).

Using the knowledge characterization of the U.S. National Academy, where knowledge is divided in 5 dimensions according to its level of development (creation, acquisition, assimilation, usage and dissemination) and considering the main actors involved in the knowledge transfer process, a conceptual framework for a better understanding of KTOs as KBs can be drawn, as illustrated in figure 1.

< Insert Figure 1 here >

In the *creation* stage PROs, under ideal preconditions for the development of research activities (e.g. critical research mass, infrastructures, or resources), create the potential for innovation, being responsible of knowledge generation. Outputs obtained respond to typical research outputs such as patents, licenses, research contracts/consultancy services and spin-offs. Expertise and know-how are also intangible outputs that can be added to this list.

The second stage, *knowledge acquisition*, involves the process whereby knowledge, new or old, is identified and acquired by KTOs through two different mechanisms. It might happen that a KTO, following a pull-demand strategy, is looking for a particular technology/development or a specific academic partner, attending a particular firm's demand. Otherwise, the push mechanism occurs when the research output is produced with the intention to be introduced in the marketplace. In this case, researchers usually contact the KTO in pursuit of obtaining assessment for the commercialization process. It is also possible that resulting from previous contacts or due to belonging to specific networks, researchers and firms interact directly without using the mediating role of KTOs. This case is represented in the scheme with a direct arrow from research results to user; nevertheless it tends to occur in a minority of cases.

The *bridging* stage, not included in the U.S. National Academy scheme but key in our understanding, stands for a linking stage, where KTOs manage all the information they have gathered from knowledge creators and users, and then move resources and suggest opportunities of exchange. The desired result is the formalization of cooperative win-to-win partnerships between universities and industry.

Once an agreement is reached, knowledge is *transmitted*. Similar to the acquisition stage, two mechanisms are devised. A pull-demand which drives users to contact KTOs in their search for knowledge; or a push-demand initiated by KTOs looking for appropriate partners for the exploitation of the knowledge-base substrate.

The *usage* or *transformation* stage is where knowledge is assimilated, transformed and used according to knowledge-users' purposes. Finally, knowledge is *disseminated* to the marketplace as goods or services, generating economic returns for firms (now acting as suppliers).

A particular case that deserves special attention is the creation of spin-offs. As spin-offs are an outcome of an entrepreneurial process initiated in a university setting based on the exploitation of a university development which generates incomes (Rasmussen, 2008), they can be directly positioned as end-users in the usage stage. Here, KTOs' advice may or not be needed, so a dashed line has been drawn on the figure.

3. Determinant factors for knowledge transfer

In the literature on PROs "knowledge transfer" is usually understood as "technology transfer" or the commercialization of research results. As knowledge is the basis for technological developments, according to the scope of this paper "knowledge transfer" and "technology transfer" would be considered as synonymous, as they both entail the knowledge flow from knowledge-creators to knowledge-users.

Within this context, approaches have been focused on comparing policies adopted by regions or universities in commercializing research (Colyvas et al., 2002; Goldfarb and Henrekson, 2003); university-industry partnership practices (Meyer-Krahmer and Schmoch, 1998; Owen-Smith et al., 2002); coordinating policies between universities, industry and government (Lee and Win, 2004); or the impact of university research on industrial innovation (Cohen et al., 2002; Feller et al., 2002).

A second strand of literature has explored the efficiency of KTOs in transferring a particular tangible research output: patents (Carlsson and Fridh, 2002; Fabrizio and Di-Mini, 2008), licenses (Chapple et al., 2005; Thursby and Thursby, 2002), R&D contracts and consultancy services (Chang and Yang, 2008; Thursby et al., 2001), or spin-offs (Lockett and Wright, 2005; O'Shea et al., 2005). This group of studies verifies our approach in using tangible outputs to measure the performance of KTOs in commercializing research results.

Some studies have also addressed the impact of structural factors and management practices of KTOs. Examples include Debackere's (2000) work, focused on governance structures, the organization of processes and the cultural context of KTOs. Siegel et al. (2003) found that critical organizational factors affecting productivity were those related to faculty reward systems, staffing/compensation practices, and the cultural barriers between universities and firms; whereas McAdam et al. (2005) and Rasmussen et al. (2006) suggested that coordination was the key. Regarding areas of improvement Chapple et al. (2005) pointed out the need to increase business skills and management capabilities of KTOs; and Thursby and Kemp (2002) as well as Siegel et al. (2004) identified culture clashes, poorly reward systems, bureaucratic inflexibility and an ineffective management of KTOs.

As reported by these studies, the quantity and quality of knowledge transferred is conditioned by multiple factors. An in-depth analysis of the literature allows us to classify these factors in seven categories according to their nature. On one hand *environmental factors* report socioeconomic and innovative features of the region, such as real output growth or GDP (Siegel et al., 2003; Wright et al., 2008), R&D intensity of the region or proportion of high-tech firms (Friedman and Silverman, 2003; Siegel et al., 2003). *Financial factors* refer to the diversity of funding sources and the amounts received for R&D activities (Chang et al., 2006; Foltz et al., 2000). *Legal or normative factors* are those regulatory frameworks that condition the management of intellectual property (Chang et al., 2009) or policies for royalties and equity (Friedman and

Silverman, 2003). Regarding *structural factors* we distinguish between those describing the internal organization of the PRO where the KTO belongs or those of the KTO. In the former, such traits can be defined by the presence of a medical school (Siegel et al., 2003), whether it is a public or a private institution (Friedman and Silverman, 2003), its size (Landry et al., 2007) or the availability of advanced infrastructures for research (O'Shea et al., 2005). In the latter, magnitudes traditionally stand for its age (Friedman and Silverman, 2003), size (O'Shea et al., 2005) or structure (Markman et al., 2005). A forth factor are *human resources*, accounting for the number of researchers (Chang et al., 2006; Landry et al., 2007) or staff's capabilities and training (Chang et al., 2009; Foltz et al., 2000). *Relational factors* describe the networks between the academia and other likewise institutions but also with businesses (Chang et al., 2009; Wright et al., 2008). Finally, the last factor are *pre-research results*, such as publications (Landry et al., 2007) or patents (Anderson et al., 2007) that may affect the development of further research results.

From a management perspective, it is obvious that knowing how these factors impact on the performance of KTOs in the knowledge transfer process is a crucial asset. A more comprehensive detailed analysis is therefore needed in order to improve the management of KTOs as organizations facilitating these services (acting as KBs). In accordance with the literature review, the preceding factors identified, and considering the use of tangible research outputs to measure KTOs' performance, the following hypothesis can be formulated:

- *H1.* A positive relationship is expected between certain factors (environmental, financial, normative, structural, human resources, relational and pre-research results) and the number of patents commercialized by the KTO.
- *H2.* A positive relationship is expected between certain factors (environmental, financial, normative, structural, human resources, relational and pre-research results) and revenues arising from R&D contracts and consultancy services.
- *H3.* A positive relationship is expected between certain factors (environmental, financial, normative, structural, human resources, relational and pre-research results) and the number of spin-offs created.

Licensing activity is a common approach for exploiting new technologies and inventions developed at universities (Di Gregorio and Shane, 2003; Siegel et al., 2003; Thursby and Thursby, 2002); therefore, it would make sense to suggest a fourth hypothesis regarding the factors that might influence the number or the revenues generated by the licensing activity. Nevertheless, after carefully examining the data for the Spanish case, we realised that this variable would entail some statistical problems, as either its number or the revenues present a highly skewed distribution. Although lagged terms for this variable were introduced, endogenity problems persist and the model obtained exerted no consistency. Using the rate "incomes per number of licenses" also showed to be meaningless, hindering the interpretation of results. Consequently we decided not to include a licensing model in this study as the variability of such dependent variable might be due to factors that largely respond to other specific circumstances, unexplained by the factors considered in the RedOTRI survey.

4. Methodology

4.1. Sample and data collection

Data of the activity of KTOs and their respective PROs was obtained from the RedOTRI annual report for the fiscal year 2008 (RedOTRI Universidades-CRUE, 2009). In this report 63 KTOs were surveyed, including both public and private institutions. To our knowledge, this report is the most comprehensive one for national source of data on knowledge transfer activity; however data presented some missing observations. Aiming to complete these information, we also employed the biannual report published by the Council of Rectors of Spanish Universities, CRUE (Hernández-Armenteros, 2010) corresponding to the academic year 2008/2009 and fiscal year 2008. Manual searches for annual reports of individual KTOs as well as direct contact with some of them were also necessary. Therefore, data was successfully completed obtaining a final sample consisting of 63 Spanish KTOs, although some missings remained unaffordable for some variables.

Data for environmental regional variables was obtained through the website of the Spanish National Institute of Statistics (Instituto Nacional de Estadística, INE).

4.2. Dependent variables

As reviewed in Section 3, the use of tangible outputs to measure KTOs' performance is largely supported by the literature. In particular the analysis addresses the number of patent applications, revenues from university-industry collaborations and the number spin-offs created. Detailed information is given as follows.

4.2.1. Patents

Patents are used as a proxy for the first step in the commercialization of academic research results (Mowery and Ziedonis, 2002).

Available data in the RedOTRI survey regarding patents comprises two groups. A first one considering the number of new priority patents application (with a national scope) or the number of applications for their extension to other countries (after a period of being only exploited nationally); and a second group accounting for the number of patents issued at a national level (by the Spanish Office of Patents and Brands), European (by the European Patent Office), or international (by the U.S. Patent and Trademark Office).

As the patenting process might take a long period before a patent is awarded, here we accounted for the number of new priority patent applications filed in by the KTO in the year surveyed (*priorit_patnts*), as our aim is to measure the performance of KTOs in a given year, while considering the number of patents granted may reflect past results (Thursby and Kemp, 2002). Additionally, the rationale for selecting priority patents instead of the extensions lies in the intrinsic logic of first applying for the patent, and only in case of its acceptance and the existence of a strong demand, its translation into the international community. Moreover, data was much more complete and representative when considering the number of new patent applications rather the extensions.

4.2.2. Revenues from collaboration with industry

A particular way of transferring knowledge to industry is through R&D joint projects with firms. Typically, these collaborations tend to respond to business' interests but also offer academics the opportunity to widen their horizons and to finance research.

Attending data on the RedOTRI survey, this variable (*value83LOUcontr*) is expressed by the total economic value of PRO-industry relationships established during the year involving a knowledge flow. Specifically, R&D contracts, technical assistance contracts, R&D collaborative projects and the provision of other services. Selecting the economic value instead of the number (Wright et al., 2008) might denote the quality of these collaborations.

4.2.3. Spin-offs

Spin-offs are considered to be one of the most effective ways to contribute to the renewal of the industry while exploiting academia-developed technology (Powers and McDougall, 2005). They can be defined as an outcome of an entrepreneurial process initiated in a university setting and based on the exploitation of a university development (Rasmussen, 2008).

Spin-off activity is generally measured by the number of new academic ventures created (Lockett and Wright, 2005; O'Shea et al., 2005). The survey of the RedOTRI provides this information; therefore the dependent variable expressing the entrepreneurial character of both the KTO and PRO is a natural count of the number of academic spin-offs created (*spinoff*).

4.3. Independent variables

Following the categorization of factors conditioning the knowledge process described in Section 3 (environmental, financial, normative, structural, human and pre-research), independent variables employed in the models are characterised. Due to the lack of reliable data regarding relational factors, we have decided not to include them in our analysis, although we are aware they should be considered in further studies.

4.3.1. Environmental factors

Empirical research suggests that knowledge creation and diffusion tend to be geographically concentrated in those areas with favourable R&D conditions. Consistent with Wright et al. (2008), GDP of the region (*provGDP*) can be used as an indicator of the level of development of the region, understanding the region as the province where the KTO is located. In those cases where the KTO serves more than one province (typically when the university where the KTO belongs has different campuses across the territory) the sum of the GDP of the provinces was computed. R&D intensity of the region (*ccaaRDintens*), reflects the ability of the public and private sector to sponsor

R&D activities at PROs (Friedman and Silberman, 2003; Siegel et al., 2003). Here the term region, as data by provinces was not available, stands for the autonomous community, the first-level of political division of Spain, integrated by provinces.

4.3.2. Financial factors

Because knowledge commercialization is possible due to previous investment in research, the commercialization of the results is likely to be influenced by the amount of R&D funding received by PROs.

RedOTRI data shows that some universities have considered R&D total funding as the sum of funds coming from public or private competitive R&D sources and private donations, ignoring the PRO own funds. Calculating internal funding requires a sophisticated cost model able to attribute part of personnel costs (especially academic staff), infrastructures and other resources used in research not directly related to a particular project. We found that the criteria used by different PROs diverge; therefore using this aggregated variable would provide neither equivalent nor valid information. Consequently, we decided to use 4 variables to control the funding of R&D expenditure, coming from both private (*RDfunding_priv*) and public R&D competitive programs (*RDfunding_publ*), donations (*RDfunding_don*) and the sum of the aforementioned three sources (*RDfunding_totF*). The use of all these variables is highly supported by the literature (Foltz et al., 2000; Landry et al., 2007).

Two extra variables reporting were included. A first one accounting for the total annual expenses of the PRO excluding infrastructure (*PRO_bdgt*), and a second one representing the proportion of the PRO budget which is R&D oriented (*RDf_ov_bdgt*), calculated as the percentage of *RDfunding_totF* over *PRO_bdgt*. According to Friedman and Silverman (2003), it is also interesting to account for the amount of seed capital managed in order to estimate the effects of venture capital availability at KTOs; however this variable showed to be useless for our sample because of the very low number of KTOs managing this kind of resources.

4.3.3. Normative factors

As normative factors we considered if the PRO has written and published policies regarding the internal regulation of inventions (*NormFw_invnt*), collaboration with industry and contract research (*NormFw_contr*), creation of spin-offs (*NormFw_spoff*), and conflict of interest (*NormFw_confl*). These magnitudes were treated as dummy variables, whether "1" indicates the existence of a specific legislation, and "0" a non-regulated system.

4.3.4. Structural factors

Based on the proposition that technological and medical inventions have greater marketability than those from other disciplines (Di Gregorio and Shane, 2003; Thursby and Thursby, 2002), and that institution type may condition the engagement in knowledge transfer activities, a dummy variable characterising the profile of the PRO (*PRO_type*) has been included, differentiating between generalist "0" and specialized "1" (technical universities, R&D centre or hospital) PROs.

Years of experience is another feature that seems to be linked to KTOs' performance (Siegel et al., 2003; Lockett and Wright, 2005). According to this perspective, the expertise gained in past knowledge transfer activities professionalizes the KTO, becoming more efficient. Therefore, the age of the KTO was measured in terms of years in operation (*KTOage*).

KTOs' managerial capabilities were also considered. In particular we included three dummy variables reflecting different functions carried on such as the management of a science park (*Funct_SPmngt*), the management of seed capital (*Funct_seedc*), and the development of continuous professional activities (*Funct_CPD*). RedOTRI survey included data about other capabilities that were not included because the answers were so uniform that they were useless as explanatory factors.

Literature often argues that the presence of innovative environments and well-equipped spaces devoted to R&D can enhance the generation and commercialization rate of knowledge (Chang et al., 2009; Lockett and Wright, 2005). Hence, to measure the influence of these supporting spaces, we examined whether or not the PRO served by the KTO was involved or provided access to innovative infrastructures such as incubator facilities (*Infr_incub*) and science parks (*Infr_scpark*).

4.3.5. Human resources

Labour force or human resources are the core of any institution for its daily operation. As we are considering the level of research results commercialized by KTOs, accounting for the number of personnel from both PROs and KTOs is necessary as control variables for their sizes. Therefore, we considered the number of full-time equivalent academic staff at PROs (*PRO_acd_staff*), and the number of full-time equivalent KTO staff (*KTO_staff*).

Functional orientation of KTO staff provides an interesting appreciation of support activities/services offered. Prior studies suggest that specific assistance in technology transfer activities is linked to a major productivity of the KTO (Chang et al., 2009). Consequently, we accounted for the number of full-time equivalent employees in KTOs involved in IPR tasks (*KTOstaff_ipr*) and spin-off assessment (*KTOstaff_spoff*). For each of these variables we also calculated the percentage they represent over the total number of full-time equivalent employees devoted to technical functions (p*KTOstaff_ipr* and p*KTOstaff_spoff*). Other functions included in RedOTRI survey were not included because the answers given by KTOs were so uniform that they were useless as explanatory factors.

4.3.6. Pre-research results

Finally, it is worth to consider some pre-research results that somehow may affect the development of other research results (Anderson et al., 2007). For instance, we consider the number of different patents cases (based on different priority filings) that were still maintained (not yet abandoned or assigned) by KTOs at the end of the evaluated year (*patent_stock*).

4.4. Models

Based on past studies in knowledge transfer performance of KTO, table 1 summarises a prior selection of the aforementioned variables for each of the three models to be tested.

< Insert Table 1 here >

5. Results

5.1. Statistical techniques

The empirical analysis is based on multiple OLS linear regressions for each dependent variable, having chosen the STEPWISE method with the criteria "Probability of F <= .050" for entering variables into the regression model and "Probability of F >= .100" for removing them. Missing values have been processed using PAIRWISE method, since it is supposed to reduce the dispersion around true scores and the average error (Roth and Switzer; 1995). A log-lineal model has been used for all dependent variables, being them calculated as LN(dependent_var+1) in order to ensure its normal distribution and the one of the residuals of the regressions (figure 2, all models), while improving the robustness of the model.

< Insert figure 2 here >

Before describing the results obtained for each model as well as some statistical issues they entail, in table 2 we sum up the correlation coefficient, R square, R square adjusted and those significant variables of the models.

< Insert table 2 here >

5.2. Patents model

Prior to estimating OLS regression, we transformed the number of priority patents into its napierian logarithm (*LNpriorit_patnts*) and analysed Pearson's correlations. Twelve independent variables showed a significant correlation with the dependent variable, being *PRO_bdgt*, *RDfunding_totF*, *RDfunding_priv* and *KTOstaff_ipr* those with a correlation index higher than 0.600.

OLS lineal regression with multiple factors was then carried to test hypothesis H1 using the STEPWISE method, and PARIWISE for missing values, obtaining 3 missing values in the worst cases (*NormFw_contr* and *Funct_CPD*) and processing the dependent variable without any (63 items).

The explanatory power of this model (R^2) is 77.3 percent and the ANOVA test calculates for $F(4;53)$ a value of 45.**233** (p-value<0.001) which supports H1, evidencing that there is a high significant lineal relationship between the number of priority patents and certain factors considered in the model. As shown in table 3, significant variables are *PRO_bdgt*, NormFw_invnt, *KTOstaff_ipr* and *ccaaRDintens*, all with a positive relationship and p-value less that 0.001, except for *ccaaRDintens*, which impacts negatively and the p-value is 0.023.

< Insert table 3 here >

The resulting model (expression, equation 1) includes two of the 4 significant variables with a higher Pearson's correlation.

$$LN(\mathit{priorit\_patnts}+1)= 0.599 + 4.004E\text{-}6*PRO\_bdgt + 0.863*NormFw\_invnt + 0.402* KTOstaff\_ipr - 0.387*ccaaRDintens + e \quad (1)$$

In order to analyze if the model fits properly and its statistical significance, we studied the residuals behaviour in terms of normality, independence, homoscedasticity and multicollinearity assumptions.

Although some authors suggest that a non-normality behaviour can be well supported in a multiple regression analysis (Greene 1999, pp. 204-205), we decided to accomplish with the normality assumption, and the dependent variable was transformed with a logarithmic function. Figure 2 (model 1), the Kolmogorov-Smirnov normality test (*p*-value=0.200) and the Shapiro-Wilk one (*p*-value=0.077) corroborate that regression residuals were normally distributed. Independence and homoscedasticity assumptions were also verified, as no autocorrelation in the residuals was observed in the Durbin-Watson's test (1.615 value inside the interval [1.5;2.5]), and the residuals variation was uniform throughout the range of predicted values (figure 3, model 1). Likewise, no collinearity problems were observed, as the maximum VIF index calculated was 1.407 (Belsey et al., 1980). Finally, Cook's distance of the residuals was calculated, obtaining a maximum value of 0.021 (lower than 1), which indicates the model obtained was statistically correct.

< Insert figure 3 here >

The model suggests four factors that directly influencing the patenting activity. In particular, financial factors (represented by PRO total annual expenses) seem to confirm that those PRO with more financial resources account a major number of patents. We could expect financial variables more directly related with R&D funding to be selected first in the regression but PRO_bdgt also includes the own financing of R&D, those not coming from competitive sources o donation, so PRO_bdgt is probably a more representative data.

Also a favourable normative in IPR has appeared to be significant, encouraging universities to have an explicit regulation which, on one hand avoid possible misunderstandings with third parties, and on the other hand, attract researchers to commercialize their results. Having specialized PRO staff devoted to give support to this particular task is also regressing positively.

Finally, and contrary to our expectations, R&D intensity of the autonomous community shows a negative relationship with the patenting activity. This finding may be due to the concentration of PROs with different orientations in knowledge transfer (e.g. polytechnic versus generalist universities, or more and less devoted to R&D activities) in regions with bigger GDP.

5.3. R&D contracts model

The dependent variable for this model is the napierian logarithm of the incomes from collaboration with industry (*LNvalue83LOUcontr*). Pearson's correlations of independent variables showing significant correlation with *LNpriorit_patnts* (index>0.600, *p*-value<0.01) are *PRO_bdgt*, *PRO_acd_staff*, *RDfunding_totF* and *RDfunding_priv*.

Operating as in the previous model, we tested H2. The number of missing values was 5 out of 63 items for the dependent variable and a maximum of 3 for the *NormFw_contr* variable.

The model calculated (expression, equation 2) explains the major proportion of the variance (R^2 of 82.1 percent) and the ANOVA calculates for F(4,51)=58.575 with *p*-value at level of 0.001, supporting H2. A very high significant relationship is found with variables *PRO_bdgt*, *Infr_scpark*, *PRO_type* and *KTOage* with positive coefficients and *p*-values lower than 0.001 (table 4).

< Insert table 4 here >

$$LN(value83LOUcontr+1) = 6.747 + 5.82E\text{-}06 * PRO\_bdgt + 0.706 * Infr\_scpar + 1.087 * PRO\_type + 0.051 * KTOage + e \quad (2)$$

Normal Q-Q plot of Unstandardized Residual components (figure 2, model 2) as well as the normality tests of Kolmogorov-Smirnov (*p*-value=0.200) and Shapiro-Wilk (*p*-value=0.966) confirmed a normal distribution of the regression residuals. Serial independence of regression residuals can be assumed since the Durbin-Watson's test calculates a value (1.430) not too far from 2, and homoscedasticity problems have not been detected (figure 3, model 2). Maximum VIF value (1.353) indicates very low probabilities of collinearity problems. The maximum Cook's distance (0.510) reinforced the model's statistically correctness assumption.

Variables regressing revenues from R&D contracts and collaboration with industry respond to financial and structural factors. Similar to the first model, the PRO annual expenses exerts a positive influence. Regarding structural factors, the profile of the PRO and in particular its specialization (polytechnic universities, hospital research centres and research institutes) is suggested to be correlated with a better achievement of R&D outputs. This type of PROs tends to produce a more attractive offer outside academia, responding better to firms' needs. Technological advances and developments are mainly produced by polytechnics, hospitals and research centres; therefore their activity is much more market-oriented, and the establishment of research contracts much more frequent.

Experience (measured by the KTO age) is also pointed to be important, thus, KTOs with no seniority should find ways of acquiring know-how from more experienced ones in order to approximate their performance.

Finally, it is not surprising that the existence of a science park seems to exert also a positive influence, as the original function of this infrastructure is to provide a space to ease the visibility of the activities carried by the agents involved and the establishment of synergies between the firms located in the park and the PROs research groups.

5.4. Spin-offs model

Last model take as the dependent variable the napierian logarithm of the number of spin-offs created (*LNspinoff*). Independent variable *patent_stock* has Pearson's correlations with *LNspinoff* greater than 0.600, and *RDfunding_priv* (0.564, *p*-value<0.01) and *PRO_bdgt* (0.500, *p*-value<0.01) are also fairly close.

The linear regression used to test hypothesis H3 follows the same method and criterion for missing values as the previous ones. In this case, a maximum of 5 items are lost for the dependent variable and the *patent_stock* one.

The model calculated (expression, equation 3) has an explanatory power of 56.9 percent and the ANOVA calculates for F(3,50)=22.047 with *p*-value at level of 0.001, supporting H3. A high significant relationship is found with variables *patent_stock*, *pKTOstaff_spoff* and *provGDP* (see coefficients and *p*-values in table 5).

$$\text{LN}(LNspinoff+1) = 0.290 + 0.007 * patent\_stock + 0.024 * pKTOstaff\_spoff - 1.57\text{E-}09 * provGDP + e \quad (3)$$

< Insert table 5 here >

The model exerts normality of regression residuals, confirmed by the Q-Q plot (figure 2, model 3), the Kolmogorov-Smirnov normality test (*p*-value=0.189) and the Shapiro-Wilk one (*p*-value=0.289). Serial independence of regression residuals was also checked with positive results on the Durbin-Watson's test (2.012). Regarding homoscedasticity, the scatter plot in figure 3 (model 3) is not as clear as in previous models, questioning the accomplishment of this assumption. Maximum VIF value (1.012) allowed rejecting collinearity problems. Cook's distance maximum value (0.153) is significantly lower than 1 discarding unusual influences between observations. Resulting from the above, we can assume the statistical validity of this model.

The resulting model points to three main factors affecting the number of spin-offs created: human resources, pre-research results and environmental factors.

Similar to what happened in the patents' model, having specialized KTO staff devoted to spin-offs support activities is positively correlated. Spin-offs tend to be initiated by researchers or students which have no previous experience in setting up a business, therefore they lack in managerial capabilities and support in the initial stage is acknowledged to be crucial.

As important as human resources is the existence of a patent stock. Spin-offs are usually created after a patent has been accepted; consequently the inclusion of this factor in the model confirms both the literature and our expectations.

Finally R&D intensity of the region appears in the model with a negative sign similar to what we found with GDP in relation with patents. As explained in more detail in the discussion section, this might be due to a geographical concentration of PROs with different orientation in regions with a bigger GDP.

6. Discussion and Conclusions

In this paper, we have suggested a theoretical framework conceptualizing the KTOs' brokering knowledge role, by proposing a six-stage process according to how knowledge evolves, from its creation until its final development and applicability. In this scheme, KTOs are depicted as the central elements, acting as suppliers but also as clients, and thus, brokering knowledge from the academia side to the industry.

We have also analysed the contribution of several internal and external factors in the KTOs' day-to-day performance, emphasizing the individual contribution of each factor in an overall model, where variables are included according to their statistical significance.

From the literature review we have been able to categorize these individual factors affecting knowledge transfer according to their nature. For instance 6 groups have been considered: environmental, financial, normative, structural, human resources, relational and pre-research. Based on the RedOTRI survey data on 63 Spanish KTOs (financial year 2008), we have identified and extracted variables measuring some specific dimensions from the aforementioned factors, except for the relational ones, as no data was available.

Statistical significant relationships between the factors considered and the performance of KTOs' (measured by the number of patents, revenues from R&D contracts and the number of spin-offs) have been observed.

Regarding environmental factors we have found that GDP and R&D intensity of the region have a negative relationship, contrasting with the finding of Wright et al. (2008) and Siegel et al. (2003). This surprising result can be explained by the fact that regions with bigger GDP are usually more densely populated and more attractive for the establishment of higher education institutions offering a diversified range of degrees and specializations in order to attend a demand for a complete education. Henceforth this translates into a less orientation in R&D activities. In addition, some of those institutions have centres in several of the richest areas of Spain. Consequently, our result can be interpreted as provinces with higher GDP attract a concentration of higher education institutions, giving priority to academic tasks than research ones, thus, influencing negatively the overall performance. We observe that provinces with a high GDP account for some of the best performing KTOs but also for those with very low outcomes. Despite this result it does not mean in any way that GDP of the region negatively affect the performance of a KTO at an individual level.

Without exception, the relationships observed with the remaining groups of factors support the positive signs suggested in the hypotheses.

Financial factors, in the form of total annual expenses of the PRO (*PRO_bdgt*), have been selected for the patents and the R&D contracts models but not for the spin-offs one. It would have been interesting to include the total R&D funding as a variable but, as explained in section 4, data about PROs' own funding was neither well characterized nor homogeneous in the responses given by PROs. Private as well as public R&D competitive funding have been closely to be considered in some of the models but due to collinearity problems with annual expenses, we have had to be obviate them.

Normative factors have been detected to enhance KTOs' performance, specifically in the patents model. Developing an explicit regulation about inventions and IPR is a good practice, as it provides guidelines to avoid possible misunderstandings with third parties and attract researchers for protecting their research results by introducing incentives for a future commercialization.

Concerning structural factors, the age of the KTO, the profile of the PRO and the existence of a science park deserve a special attention as they are influencing the knowledge transfer activity of KTOs in terms of R&D contracts and collaborations with industry. Consistent with Di Gregorio and Shane (2003) and Thursby and Thursby (2002), specialized PROs (polytechnic universities, hospital research centres and research institutes) tend to produce a more attractive offer outside academia, responding better to firms' needs. Therefore their activity is much more market-oriented, and the establishment of R&D contracts with industry much more frequent. Also, the specialization allows for economies of scale in a particular domain making the PRO more productive in that field. KTO age represents the years of experience and the expertise gained in past knowledge transfer activities; thus, as a consequence of years of being involved in such activities KTOs get professionalized, becoming more efficient in their tasks (Siegel et al., 2003; Lockett and Wright, 2005). KTOs with no seniority should find ways of acquiring know-how from more experienced ones in order to approximate their performance. Finally, science parks, as spaces that bring together market needs and knowledge production, also favour the crystallization of collaborative projects.

Having specialized KTO staff devoted to assist in specific technology transfer activities providing quality services also increases its performance (Chang et al., 2009), while improves the external perception of the institution. Here this statement is true by the number of KTO staff specialized in IPR and spin-off tasks, showing a positive relationship with the corresponding outcomes (priority patents applications and spin-offs creation). It is worth to mention that the number of full-time equivalent academic staff of the PRO (*PRO_acd_staff*) could have been another significant factor for both the priority patents and R&D contracts models. In fact, this factor and the annual expenses one (PRO_bdgt) often enter as significant variables generating collinearity problems. Thus we make sense that the number of full-time equivalent academic staff of the PRO might be included within the total annual expenses factor, being consistent with the fact that salaries are an important part of the PRO expenses.

Finally, pre-research factors, measured by the existence of a knowledge stock in a patent format is positively related with the number of spin-offs, as such new ventures are usually created after a patent has been awarded.

We think this paper entails important theoretical and managerial implications from both academic and policymakers. From a theoretical perspective, this paper has characterized the role of KTOs as KBs suggesting a new conceptual framework where KTOs act as intermediate agents in the knowledge transfer process. Additionally we have analysed which factors (both internal and external) are conditioning KTOs' tasks, in order to find out which elements or dimensions have to be stressed to improve their performance. Finally and adopting a managerial approach, results obtained have been highlighted, pinpointing potential areas of improvement. These improvements are mostly focused towards an internal organizational design, where KTOs are susceptible to take management decisions. Nevertheless, results also showed that some factors cannot be controlled by KTOs, as they fall under the realm of science policy and their competent authorities.

Limitations of this work are linked to the characteristics of the Spanish knowledge transfer system. As R&D transfer is very sensible to cultural, tradition and business structure of regions, it would be interesting to replicate a similar analysis in other countries in order to generalize. A cross-country analysis could then generate interesting areas for future research. Nevertheless, we are aware of the divergences in the collection of the data, so cross-country comparisons may be difficult to be carried. Further lines of research may also include an in-depth analysis of the six categories of factors identified, in order to achieve a better understanding of their impact on KTOs' performance, and thus, draw adequate practices and policies that enhance the role of KTOs as KBs.

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Figure 1. Conceptual framework for the characterisation of KTOs as KBs. Author's source.

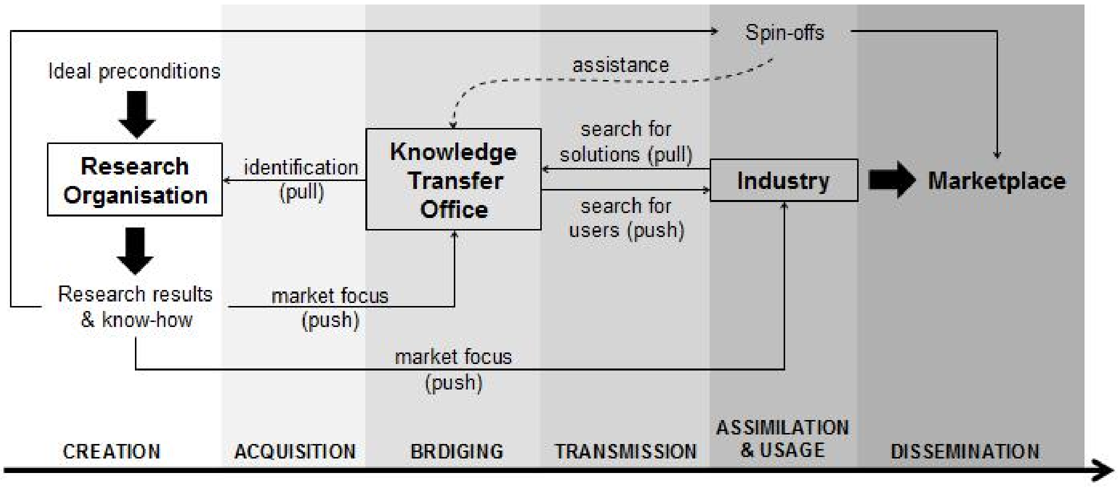
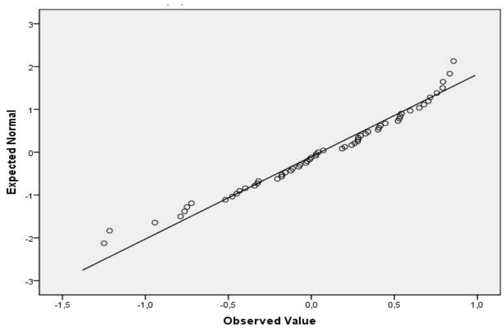
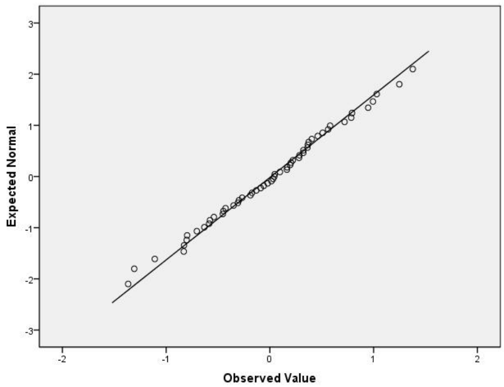


Figure 2. Normal Q-Q plot of unstandardized residual of each model.

Model 1: priority patents



Model 2: R&D contracts model



Model 3: Spin-offs model

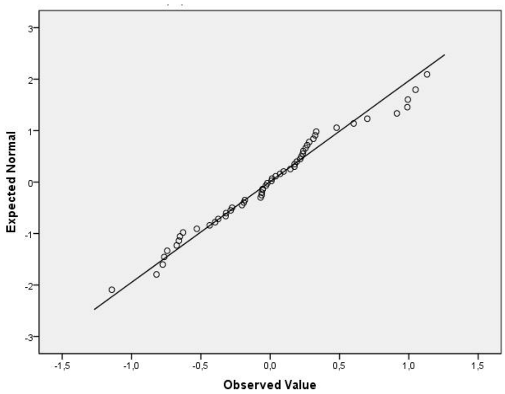
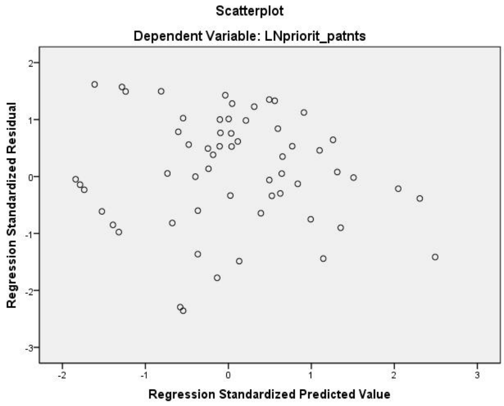
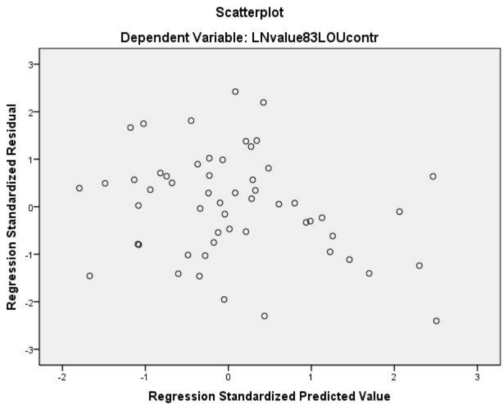


Figure 3. XY plots of standardized predicted value and standardized residual of each model.

Model 1: priority patents



Model 2: R&D contracts model



Model 3: Spin-offs model

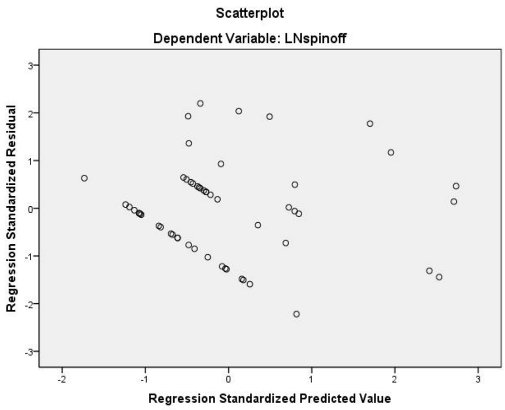


Table 1. Variable selected a priori for each model.

Factor	Variable	Priority Patents (PATENTS)	Revenues from industry collaboration (R&D_IND)	Spin-offs (SPINOFFS)
Environmental	Province GDP (provGDP)	X	X	X
	Autonomous community R&D intensity (ccaaRDintens)	X	X	X
Financial	R&D public competitive funding (RDfunding_publ)	X	X	X
	R&D private competitive funding (RDfunding_priv)	X	X	X
	Donations (RDfunding_don)	X	X	X
	R&D total funding (RDfunding_totF)	X	X	X
	PRO total annual expenses excluding infrastructure (PRO_bdgt)	X	X	X
	Proportion of the PRO budget R&D oriented (RDf_ov_bdgt)	X	X	X
Normative	Existence of specific policies in inventions (NormFw_invnt)	X		
	Existence of specific policies in collaboration with industry and contract research (NormFw_contr)	X	X	
	Existence of specific policies in spin-offs (NormFw_spoff)			X
	Existence of specific policies dealing with conflicts of interest (NormFw_confl)			X
Structural	Profile of the PRO (PRO_type)	X	X	X
	KTO Age (KTOage)	X	X	X
	Management of Science Park functions (Funct_SPmngt)			X
	Management of seed capital functions (Funct_seedc)			X
	Development of continuous professional activities (Funct_CPD)	X		
	Existence of a business incubator (Infr_incub)			X
	Existence of a science park (Infr_scpark)	X	X	X
Human resources	Academic Staff (PRO_acd_staff)	X	X	X
	KTO Staff (KTO_staff)	X	X	X
	KTO staff dedicated to IPR protection (KTOstaff_ipr and pKTOstaff_ipr)	X		
	KTO staff dedicated to spin-offs (KTOstaff_spoff and pKTOstaff_spoff)			X
Pre-research	Patents cases maintained by the KTO at the end of the year (patent_stock)			X

Table 2. Results Overview

Results Overview	Model 1 Priority patents	Model 2 R&D contracts model	Model 3 Spin-offs model
R*	0.879 (high)	0.906 (Very high)	0.755 (High)
R Square	0.773	0.821	0.569
Adjusted R Square	0.756	0.807	0.544
		Significant Variables**	
provGDP			(-)
ccaaRDintens	(-)		
PRO_type		(+)	
PRO_bdgt	(+)	(+)	
NormFw_invnt	(+)		
Infr_scpark		(+)	
KTOage		(+)	
KTOstaff_ipr	(+)		
pKTOstaff_spoff			(+)
patent_stock			(+)

Notes:

* Codification for r: Very low [.0-.2); Low [.2-.4); Moderate [4..6); High [6..8); very High [8..10]

**(+) Positive interelationship / (-) Negative interrelationship

Table 3. Coefficients for significant variables in model 1 (priority patents)

	B	Std error	t	VIF
(Cte)	0.599	0.283	2.118*	
PRO_bdgt	4.00E-06	0.000	6.572**	1.304
NormFw_invnt	0.863	0.184	4.687**	1.172
KTOstaff_ipr	0.402	0.094	4.283**	1.407
ccaaRDintens	-0.387	0.166	-2.336*	1.059

*p-value<0.05; **p-value<0.001

Table 4. Coefficients for significant variables in model 2 (R&D contracts model)

	B	Std error	t	VIF
(Constant)	6,747	,198	34,058**	
PRO_bdgt	5,816E-06	,000	8,585**	1,352
Infr_scpark	,706	,158	4,463**	1,079
PRO_type	1,087	,231	4,715**	1,019
KTOage	,051	,013	3,814**	1,353

*p-value<0.05; **p-value<0.001

Table 5. Coefficients for significant variables in model 3 (spin-offs model)

	B	Std error	t	VIF
(Constant)	0,290	0,129	2,254*	
patent_stock	0,007	0,001	7,213**	1,012
pKTOstaff_spoff	0,024	0,010	2,347*	1,012
provGDP	-1,573E-09	7.727E-10	-2,036*	1,000

*p-value<0.05; **p-value<0.001