WORKING PAPER

"University knowledge, open innovation and technological capital in Spanish science parks: Research revealing or technology selling?"

Manuel Villasalero
University of Castilla-La Mancha
manuel.villasalero@uclm.es

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University knowledge, open innovation and technological capital in Spanish science parks: Research revealing or technology selling?

Manuel Villasalero
Associate Professor
Department of Business Administration
University of Castilla-La Mancha
Ciudad Real (Spain)

Corresponding author: Manuel Villasalero
manuel.villasalero@uclm.es

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Manuel Villasalero is an Associate Professor in the Department of Business Administration at University of Castilla-La Mancha (UCLM), Spain, from which he received his PhD. He has experience as a director in several firms and currently serves as vice chancellor for economics and planning at UCLM. His research interests include corporate strategy, knowledge management and human resource management. He has published articles in *International Journal of Human Resource Management, Journal of Knowledge Management, Journal of the Knowledge Economy, Journal of Euromarketing*, and others. Manuel Villasalero can be contacted at: manuel.villasalero@uclm.es

| Purpose | This study investigates the connection between university research and technological capital developed by science park firms in order to elucidate whether the causal linkage is owing to non-pecuniary research spillovers or pecuniary technology transfer activities. |
| Design/methodology/approach | Two publicly available surveys, one dealing with the research and transfer activities of 45 Spanish universities and another with the patenting activities of 44 Spanish science parks, are matched in such a way that hypotheses can be tested using regression analysis. |
| Findings | The patenting performance of science park firms is positively related to the competitive R&D projects undertaken by the universities to which they are affiliated and negatively related to the technology transfer activities carried out by those universities. These findings suggest that the scientific knowledge produced by universities principally contributes to private technology-based firms’ technological capital through non-pecuniary research spillovers, whereas the pecuniary technology transfer agreements remain uncertain or may even prove to be detrimental. |
| Practical implications | Firms that are considering locating or remaining in a university-affiliated science park should be aware that the university’s pecuniary orientation when managing its intellectual capital may become a barrier as regards the firm filling its technological capital shortages. From a university administrator perspective, the complementary or substitute role of technology transfer offices vis-à-vis science parks should be considered in the light of the selling or revealing approach adopted by the university in order to commercialize and diffuse potential inventions. |
| Originality/value | This study contributes to existing literature by shedding light on the causal linkage between university research and firm innovation, obtaining evidence in favor of an upstream, non-pecuniary and revealing role of universities in support of the accumulation of technological capital amongst science parks tenant firms. |

Intellectual capital, knowledge transfer, knowledge spillovers, tacit knowledge, patents, licensing income, contract research, scientific publications, academic research, technology transfer.

Empirical paper.
University knowledge, open innovation and technological capital in Spanish science parks: Research revealing or technology selling?

1. INTRODUCTION

Knowledge, creativity and innovation have become increasingly important for those firms that wish to remain competitive in the marketplace (Schiavone and Villasalero 2013), thus pushing them to tap into knowledge networks, either within or outside organizational boundaries (Büchel and Raub 2002, Inkpen and Tsang 2005). Firms can rely on intra-organizational knowledge networks such as those arising in multi-business firms (Villasalero 2014a), multinational corporations (Williams and Lee 2009), multidivisional organizations (Nerkar and Paruchuri 2005), team-based organizations (Hoegl et al. 2003) or combinations of the above (Hansen et al. 2005). On the inter-organizational level, firms may benefit from geographically dispersed knowledge networks as is the case of international alliances and partnerships (Hagedoorn 2002) or geographically bounded knowledge networks consisting of countries (Villasalero et al. 2012), industrial districts (Boschma and ter Wal 2007), business clusters (Giuliani 2007), innovative milieus (Todtling and Trippl 2007), regional innovation systems (Cooke 2008), science parks (Koçak and Can 2014) and business incubators (Soetanto and Jack 2013).

The studies dealing with the performance advantages of being located within a science park (SCP) abound with predominantly mixed results, particularly when on-park firms are compared with matched samples of off-park firms (Link and Scott 2014, Phan et al. 2005). These findings run counter to the theoretically grounded claims concerning the value added contributions of SCPs to tenant firms’ physical, financial and intellectual capital. With regard
to the latter, it is argued that tenant firms may benefit from high quality human resources (human capital), key technologies and innovation-related knowledge (technological capital) and highly regarded corporate reputation (relational capital) derived from being located in an SCP with preferential access to the university’s graduates, staff, research projects, patent portfolios, public recognition and social legitimacy, aside from more the tangible advantages of housing (physical capital) and venture capital (financial capital) (Massey et al. 1992). These studies revolve around the tenant firms’ behavior but overlook the university side. In fact, the behavior of the focal universities in SCPs remains a largely neglected issue in this field of research (Link and Scott 2003).

This study explores the overlooked issue of how the focal university’s behavior conditions SCPs tenant firms’ accumulation of technological capital. In particular, the university strategy used to manage its technological capital is argued to impact on the tenants’ ability to improve their own technological capital. Taking an open innovation perspective (Chesbrough 2003, 2006), SCPs and technology transfer offices (TTOs) are conceptualized as alternate intermediaries through which research-based knowledge may become a potential innovation, with SCPs favoring non-pecuniary knowledge spillovers and TTOs fostering pecuniary transfer efforts. The university could therefore use the best known classification of open innovation strategies (Dahlander and Gann 2010) in order to adopt either a “selling” strategy based on R&D contracts and TTOs or a “revealing” strategy based on R&D projects and SCPs. According to this open innovation theoretical framework, it is hypothesized that selling hampers tenant firms’ accumulation of technological capital, whereas revealing improves it.

The findings support the hypothesized relationships between the tenant’s accumulation of technological capital and the strategy used by the university to manage intellectual capital. The tenants’ patenting outcomes increase with university R&D projects and decrease with
university R&D contacts and the size of the university TTO, thus suggesting that a selling strategy is detrimental to tenants’ technological capital whereas a revealing strategy is, on the contrary, beneficial to it. These findings are based on two matched samples of 44 SCPs and 45 universities in Spain that account for the vast majority of universities and SCPs.

This study contributes to the ongoing debate concerning the best the way in which university research-based knowledge can be absorbed by private firms in order to foster innovations for the wellbeing of society as a whole (Mowery et al. 2001, Nelson 2001). In the Spanish case, the results suggest that knowledge spillovers through SCPs are preferable to research transfer through TTOs, at least as regards the technological capital accumulation of tenant firms. This study also makes theoretical contributions to the fields of intellectual capital and open innovation by showing the new horizons that open innovation models may open up with regard to furthering the understanding of firms’ intellectual capital accumulation in a context specific situation, as is the case of SCPs.

2. THEORY AND HYPOTHESES

The underlying logic for SCPs is that «[…] universities have many brilliant people making new discoveries but that they lack the means or the will to reach out to the market. SCPs constitute a channel by which academic science may be linked to commerce. Thus SCPs are there to promote, not ‘science’, but its application to technology» (Massey et al. 1992: 56). More specifically, SCP tenant firms are argued to be in a position to build up intellectual capital from three types of networks: (1) the ties with the universities (Colombo and Delmastro 2002, Dettwiler et al. 2006, Fukugawa 2006, Löffsten and Lindelöf 2003, 2005); (2) the ties among tenants (Chan et al. 2010, Colombo and Delmastro 2002, Koçak and Can 2014); and (3) the ties between tenant firms and stakeholders outside the SCP boundaries (Löffsten and Lindelöf 2003, Chan et al. 2010).
2.1. SCPs and intellectual capital

The three types of networks mentioned above allow on-park firms to accelerate the accumulation of intellectual capital beyond the more visible benefits derived from premier housing (physical capital) and available venture capital (financial capital). Their preferential access to universities’ graduates and staff, research projects and patent portfolios, along with public recognition and social legitimacy are levers for the accumulation of human, technological and relational capital, respectively.

Universities are the recipients of talented people, explore the frontiers of scientific knowledge, have cutting-edge technologies and enjoy widely held social legitimacy (Huggins et al. 2008). On-park firms may benefit from these valuable assets as a result of their geographic proximity to and collaborative climate with the university to which the SCP is affiliated (Sorenson et al. 2006). Tenant firms are thus in a position to accumulate intellectual capital at a greater pace than similar firms located elsewhere, which may in turn create and sustain performance differentials between on-park and off-park firms. The evidence amassed to date is, however, contradictory in this regard (Link and Scott 2014, Phan et al. 2005, Siegel et al. 2003b). Some studies have found that on-park firms outperform off-park firms in final performance outcomes such as survival, growth and profitability (Westhead and Storey 1995), whereas other studies have detected that negligible advantages are derived from SCP membership (Ferguson and Olofsson 2004, Lindelöf and Löfsten 2003, 2004, Westhead and Storey 1994, Westhead et al. 1995). Leaving aside the final performance outcomes, the existing evidence on differentials between on-park and off-park firms in intellectual capital indicators is also mixed.

The study of relational capital in SCPs has attracted considerable attention over the last few years (Martínez-Cañas and Ruiz-Palomino 2010), but the most frequently studied component of intellectual capital in SCPs is technological capital, which has been widely
proxied through the tenant firms’ R&D activities and patenting behavior. Some studies have found that on-park firms outperform off-park firms in patenting outcomes (Squicciarini 2008, Yang et al. 2009) and research productivity (Siegel et al. 2003a), whereas the results derived from other studies do not detect such differentials (Chan et al. 2011, Lindelöf and Löfsten 2002).

Various theoretical explanations have been advanced to account for the fact that SCP membership does not always entail the advantages predicted in terms of performance outcomes or intellectual capital accumulation, such as the excessive dependence on the SCP’s knowledge network (Broekel and Boschma 2012, Howells 2012), the lack of heterogeneous and external knowledge inflows for tenant firms (van Geenhuizen and Soetanto 2012), the unintended dissemination of knowledge between tenant firms (Breschi and Lissoni 2001) or the frictional assimilation of knowledge by tenant firms (Hansson et al. 2005, Schillaci et al. 2012). The first two explanations are rooted in a social network perspective and can be summarized within the problem of over-embeddedness (Andersen 2013) or, more generally, the issue of the optimal level of network embeddedness (Andersen 2011) which also includes the possibility of very low levels of networking and their corresponding disadvantages as regards under-embeddedness. The last two explanations, which are based on knowledge and organizational learning perspectives, revolve around the issue of knowledge stickiness and the problems linked to knowledge transfer such as the unintended dissemination and defective assimilation of knowledge (Villasalero 2013).

The aforementioned explanations only considers the SCP side of the coin and leave aside the university side. In almost all studies in this field of inquiry the universities’ behavior is simply overlooked in order to focus interest on the SCP dynamics as regards either the tenant firms’ behavior or the SCP’s influence on them. Put in other terms, current research into SCPs neglects how the knowledge source’s behavior impacts on the receiver’s knowledge stock. It
is as if all the responsibility for the research-based knowledge transference lies downstream, thus assuming that the upstream source has nothing to do but simply passively play its role of knowledge provider. This biased research trajectory is evident when existing empirical studies are classified according to the unit of analysis (as in Fukugawa 2006: 386), which reveals that the predominant choices are the tenant firm or the SCP with only one study adopting the university as the unit of analysis. In this unique case (Link and Scott 2003) the research question is how having an SCP impacts on the university rather than the other way around, which is the research question posed in this study.

Another related gap in the research on SCPs is that of the theoretical perspective adopted. As indicated previously, social network, knowledge-based and organizational learning perspectives are frequently used in the analysis of the upstream side of the phenomenon. Surprisingly, and despite its notable development in recent years (Chesbrough 2003, 2006, 2011), no attempt has been made to apply an open innovation approach to the analysis of the upstream side, that is to say, the universities’ behavior in innovation-related issues. The two intended contributions of this study are therefore to bring universities back into the picture in the research on SCPs and to do so by adopting an open innovation paradigm.

2.2. Universities strategies for open innovation

The open innovation paradigm advocates a more porous means to allow firms to manage innovations in order to remain competitive in the marketplace (Schroll and Mild 2011). Rather than vertically integrating the production and commercialization of innovations as was the rule in the past, the open innovation perspective considers the advantageous separation of both stages in such a way that firms can innovate by relying on outside technologies and ideas and to make it possible for others to innovate by using the firms’ own technologies and ideas (Villasalero 2014b).
University research-based knowledge is an important external source of innovation for firms in an open innovation context (West and Bogers 2014) since universities are major producers of technologies and new ideas, while they are not interested in the commercialization of the innovations that are based on them to the same degree. Despite the fact that universities around the world are increasingly profiting from research-based knowledge in various ways (Perkmann and West 2014), they are not, nor can nor should probably be, commercial enterprises (Nelson 2001, Sterckx 2011). The imbalanced profile of universities as powerful producers of innovation-related knowledge and poor marketers of commercial innovations leaves room for private firms to tap into university knowledge as a key external source of innovation. In fact, industrial innovation has always been based on academic research, which has also laid the foundations for corporate and government research in some industries (Furman and MacGarvie 2009). Overall, academic research accounts exclusively for more than 10% of corporate innovations and plays a determining role in more than 20% of them, with peak contributions being as high as 25% and 35%, respectively, in industries such as those that produce drugs and medical products (Mansfield 1991, 1998).

The fact that academic research is an external source of innovation for private firms is not new. What is new is the dramatic change in the mechanisms that allow innovating firms to gain access to university research-based knowledge. Before the 1980s, universities hardly had patents, licenses or spin-offs, and even the amounts of R&D contracts were quite modest. From the 1980s onwards, the number of patents, licenses, spin-offs and R&D contracts expanded exponentially around the world, first in the US and later in Europe and Japan. The reasons behind this radical change in the way that universities manage their intellectual capital are somewhat controversial, with some studies adducing normative changes in the intellectual property system such as the Bayh-Dole Act in the US (Fabrizio 2006), others referring to the maturity of some academic disciplines such as biochemistry or computer science (Mowery et
al. 2001, Nelson 2001), and others even attributing it to a more applied orientation in the recent academic research carried out at universities (Cohen et al. 2002, Mansfield 1998). Leaving aside the reasons behind these fundamental changes, this study is interested in their implications for universities and, specifically, how universities confront the issue of managing their intellectual capital and what, if any, the consequences are for private firms that are willing to tap into university knowledge-based research. Using the widely known classification of strategies for open innovation advanced by Dahlander and Gann (2010), according to which the organizations that produce technologies in excess of those which can be commercialized may opt for the pecuniary selling or non-pecuniary revealing of their technological capital, it follows that universities have massively changed from revealing (before the 1980s) to selling (from the 1980s onwards), and that this change has and currently entails considerable implications for those private firms that are seeking to accumulate technological capital from academic research.

2.3. Universities strategies and technology transfer

In accordance with its principles and academic missions (Link and Scott 2003, Sterckx 2011), a specific university may choose a strategy with which to manage its technological capital along the continuum between the extreme positions of pure revealing and pure selling. This choice has implications for the channels and conduits used by private firms to access such technological capital and the predominant form that the technology transfer takes.

The paradigmatic technology transfer channels in a revealing strategy are those of scientific publications and informal interactions. Academic scientists are accustomed to sharing their findings in scientific publications and conferences in the open domain. Evidence suggests that publications and reports represent by far the largest channel through which industrial research benefits from public research, as indicated by 41.2% of industrial R&D managers in a large US sample study. Other non-pecuniary industry-university channels that
are highly related to publications in the open domain include informal interactions and meetings and conferences, which have the second and third largest impact on industrial research. What is more, the flow of recent graduates from universities to industry is also an important non-pecuniary channel (Cohen et al. 2002). These findings are parallel to those obtained from European firms, according to which publications, informal contacts, hiring and conferences are the most important sources of industrial innovation from public research (Arundel et al. 1995). Knowledge spillovers are the mechanism used by private firms to access research findings, prototypes and techniques that are openly available in published research and conferences and are complemented with informal contacts and the recent hiring of university graduates (Salter and Martin 2001).

Alternatively, the paradigmatic technology transfer channels in a selling strategy are those of licensing and contact research. In both cases, the private firms have to pay to access university research-based knowledge, the only difference being whether the knowledge transferred is protectable or non-protectable, respectively. Patents and licenses were considered as significant transfer channels by more than 10% of US industrial R&D managers, whereas contract research and consulting agreements were mentioned by more than 25% of them (Cohen et al. 2002). In a parallel European study, contract research was rated as important by 36% of respondents (Arundel et al. 1995). Knowledge trade is the mechanism used by private firms to access the research-based codified knowledge in the form of patents and licenses, or tacit knowledge in the form of contract research and consulting agreements.

Not only do the transfer channels and mechanisms differ depending upon the revealing or selling strategy adopted by universities in order to manage their intellectual capital, but so do the organizational arrangements set up to intermediate the university-industry relationships. A selling strategy requires the university to have a well-developed TTO in charge of the task
of protecting, marketing and brokering the research-based knowledge in order to generate R&D contract revenues and licensing income (Caldera and Debande 2010).

A revealing strategy, however, involves organizational arrangements that promote knowledge spillovers to interested firms. Research on knowledge spillovers has uncovered that this type of knowledge transfer is unintended, untraded and geographically localized (Salter and Martin 2001). Many studies indicate that the results of academic research do not flow geographically in a regular manner, but tend to be locally concentrated since the tacitness of knowledge requires face-to-face interactions amongst the people who embody the technological knowledge to be transferred (Storper 1995). These interactions are usually untraded, and this creates a social environment in which the reciprocal sharing of knowledge between entrepreneurs and scientists flourishes, thus resulting in place-specific and context-dependent technology transfer flows. Consistent with this view of localized knowledge spillovers, Mansfield and Lee (1996) found that firms which are less distant from where academic research occurs are more likely to be the first to apply the findings of this research than more distant firms. SCPs are among the organizational arrangements that are designed to promote and enhance knowledge spillovers between university research and industrial innovation (Massey et al. 1992).

In accordance with the view described above, in which SCPs are typical organizational arrangements for the fostering of knowledge spillovers and TTOs play the counterpart role for knowledge trade, this study contends that the university contribution to the tenants’ technological capital accumulation cannot be adequately analyzed without taking the university strategy for managing its intellectual capital into account as an endogenous variable (Table 1).
In particular, the adoption of a revealing strategy is predicted to be beneficial for the tenant firms’ technological capital accumulation, whereas the application of a selling strategy is expected to be detrimental. The following two hypotheses are thus put forward:

\[H_1: \text{A university’s revealing strategy has a positive impact on SCP tenant firms’ technological capital accumulation.}\]

\[H_2: \text{A university’s selling strategy has a negative impact on SCP tenant firms’ technological capital accumulation.}\]

3. METHODS

An exploratory testing of the hypotheses was designed by using Spanish SCPs and the universities to which they are affiliated.

3.1. Setting and research design

Two publicly available databases were matched in order to bring university behavior back into the analysis of the relationship between SCP membership and tenant firms’ technological capital accumulation. One database is compiled by the national association of Spanish universities, formally called the Conference of Spanish University Rectors (CRUE), and includes self-reported information on the research and knowledge transfer activities of almost all Spanish universities (CRUE 2011). Another database is elaborated by the national association of Spanish SCPs, formally called the Association of Science and Technology Parks in Spain (APTE), which includes self-reported information on patents granted by the Spanish Patent and Trademark Office (OEPM) to tenant firms located in almost all Spanish SCPs (APTE 2011).

Both databases refer to the year 2010. Although it would have been preferable to introduce a lag between university research and knowledge transfer activities and SCP tenant firms’ patenting outcomes, it was impossible to do so because the latter information was only
available in 2010 and the former information before 2010 is not as complete as in 2010. The use of a contemporary cross-section sample was therefore imposed by data availability.

3.2. Measures

The procedure used to match the two databases was straightforward, resulting in 44 SCPs paired with the corresponding 45 universities to which they are affiliated. The dependent variable is the tenant firm’s technological capital accumulation on the SCP database (APTE 2011) and the independent variables are the research and knowledge transfer activities undertaken by the university to which the SCP is affiliated on the university database (CRUE 2011).

Technological capital accumulation

The patenting performance of SCP tenant firms was used as a proxy of technological capital accumulation. Despite the known shortcoming of disregarding the accumulation of non-protectable technological knowledge, it is a widely accepted measure of technological capital. The final measure is the simple count of the number of patents granted by the Spanish Patent and Trademark Office (OEPM) to the tenant firms sampled.

Revealing strategy

Three indicators were chosen to approximate the level to which a concrete university is committed to a revealing strategy as regards managing its intellectual capital, these being competitive funded research projects, scientific publications and PhD graduates. As indicated above, major channels of university knowledge spillovers to private firms include scientific publications and the recent hiring of university graduates, which are in turn based on the basic research undertaken at the university (Arundel et al. 1995, Cohen et al. 2002, Salter and Martin 2001). Of the three, the most robust measure of knowledge spillovers in the Spanish university system is that of competitive funded basic research, since the distribution of publicly funded
research follows a rigorous and time-consuming procedure that produces highly efficient allocations of funds. The remaining indicators are used with caution in this study, because the number of scientific publications is a gross measure that is unadjusted to the quality of the publication, whereas the number of PhD graduates could make little sense in this study given the scant valuation of PhD degrees in Spain-based industry. They are, nonetheless, retained in this study in order to ensure comparability with similar studies. These three measures were taken from the self-reported figures contained in the university database (CRUE 2011).

Selling strategy

The university’s commitment to a selling strategy was measured by using license revenues, contract research income and the size of the TTO. Given that Spanish universities are just beginning to patent and obtain license revenues, contract research income is a much better indicator of knowledge trade than license revenues in this regard, but the license revenue variable was retained on the grounds of comparability issues. Similarly, TTOs are also widespread organizational solutions that are adopted in the Spanish university system to promote knowledge trade. These three measures were also taken from the self-reported figures provided in the university database (CRUE 2011). The license revenues and contract research income were measured in thousands of euros, while the size of the TTO was measured as the natural logarithm of the full-time equivalent number of employees working in these offices (Caldera and Debande 2010).

Control variables

Three variables were used to control for the varying impact of universities on SCP tenant firms other than those derived from research and knowledge transfer activities. The public or private property, the generalist or polytechnic character and the number of academic scientists of the focal university were considered. The first two variables were dummy variables
indicating whether the university is a private and/or polytechnic university, respectively. The last variable accounts for the scientific size of the university by counting the number of academic scientists. Again, the property and character of the university would be non-meaningful because the numbers of private and polytechnic universities are very small in comparison to other countries’ university systems.

3.3. Statistical analysis

Given that the dependent variable is a count measure (number of patents granted to tenant firms), a negative binomial regression is preferable to an ordinary least square (OLS) regression. The results of the OLS regression are, however, the same as those derived from the best-fitted negative binomial regression (negative binomial parameter free and logarithm linkage function). Since the statistics and goodness of fit tests of the OLS regression are more familiar than those resulting from negative binomial regressions, the former results are subsequently reported in this study in order to facilitate the interpretation of the findings.
4. RESULTS

Multicollinearity is an issue, since some correlations are above 0.4, particularly those representing the university size effect and the polytechnic university effect on the research and knowledge transfer variables (Table 2).

Only two independent variables significantly correlate with the dependent variable SCP tenant firms’ technological capital accumulation, and these are the number of academic scientists and the amount of competitive funding raised for basic research. With regard to the correlations amongst the independent variables, the size effect is that the greater the scientific base of the university, the greater the university research and knowledge transfer outcomes. Both private and polytechnic universities have a well-differentiated profile. Private universities in Spain are smaller, raise less competitive funding for research, publish less scientific findings, educate less PhD graduates and have smaller TTOs than their public counterparts. Polytechnic universities attract greater amounts of competitive funding for research, collect more licensing revenues, have more contract research incomes and have larger TTOs than generalist universities. The potential multicollinearity issue was confronted by inspecting the Variance Inflation Factors (VIF) in the regression models.

The dependent variable technological capital accumulation is regressed in all the variables in Model 1, whereas scientific publications and licensing revenues have been exclude from Model 2 in order to improve the overall goodness of fit and to keep all the VIF values below the 5.0 threshold above which regression estimators become unstable (Cohen et al. 2003). The results from both models are basically the same, with the exception of that of
academic scientists, which attains marginally statistical significance in the best-fitted model (Table 3).

Partially consistent with the first hypotheses concerning the effects of a university revealing strategy, the results show that the amount of competitive funding for basic research raised by the university has beneficial effects on tenant firms’ technological capital accumulation, in contrast with the unexpected negative effect that PhD graduates have on it. The results conform with the second hypothesis which contends that a university selling strategy is detrimental to SCP tenant firms’ technological capital accumulation, with significant and negative signs for contract research income and TTO size.

5. DISCUSSION

Consistent with the literature review, the revealing strategy was proxied by using the amount of funding raised for basic research, the number of scientific publications and the number of PhD graduates. Consistent with the first hypothesis and in conformity with expectations, the amount of funding raised for basic research is the best indicator of knowledge spillovers in this study sample. As indicated in the methods section, the system used to allocate funds to basic research in Spain produces near-efficient results and is thus a good indicator of the level to which a university can contribute toward expanding publicly available scientific knowledge to society. The number of scientific publications did not eventually enter the best-fitted regression model, probably because the measure used failed to adjust for the quality of the publications.

Contrary to the first hypothesis, the impact of the number of PhD graduates has a negative impact on SCPs tenant firms’ technological capital accumulation, which is not, however, an
unexpected result in light of the singularities of the Spanish labor market and university system. In Spain, the fact of being a PhD graduate is of virtually no significance in the labor market, even amongst high-tech firms. As a result, in the last decade most PhD graduates have followed an academic career in universities and research centers rather than breaking into the labor market and spilling leading-edge knowledge regarding scientific findings, modern techniques and prototyping experience amongst employer firms. Rather than promoting knowledge spillovers with PhD graduates, the situation is just the opposite in Spain; most talented people who qualify for a PhD are retained within the university and research system and prevented from going to industrial R&D laboratories. This does not mean that the education of PhD graduates is detrimental to technological capital accumulation or innovation, but that the locus in which these outcomes are collected have, to date, been principally universities, and that the knowledge transfer mechanism based on knowledge spillovers has been fairly limited in this regard. Future studies may investigate whether PhD graduates are more related to the knowledge transfer mechanism based on the knowledge trade in Spain and what, if any, are the effects of the recent incorporations of PhD graduates into the labor market as a consequence of their limited remaining opportunities as regards following an academic career in the current Spanish university system.

The selling strategy was measured by using licensing revenue, contract research income and the size of the TTO. As expected, licensing revenue is still not a good indicator given the limited experience of Spanish universities in this respect and the uneven distribution of licenses and licensing income amongst them. With the exception of polytechnic universities, Spanish universities are just starting to patent and sign licensing agreements, and are therefore quite inexperienced in comparison with their German, Japan and US counterparts. In contrast, contract research income and TTOs are well-developed phenomena in the Spanish university system, thus appropriately representing the emphasis placed by a concrete university on selling
its research-based knowledge. Consistent with the hypothesis, this emphasis is counterproductive to the SCP tenant firms’ technological capital accumulation.

The findings deriving from this study have implications for research on SCPs, intellectual capital and economics of science. The studies on SCPs’ consequences for tenant firms have placed too much emphasis on the SCP side, whilst leaving the university side unexplored (Fukugawa 2006). This study is the first to consider the impact of focal university policies on tenant firms located in the SCP to which that university contributes (Link and Scott 2014). Put in other terms, the recipients (tenant firms; SCPs) are not the only important entities as regards inter-organizational knowledge transfer taking place, and the providers (research groups; universities) are also at least as important as them. The type of multi-level approach adopted in this study is illustrative of the new horizons that may be opened up by combining both sides of the knowledge transfer process and different actors within each side.

Research efforts on intellectual capital and open innovation have remained surprisingly isolated from one another, when they are in fact dealing with a common core issue which is the access to and accumulation of valuable intangible resources. This study shows how the research on the technological component of intellectual capital can be enriched by using an open innovation perspective around the options of revealing and selling (Dahlander and Gann 2010). Future studies may explore the consequences of building technological capital derived from the remaining open innovation options based on sourcing and acquiring.

Although this study focuses on the limited-scope issue of technological capital accumulation within SCPs, its findings are relevant to the so-called economics of science, i.e., how science dynamics impacts on innovation and economic development (Stephan 1996). Central to the present study is the idea that knowledge transfer from universities to interested parties in society can take at least two forms, such as knowledge spillovers and knowledge trade, and that the former is sometimes preferable to the latter. Contrary to the movement which
advocates more applied research and a strong emphasis on technology transfer in universities, the findings derived from the this study indicate that knowledge spillovers are in fact a technology transfer mechanism, something that is usually overlooked by the aforementioned advocates, and is that which renders benefits for private firms when coupled with appropriate organizational solutions such as SCPs. There would appear to be no contradiction between untraded publicly funded basic science in the open domain and an efficient knowledge transfer to make university research-based knowledge a powerful driver of technological innovation undertaken by private firms. In this respect, this study adds to the growing evidence-driven literature that questions whether a strong emphasis on selling technology amongst universities could better serve the interest of economic advancement than their performing the traditional strategy of revealing technologies and retaining their dominant role in the upstream of the science, technology and innovation value chain (Mowery et al. 2001, Nelson 2001, Sterckx 2011).

CONCLUSION

These results support the view held in this study that research on SCPs should consider the innovation-related behavior of the university to which the SCP is affiliated. Given that SCPs are organizational solutions that are designed to promote knowledge spillovers rather than knowledge trade, it follows that a university strategy that stresses the untraded free revealing of academic research has beneficial effects on the SCP tenant firms’ technological capital accumulation. On the contrary, a university emphasis on the knowledge trade by selling its research through well-developed TTOs hampers SCPs as regards meeting their objectives of spreading the university knowledge-based research amongst tenant firms in order for them to accelerate the process of technological capital accumulation.
This study has limitations owing to the secondary databases on which the testing of hypotheses is based. Despite the advantage of relying on objective information from almost all the universities and SCPs in Spain, the data imposed unavoidable restrictions such as those derived from the contemporary cross-sectional design, the limited availability of control variables, the lack of SCP variables other than patents granted to tenant firms and the crude measures of some of the variables. Future studies may supplement the data used in this study with additional secondary databases or even survey information collected from universities, SCPs and tenant firms.

The findings of the study reported herein should be interpreted by bearing in mind that the Spanish university system is, in many respects, singular, i.e., the low proportion of private and polytechnic universities, the atypical profile of private universities, the very early phase that universities are at in terms of patenting, licensing and spinning off, or the scant valuation of PhD graduates amongst firms. Given that most of the studies on technology transfer are based on the US, Central and Nordic European countries and Japan, the results derived from this study provide a different picture of the phenomenon in comparison to those which can be found in other studies and should, in this respect, be viewed within the context described. Future studies may pursue comparisons of multiple countries in order to discern whether technology transfer is notably conditioned by the features existing in each country.
### TABLE 1

**Open innovation strategies used by universities to manage technological capital**

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<tr>
<th>Key Differences</th>
<th>Revealing Strategy</th>
<th>Selling Strategy</th>
</tr>
</thead>
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<tr>
<td>Nature of knowledge transfer</td>
<td>Knowledge spillovers</td>
<td>Knowledge trade</td>
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<td>Logic of knowledge transfer</td>
<td>Non-pecuniary</td>
<td>Pecuniary</td>
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<td>Knowledge transfer channels</td>
<td>Scientific publications</td>
<td>Contract research</td>
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<td>Research projects</td>
<td>Licensing income</td>
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<td>Ph.D. graduates</td>
<td>Spinning off</td>
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<tr>
<td>Position on the value chain</td>
<td>Upstream</td>
<td>Downstream</td>
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<td>Organizational arrangements</td>
<td>Science parks (SCPs)</td>
<td>Technology transfer offices (TTOs)</td>
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## TABLE 2
Descriptive Statistics and Pearson Correlation Coefficients (n=47)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Descriptives</th>
<th>Pearson Correlation</th>
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<td>Mean</td>
<td>SD</td>
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<td>2.</td>
<td>3.</td>
<td>4.</td>
<td>5.</td>
<td>6.</td>
<td>7.</td>
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<td>1. Technological capital accumulation</td>
<td>3.043</td>
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<tr>
<td>2. Private university(1)</td>
<td>.110</td>
<td>.312</td>
<td>.005</td>
<td>1</td>
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<tr>
<td>3. Polytechnic university(1)</td>
<td>.060</td>
<td>.247</td>
<td>-.031</td>
<td>-.090</td>
<td>1</td>
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<tr>
<td>4. Academic scientists</td>
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<td>1,457.819</td>
<td>.315*</td>
<td>-.386**</td>
<td>.138</td>
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<td>5. Competitive basic research funding</td>
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<td>-.346*</td>
<td>.325*</td>
<td>.794**</td>
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<td>6. Scientific publications</td>
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<td>.128</td>
<td>.827**</td>
<td>.670**</td>
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<td>7. PhD graduates</td>
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<td>167.064</td>
<td>.161</td>
<td>-.319*</td>
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<td>.890**</td>
<td>.726**</td>
<td>.776**</td>
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<td>8. Licensing revenue</td>
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<td>83.331</td>
<td>.060</td>
<td>-.167</td>
<td>.586**</td>
<td>.461**</td>
<td>.360*</td>
<td>.424*</td>
<td>.405*</td>
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<td>9. Contract research income</td>
<td>8,549.510</td>
<td>12,328.976</td>
<td>.040</td>
<td>-.224</td>
<td>.642**</td>
<td>.494**</td>
<td>.688**</td>
<td>.452**</td>
<td>.388*</td>
<td>.540**</td>
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<tr>
<td>10. Technology transfer office size(2)</td>
<td>.793</td>
<td>.295</td>
<td>-.057</td>
<td>-.428**</td>
<td>.284*</td>
<td>.503**</td>
<td>.510**</td>
<td>.563**</td>
<td>.503**</td>
<td>.284*</td>
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</tbody>
</table>

** p<.01 (two-tailed); * p <.05 (two-tailed); + p <.10 (two-tailed).

(1) Dummy variable (Kendall and Spearman correlation coefficients provide similar results to those shown).

(2) Natural logarithm transformation to correct for skewness.
<table>
<thead>
<tr>
<th>Effect</th>
<th>Variable</th>
<th>Model 1</th>
<th>Model 3</th>
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<tr>
<td></td>
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<td>Full Model</td>
<td>Best Model</td>
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<td><strong>Control</strong></td>
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<td>3.200</td>
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<td></td>
<td>(0.400)</td>
<td>(.390)</td>
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<td></td>
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<td>0.290</td>
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<td></td>
<td>(0.653)</td>
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<td>1.664*</td>
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<tr>
<td></td>
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<td><strong>Revealing strategy</strong></td>
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<td>(0.889)</td>
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<td><strong>Selling strategy</strong></td>
<td>Licensing revenue</td>
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<td>-1.773*</td>
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<td>(0.737)</td>
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<td>Contract research income</td>
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<td>(0.524)</td>
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<td>Technology transfer office size</td>
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<td>-0.917*</td>
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<td></td>
<td>(0.524)</td>
<td>(0.498)</td>
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<td><strong>Goodness of Fit</strong></td>
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<td>3.562**</td>
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<tr>
<td></td>
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<td>47</td>
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** p <.01; * p <.05; + p <.10
REFERENCES


APTE. (2011), *Patentes en los Parques Científicos y Tecnológicos Miembros de APTE*, Asociación de Parques Científicos y Tecnológicos de España, Málaga.


