Impact on firms of the use of knowledge providers: a systematic review of the literature

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8 June 2013

Impact on Firms of the use of Knowledge Providers: A Systematic Review of the Literature

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Keywords

Impact Assessment, Firms, Knowledge Providers, Collaboration, Innovation, R&D, Industry, Literature Review

Abstract

This study summarizes the main conclusions from a systematic review of the empirical literature regarding the impact on firms of the use of knowledge providers (universities, research institutes and knowledge intensive business services). With the aim to organize the literature, we classify the different works according to the research question addressed: (i) Which firms use knowledge providers?; (ii) Do firms using knowledge providers achieve better results?; (iii) Which firms benefit more from using knowledge providers? Stylized facts are that larger, more R&D intensive and high tech firms are more likely to use knowledge providers and that use of knowledge providers is associated to firms higher technical results. Less attention has been paid to the third question and no stylized facts can be developed on it. Several recommendations for future research emerge. First, to take in greater consideration methodological issues so that potential biases in the results, caused by sample selection and endogeneity, are handled properly. Second, to develop comparative analysis of the differential features of different knowledge providers. Third, to pay more attention to the determinants of impact, and fourth, to take into account depth and breadth of collaborations.

1. Introduction

Firms' direct links with knowledge providers has grown remarkably in the last decades (Amara and Landry, 2005) fostering the interest of academics and policy-makers in this area (Perkmann and Walsh, 2007). On the side of government and policy-makers, several initiatives have been launched for fostering links between firms and knowledge providers (Geroski, 1992; Martin, 1996). As a consequence, these linkages are currently being analyzed and evaluated more systematically to improve political instruments promoting collaboration (Mowery, 1999; Jaffe, 2008). Yet this growing literature is highly fragmented (Lichtenthaler, 2005) and no systematic review has been carried out on their findings and methodological choices.

We analyze how the scientific community has approached the quantitative evaluation of direct linkages between firms and knowledge providers with the triple purpose of (i) developing stylized

facts, (ii) analyze the methodological choices made by researchers and (iii) highlighting avenues for future research.

The term 'knowledge providers' is restricted in this work to those organizations whose direct interactions with firms are focused on the provision of knowledge services. Such organizations can be grouped into three categories: universities, research institutes and knowledge intensive business firms (including consultants)[1].

The method followed is the systematic literature review procedure (Tranfield et al, 2003). A systematic search for articles published on this topic was executed employing specific criteria for inclusion and exclusion of articles in and from the review. A total of 84 articles were finally included. These articles' key information was stored in a data repository specifically designed for recording their characteristics. The articles were then classified into three groups according to the research question they addressed: (i) What are the determinants of the use of knowledge providers?, (ii) Do knowledge providers have an impact on firms' results (and how much impact do they cause)? and (iii) What are the determinants of impact? This strategy allows us developing stylized facts about the benefits achieved by firms using knowledge providers, analyzing the approach followed by researchers to deal with this topic and identifying future areas of research.

The rest of the paper is organized as follows: Section 2 describes the methodology followed in the literature review; section 3 describes the main features of the final dataset of papers; section 4 provides the results from an in-depth review of the papers; and section 5 discusses the main findings and conclusions.

2. Methodology of the literature review

For achieving the goals of this research, a systematic review of the empirical literature was executed. This study followed the procedure described by Tranfield et al. (2003). Overall, the procedure describes three main stages (Table 1). In the first stage the main goal of the research and the review plan are defined. Both of these elements are employed for guiding the execution of the review at all times. In the second stage the articles are selected, classified and reviewed. As a result the information of interest to this research is stored in the data repository for its analysis. Finally, in the last stage, the main conclusions from the analysis of the data repository are presented. For properly synthetizing the content of the articles from the literature review and for avoiding subjectivity, the process for extracting the data was strongly structured: (i) Strict and precise inclusion criteria were employed for selecting the relevant literature and (ii) the key information extracted from papers and used for the analysis was extracted from output tables of

[1] Although customers, providers of goods and machinery, or competitors are also important sources of information for the firms' innovation process, the relationships established are usually not focused on the provision of knowledge services so that they should be analyzed separately

the empirical analyses: Dependent variables, independent variables, coefficients and significance levels.

Table 1 – Systematic Review Procedure

SYSTEMATIC REVIEW PROCESS DIAGRAM		
Stage I – Planning	**Stage II – Executing**	**Stage III - Reporting**
- Identification of the review inquiry - Preparation of the review plan (protocol)	- Identification of studies - Selection of studies - Quality assessment - Data extraction and Data Repository	- Elaboration of the systematic review report (Synthesis) - Recommendations

Source: own elaboration based on Tranfield et al (2003)

2.1 Identification of Studies

In order to fulfill this study objective, it became essential to find a procedure for selecting keywords that would maximize the quality and efficiency of the search. It was necessary to choose keywords that would be (i) relevant for finding articles addressing the utilization of knowledge providers and (ii) precise enough to avoid as much as possible the inclusion of non-relevant publications. The chosen keywords were grouped into four categories (Table 2). The first category was used for grouping keywords referring to impact assessment (C1 – Impact). The second category collected terminology for firms (C2 – Industry). The third group included terms to describe a "utilization" condition (C3 – Relationship). The fourth and final group collected keywords addressing the linking activity (C4 – Activity). Due to the multiplicity of names and terminology given to some knowledge providers, the inclusion of the typology of knowledge providers, as part of the search string, was considered inappropriate.

Like in other studies (Di Stefano et al, 2012) we chose the ISI Web of Knowledge (WoK) for this study. The search string returned a total of 32,542 publications. The list of publications was then narrowed to those articles under the social science category. The total number lessened to 13,895 results. Finally the results were refined by subareas. A total of 32 subareas were included in the search string (see Appendix 2). The final search returned a total of 12,650 publications.

Table 2 – Keywords and Search Strings

CATEGORY	KEYWORDS
C1 – IMPACT	impact* OR assess* OR evaluat*
C2 – INDUSTRY	Firm* OR Enterprise* OR "Private Sector" OR Industr* OR SME* OR Compan*
C3 – RELATIONSHIP	Link* OR Relation* OR Cooperat* OR Collaborat* OR External OR Partner* OR Alliance
C4 – ACTIVITY	Innovat* OR R&D OR research OR transfer* OR support OR consultan*
SEARCH STRING 1 May 31st 2012 32,542 Results	Topic=(impact* OR assess* OR evaluat*) AND Topic=(Innovat* OR R&D OR research OR transfer* or support or consultan*) AND Topic=(Firm* OR Enterprise* OR "Private Sector" OR Industr* OR SME* OR Compan*) AND Topic=(Link* OR Relation* OR Cooperat* OR Collaborat* OR External OR Partner* OR Alliance)
SEARCH STRING 2	Topic=(impact* OR assess* OR evaluat*) AND Topic=(Innovat* OR R&D OR research OR transfer* or support or consultan*) AND Topic=(Firm* OR Enterprise* OR "Private Sector" OR Industr* OR

May 31st 2012 13,895 Results	SME* OR Compan*) AND Topic=(Link* OR Relation* OR Cooperat* OR Collaborat* OR External OR Partner* OR Alliance) Refined by: General Categories=(Social Science)
SEARCH STRING 3 May 31st 2012 12,650 Results	Topic=(impact* OR assess* OR evaluat*) AND Topic=(Innovat* OR R&D OR research OR transfer* or support or consultan*) AND Topic=(Firm* OR Enterprise* OR "Private Sector" OR Industr* OR SME* OR Compan*) AND Topic=(Link* OR Relation* OR Cooperat* OR Collaborat* OR External OR Partner* OR Alliance) Refined by: General Categories=(Social Science AND 32 Sub Areas)

2.2 Selection of studies

Once all results had been collected, they were imported into citation management software – EndNote™ X2. Afterwards, the 12,650 articles' titles and abstracts were reviewed to select those relevant to this study. We wanted eligibility criteria to be as objective as possible. Accordingly, we use the four following criteria that match with our main objective: to review the *quantitative* evidence of the *impact on firms* of their *direct links* with *knowledge providers*.

1. The article must use empirical quantitative methods.
2. The impact must be inflicted upon firms. Hence the unit of analysis is to be the firm itself rather than the sector or geographical region.
3. There must be a direct or formal relationship established between the impact-inflicting and the impact-receiving party (analysis of pure spillovers were excluded)
4. The article must refer to the impact of the use of knowledge providers. The knowledge providers were grouped as: Universities (UNI), Research Institutes (RI) and Knowledge-Intensive Business Firms (KIBS).

A total of 127 articles remained once the title and abstract review had been done.

2.3 Quality Assessment

The 127 articles from the review were fully read and the final sample was reduced to a total of **84** articles. The reason to exclude some articles was that they did not match any of the four criteria, although this was not clear from the abstract. The top motives for exclusion were:

- The utilization of knowledge providers was combined with the utilization of other categories of agents beyond the scope of this research (e.g. customers or competitors). As a result, the impact from knowledge providers could not be disentangled.
- No formal relationships existed between firms and knowledge providers. That is to say, pure spillovers were the focus of the analyses.
- The unit of analysis was not the firm but the knowledge provider, the region or the sector.
- The data analysis was merely descriptive.

2.4 Data extraction and Data Repository

Two types of information from each article were retrieved and stored in the data repository: (i) General data from the articles (year, journal, geographical scope, industrial scope, data source, etc.) and (ii) data from the empirical research executed (method, sample, dependent variables, independent variables, results, etc.). Articles were classified in three different types according to their main purpose: (i) those studying the determinants of the use of knowledge providers (T1); (ii) those analyzing the existence and/or magnitude of different impacts (technical, economic, etc.) on firms from the use of knowledge providers (T2), and (iii) those focusing on the determinants of these impacts (T3). These three types of studies were not mutually exclusive, as some works (around 25% of the sample) addressed several research questions.

The first category – T1 – grouped articles dealing with the characteristics of firms that use knowledge providers. 31 articles were classified as T1. The articles classified into the second group – T2 – were those addressing the existence and/or magnitude of impact on companies out of the utilization of knowledge providers. In other words, these are studies aiming to determine if some indicator of impact differs between user and non-users of knowledge providers. 55 articles were classified as T2. Finally, the third group – T3 – collects articles investigating the characteristics of the firms that influence the impact of using knowledge providers. They focus on investigating which types of firms receive the greatest impact out of the use of knowledge providers. 26 articles were classified as T3. These articles were divided into two subcategories of articles. The first subcategory – T3A – is made up of articles aimed at studying the characteristic of firms affecting the impact of using knowledge providers (16 articles). The second subcategory – T3B – was an indirect result from the review of the articles. It is made up of T2 articles analyzing the impact of using knowledge providers in different subsamples of firms according to some specific characteristics (e.g. small vs. large firms), allowing for indirect determination of characteristics of the firms that influence the impact of knowledge providers (10 articles).

3. Overview of articles resulting from the literature review

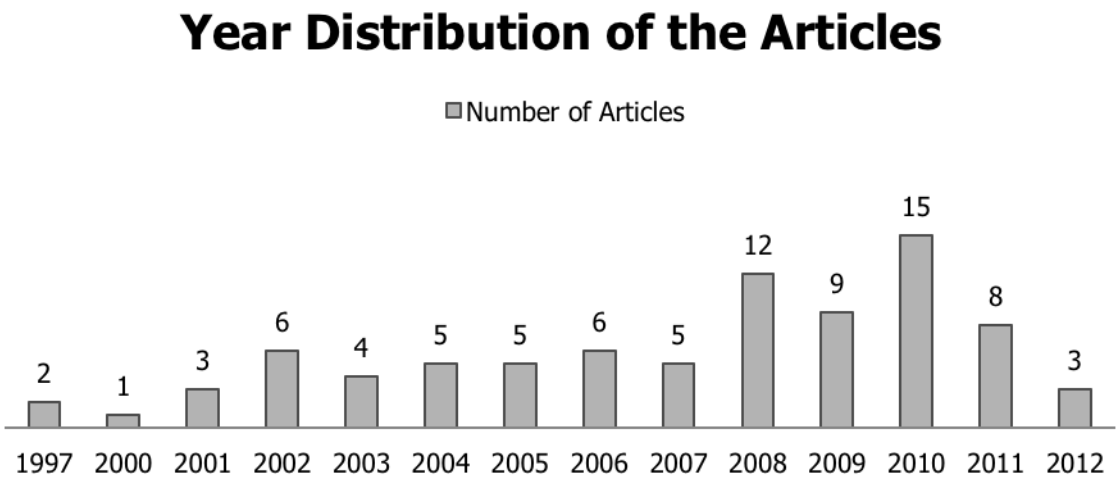
3.1 Year and data of the sample

The sample's year distribution is from 1997 to 2012 (May). Over 55% of the sample is from articles published between 2008 and 2012. Hence most of the articles included in this research are recent studies. The highest percentage of articles in a single year is from 2010 (15 articles, 18%) followed by the years 2008 (12 articles, 14%) and 2009 (9 articles, 11%). The most commonly exploited data sources were Community Innovation Survey (CIS) and other CIS-style[2] surveys (30 articles, 36%). The list of CIS-style surveys is made up of Mannheim Innovation Panel (MIP) from Germany, Panel de Innovación Tecnológica (PITEC) from Spain and surveys from Canada, Korea

[2] Using the Guidelines for Collecting and Interpreting Innovation Data included in the Oslo Manual

and Taiwan. Other surveys employed are Cambridge Business Research Survey (CBR) and Know Survey.

The number of articles published from 1997 to 2001 was very small (always less than 4 articles per year). Between 2002 and 2007, the number of articles rose to 4 to 6 per year. To the end of the time period, it is possible to see an increase in the number of articles published per year. This behavior shows an increasing interest from the scientific community on this topic.



Note: Only 4 months of 2012 were included

3.2 Journals

The articles from the sample were published in a total of 30 different journals. Out of the total list of journals, *Research Policy* is the one with the largest number of articles from the sample (20 articles, 24%) followed by *Technovation* (9 articles, 11%). There are several journals with 4 articles each one (6%).

Table 3 – Most found Journals from the review (3 or more articles)

JOURNAL	ARTICLES
Research Policy	20
Technovation	9
Industrial and Corporate Change	4
International Journal of Technology Management	4
Journal of Product Innovation Management	4
Journal of Technology Transfer	4
Regional Studies	4

3.3 Studied countries and industries

The utilization of knowledge providers was studied in 18 countries, most of which are European. The share of EU countries accounts for 61% of the countries from the sample. Out of the list of EU countries, Spain and UK have the leading position with 16 and 14 articles respectively. The

phenomenon has also been studied several times in US (12% of the articles). From the industry perspective, the study of the impact of the utilization of knowledge providers almost always included firms from manufacturing industries (98% of the articles). Articles addressing exclusively manufacturing firms accounted for 50% of the sample. The service sector was addressed together with the manufacturing sector in 48% of the articles. In only one article the service sector was addressed exclusively (2%). Specific sectors were addresses in 17 articles focusing mostly on medium or high tech manufacturing industries like Pharmaceutical, Electronic, Chemical, Biotechnology and ICT.

4. What is known about the impact on firms of the use of knowledge providers?

As explained before, the articles resulting from the review of the literature were grouped into three categories: T1, T2 and T3. The grouping criteria depended upon the focus of the study regarding the utilization of knowledge providers. More precisely, three different research questions were considered: (i) What kinds of firms do use knowledge providers? (ii) Do firms benefit from using knowledge providers? (iii) Which firms receive more impact?

4.1 What kinds of firms do use knowledge providers?

About 37% of the articles from the review were classified into T1 (31 articles). Out of the 31 articles from T1, 48% melted different knowledge providers together. For example, research institutes and universities were considered as a single type of organization. Another 35% analyzes the determinants of just one knowledge provider each. Finally just 16% compares the determinants of using different types of knowledge providers. All in all, universities were included in 24 articles (77%), research institutes in 21 articles (68%) and KIBS in 9 articles (29%)

The exploited **databases** are mostly made out of data from surveys like CIS, MIP, KNOW, CBR or public agency surveys. CIS is the most frequently exploited one (32%). For the **sample characteristics**, 94% of studies use cross-section data and 6% of studies use panel data. With respect to the *sample size*, there are a couple of figures to talk about. First, the total number of firms from the sample (N) and, second, the total number of firms from the sample using knowledge providers (n). The total sample *N* varies from a few hundred to several thousand firms. The largest samples are often from articles using CIS. On average, the sample is made out of approximately 2.274 firms. The subsample *n* is on average 43% of *N*. As well as the total sample *N*, the largest values from *n* are used in articles with data from CIS. On average, *n* is made out of 749 firms.

An important methodological issue is the potential existence of sample selection as samples are usually composed of innovators or R&D performers. If this is the case, results should not be generalized to the whole population of firms unless this selection issue is dealt with, something that none of T1 studies does.

In these studies **dependent variables** (Yi) are indicators of utilization. In most cases the indicator is a binary variable tracking whether the firm had some kind of link with knowledge providers (87%). The few articles employing continuous variables used value or the number of R&D projects, the number of links between the firm and knowledge providers and R&D monetary amount spent on knowledge providers, as a share of total R&D expenditure. Regarding **independent variables** (Xi), we grouped them into (i) those referring to characteristics of the firm and (ii) those addressing firms' motives for using knowledge providers. The 97% of the articles from T1 assess variables related to characteristics of the firm. Articles studying the motives for using knowledge providers stand for 32%. Each of these groups is described in following sections.

4.1.1 Main studied characteristics for using knowledge providers

The most frequently studied characteristic of the firms using knowledge providers is the ***Size*** (23 articles). Size is studied employing both continuous (84%) and discrete (16%) variables. Out of the studies using continuous variables, the most frequently employed indicators are the *logarithm of the total number of employees* (32%), *total number of employees* (29%) and *logarithm of sales* (6%). In the case of discrete indicators, they are grouped using values either from predefined ranges (6%) and quartile position (10%) of the number of employees of the firm. Regardless of the indicator type, the results are conclusive: Firm size influences the utilization of knowledge providers in a positive, statistically significant, way.

STYLIZED FACT 1: The size of the firm positively affects the utilization of knowledge providers

The second most studied characteristic is ***R&D Activity*** (20 articles). This characteristic is studied employing several types of indicators. 65% employ continuous indicators, using R&D employees or R&D expenditure. Out of the articles using discrete indicators (50%), over half of them target *Continuity* and *Ocurrence* of the research and/or innovation activity (30%). Regardless of the indicator, results agree that the influence of R&D activity for the use of knowledge providers is positive and statistically significant.

STYLIZED FACT 2: Internal R&D Activities positively affects the use of knowledge providers

The firm's ***Industry*** is the third most studied characteristic of the firms using knowledge providers (11 articles). Out of the indicators assessed, the most frequently employed industry taxonomies are OECD's (63%) and Pavitt, K. (1984) (18%). The rest of articles use industry dummies or address specific industries. As mentioned in previous sections, the articles usually evaluate manufacturing firms. Due to the convergences from the OECD and Pavitt taxonomy in their way of classifying industrial sectors, the results from both taxonomies are compatible. It is possible to

state that as the technological level of the firm' industry increases, so does the utilization of knowledge providers[3].

STYLIZED FACT 3: The technological level of the firm's industry positively affects the use of knowledge providers

The rest of the characteristics are not studied as often as the previous ones. However some of them are worth mentioning. *Education Level of Employees*, *Education Level of Executives*, *Export Activity* and *Public Subsidies* usually show positive coefficients[4]. Finally, when *Foreign* firms are distinguished, no statistically significant effect is found.

4.1.2 Main studied obstacles for innovation that motivate using knowledge providers

There are other indicators dealing with the use of knowledge providers but they are not strict characteristics of the firm. These indicators analyze the effect of the main obstacles for innovation on the utilization of knowledge providers (10 articles). These obstacles are studied using discrete variables. Out of these indicators, *Cost* (60%) and *Risk* (50%) are the most often studied ones. These two obstacles, and specially *Cost*, positively affect the use of knowledge providers.

STYLIZED FACT 4: Cost of the innovation process positively affects the use of knowledge providers

4.2 Do firms benefit from using knowledge providers?

Examining the benefits for firms using knowledge providers is the most frequently studied topic in the literature. A total of 55 articles address this topic. Likewise in articles from T1, most studies address the joint impact of several types of knowledge providers (58%). In most cases the combined impact of utilizing universities and research institutes is studied (49%). Only in a few of articles the impact of these two knowledge providers is assessed together with the utilization of KIBS (11%). In the articles studying the impact of knowledge providers individually (42%), the impact from universities is the most frequently evaluated one (31%). The individual impact of using research institutes (13%) or KIBS (11%) is hardly studied. All in all, universities are studied in 49 articles (89%), research institutes in 39 articles (71%) and KIBS in 11 articles (20%).

The **databases** exploited are mostly from surveys like CIS, MIP, CBR or public agency surveys. CIS is the most frequently utilized source of data (31%). The most commonly employed waves are from 1998 – 2000 and 2002 – 2004.

Regarding the **sample characteristics**, cross section data are used by 76% of the studies and panel data by 24%, being time dimension quite short (from two to five waves). In relation to the

[3] Note that this stylyzed fact is different from the previous one as there are R&D intensive firms in low tech sectors and vice versa (Barge-Gil et al, 2011).

[4] Note that some of the public subsidies *require* the firm to cooperate in order to be eligible for the aid

number of firms, the total sample (N) varies from figures close to one hundred to over five thousand firms. On average the value of N is 1.637 firms. The number of firms using knowledge providers (n) is on average 53% of N (591 firms).

In T2 studies, a very important issue to deal with is that of endogeneity. The decision to establish a link with a knowledge provider is potentially endogenous. That is, it is likely to be correlated with unobserved factors that also influence firms' results (e.g. 'managerial ability'). If this is the case and endogeneity is not taken into account, results will be biased. Despite the great importance of endogeneity issues in recent economic and managerial literature, they have seldom been addressed by T2 studies. Only three studies (Arvanitis et al, 2008; Eom et al, 2010 and Cummings and Fisher, 2012) have addressed endogeneity. The three of them used instrumental variable methods although they do not provide much discussion on the instruments selected and why they can be considered exogenous[5]. In these studies the main **independent variable** captures the link between the firm and the knowledge providers. In most cases, discrete variables are employed (85%). In the few cases where continuous variables are utilized (15%), the indicators refer to *the number of co-publications*, *the number of partnerships* or the number hours of interaction with knowledge providers.

Finally, **dependent variables** (Yi) are indicators of impact. Up-to 30 different impacts were assessed and 117 impact indicators analyzed in the sample of articles from T2. To simplify the analysis of the vast number of assessed impacts, they were grouped into three categories, following Barge-Gil and Modrego (2011). The first category is *Technical Impacts*. This category groups the studied technical outcomes of the utilization of knowledge providers, such as new products, new processes or patents. The second category is *Economic Impacts*. This category gathers the evaluated outcomes from the use of knowledge providers on the economic figures of the firm, such as sales, profits or productivity. The third category – *Investment Impacts* – collects those assessed impacts from using knowledge providers that change the resource allocation behavior of the firm, for example R&D or capital investments.

4.2.1 Main studied impacts out of the use of knowledge providers.

The most frequently assessed impacts are **Technical Impacts** (34 articles). These impacts are mainly studied using discrete and binary indicators (79%). The impacts evaluated are mainly: *Product Innovation* (35%), *Patenting* (32%), *Process Innovation* (18%) and *Degree of Novelty* (9%). The results are mostly positive and statistically significant (77%) with only 9% of the

[5] Nieto and Santamaria (2010) test for endogeneity and do not reject exogeneity on the collaboration. Frenz and Ieto-Gilles (2009) acknowledge the problem and the difficulty to find valid instruments so that they decide to address it by using lags of collaboration variables. Finally, Fabrizio (2009) uses a fixed effects regression to control for time-invariant unobserved heteroegeneity as a robustness check.

studies finding negative results[6]. The results are predominantly significant for *Product Innovation and Patenting*.

STYLIZED FACT 5: Utilizing knowledge providers positively affects Technical Results

The second most frequently studied impacts in the literature are **Economic Impacts** (32 articles). The economic outcomes from using knowledge providers are assessed employing mainly continuous indicators (78%). The economic impacts most studied in the literature are *Innovation Sales, Sales and Added Value*. For *Innovation Sales* (53%) the results are mostly positive (71%), usually statistically significant (53%). When the impact is found to be negative (29%), it is significant in 12% of the sample (2 articles)[7]. In the case of *Sales* (22%), the results are always positive (100%), but only 43% of them are statistically significant. For *Added Value* (19%), the results are again positive (100%), with 34% of them being statistically significant (34%). Evidence on the association between using knowledge providers and economic results is not conclusive. A positive association is more usually found when *Innovation Sale* is analyzed rather than *Sales*.

The third most commonly studied impact of using knowledge providers is **Investment Impacts** (7 articles). These impacts are assessed using only continuous indicators. The addressed impact is *R&D Expenditure*. The use of knowledge providers has a positive (86%), usually statistically significant impact (71%)[8],

STYLIZED FACT 6: Using knowledge providers has a positive association with Investment Impacts

4.3 Which firms receive a greater impact?

One recent trend in impact evaluation literature is in the analysis of heterogeneous effects. That is, the consideration that some firms may benefit more than others from using knowledge providers. Articles classified as T3 focus on analyzing firms' characteristics influencing the intensity of the impact inflicted by knowledge providers. Only 31% of the sample was classified as T3 (26 articles) accordingly, the articles aiming to explore the determinants of the impact are the least frequent ones in the literature. In addition, types of analyzed impacts in T3 study vary a lot so that generalization of results is not possible.

In contrast to the previous categories, in T3 most articles study knowledge providers separately from one another (65%). In these articles, the determinants of the impact of firms using universities are the most studied ones (34%). The 23% study the determinants of the impact of firms using KIBS. The remaining 35% of articles from T3 study a combination of different types of

[6] These three studies refer to New Patents in the pharmaceutical industry, Early-termination of R&D projects financed under the NIST program in USA and New Products and Processes in manufacturing SMEs from UK, respectively. In all three articles the knowledge provider are Universities

[7] Both studies take place in Taiwan and analyze low- and medium-technology sectors from the same sample.

[8] The only exception to this statement (negative although non-significant) in a work focused only on biotechnology firms. Possibly because this is a sector that already dedicates a large amount of resources to R&D with low inter-firm variation of R&D

knowledge providers. Out of these articles, the determinants of the impact of firms using either universities or research institutes are the most studied ones (27%). The other 2 articles evaluate the determinants of the impact of firms using any type of knowledge provider within the scope of this research (8%).

The **databases** employed in the articles from T3 are mostly from independent surveys (12 articles, 46%). Other surveys like CIS (9 articles, 35%) and CBR (3 articles, 12%) were commonly exploited as well. About the **firm sample**, cross section data are used by 88% of the articles and panel-data are used by 12%. About the *number of firms*, the number of firms from the sample (N) is on average 1.553 firms. The subsample of firms using knowledge providers is in average 687 firms. The subsample *n* is about 50% of *N*.

Again, selection issues are very important in these types of studies. If the sample is composed only of firms with links with knowledge providers, results should not be extended to the whole population of firms unless this selection issue is dealt with, something that none of T3 studies does.

4.3.1 Main studied determinants of the impact of knowledge providers

The ***Size*** of the firm is the most frequently studied determinant of the impact of knowledge providers (12 articles). Different impact indicators were evaluated in several articles so that the total number of evaluations was 46. Results were usually statistically non-significant (70%). *Size* is found to be positive and significant in 23% of the evaluations while negative and significant in 7% of the evaluations. It is worth noting that samples are usually selected (e.g., only SMEs) and, when using discrete indicators, the definition of size groups differs considerably across studies.

R&D Activity is the second most studied determinant of the impact of utilizing knowledge providers (10 articles). It was evaluated on 36 occasions using different impact indicators. Different proxies for R&D activity were used (R&D Expenditure / Sales, R&D Employees / Employees, R&D Expenditure / Employees, R&D Activity and R&D Experience). In 47% of the evaluations the results are statistically non-significant. In 31% of the evaluations the results are positive and significant. Negative and significant results are found on 22% of the occasions.

The third most studied determinant is the ***Industry*** of the firm (6 articles). It was evaluated on 21 occasions (due to sectoral comparisons). Discrete and binary variables are used in all articles. In 47% of the evaluations, the results were positive and statistically significant. Positive, non-significant results accounted for the 43% of the evaluations. Significant and negative results were found in the 10% of the evaluations.

Some more determinants were studied. In most cases they were studied in a single article, so it is not possible to extract any conclusion or assessment out of them. Also the number of characteristics of the firms assessed is considerably lower in T3 studies than the number of characteristics studied in articles from T1. Therefore, the study of the determinants of the impact

of knowledge providers is in need of further research in order to generalize results and to investigate the role played by other firms' characteristics different from size, R&D and industry.

5. Discussion and Conclusions

Nowadays it is possible to evidence an increasing interest of the scientific community and policy-makers over the links between firms and knowledge providers (Amara and Landry, 2005; Perkmann and Walsh, 2007). Due to an increasing number of public initiatives to foster these links (Geroski, 1992; Martin, 1996), they are more frequently assessed (Mowery, 1999; Jaffe, 2008). In this study, we carried out a systematic review of this literature with the triple purpose of: (i) developing stylized facts, (ii) analyze the methodological choices made by the researchers and (iii) highlighting lines of future research.

Regarding the first purpose, we can classified empirical evidence according to the type of research question addressed by the different works: (i) What are the determinants of the use of knowledge providers?, (ii) Do knowledge providers have an impact on firms' results (and how much impact do they cause)?, and (iii) What are the determinants of impact?

The more stable results belong to studies aiming to answer the question: What kinds of firms do use knowledge providers? Size, R&D intensity and technological level of the industry positively influence the use of knowledge providers. It should be however highlighted that empirical studies have disproportionally focused on the likelihood of use rather than on the breadth and depth of use. Some authors have pointed out that the influence of these variables on intensity of use could be different; being the smaller and less R&D intensive firms those using more intensively external resources (Barge-Gil, 2010).

Regarding the impact of the use of knowledge providers, the stylized facts are that the utilization of knowledge providers show a positive relationship with technical impacts, such as new products and processes, and with investment. However, no robust evidence of a positive relationship with economic results is found, especially if total sales (rather than innovation sales) are analyzed. As in the previous group of studies, attention has been mainly focused on the existence of use of knowledge providers and not in the breadth and depth of use. Their inclusion on future works could be helpful in solving the controversies found. In addition, little attention has been paid to intangible impacts.

The answer to the question of which firms receive a greater impact from knowledge providers is still to be developed. In a world of heterogeneous outcomes it is increasingly important to understand under which circumstances links succeed or fail. However, fewer studies have addressed it and their results are far from conclusive. Besides the smaller number of studies, this could be explained because, on the one hand, samples are often selected (for example, including only SMEs or firms with R&D activity) and this selection is not accounted for so that populations differ across studies. On the other hand, discrete indicators are often employed and the definition of size (or R&D) groups differs across studies. In addition, different contexts or knowledge

providers have been analyzed. As a result, heterogeneity across studies is too high to develop stylized facts.

Regarding the second purpose, our analysis focused on existing biases caused by methodological issues, lack of comparison among knowledge providers and countries and industries analyzed.

First, the great majority of studies show important methodological shortcomings. More precisely, they do not account for issues of sample selection and endogeneity. Samples are usually selected in some way (for example, by including only innovative firms, only SMEs or only firms using knowledge providers). Sample selection may prevent results to be extended to the whole population of firms unless selection is addressed. In addition, endogeneity is usually not taken into account. This is a very important issue when assessing the existence of impact. Firms using knowledge providers could obtain better economic or technical results even if they had not utilized knowledge providers because some unobserved factors (e.g. managerial ability) could influence both the utilization of knowledge providers and the results from innovation processes so that coefficients would be biased. Many studies seem to be unaware of this problem, while others acknowledge it and a few of them try to address it by using instrumental variable methods. However, even these studies lack appropriate discussion of instruments' validity. Accordingly, and despite the fact that only the most robust empirical facts have been reported here, caution is suggested when interpreting the results from the previous literature as causal effects.

Second, an important drawback from the empirical literature is that in almost all articles the assessment is done without comparing different knowledge providers. The joint analysis of partner types and firms characteristics is a very important matter for both managers and policy makers. On the one hand, managers are in need of assistance regarding the selection of the most suitable partner among the available ones. On the other hand, as the 'one size fits all' approach has proved unsuccessful (Tödtling and Trippl, 2005), policy makers require guidance about (i) the complementarity or substitutability amongst different knowledge providers and (ii) the most appropriate choices according to which type of firms they are addressing. For example, Barge-Gil et al, (2011) find that smaller, non-R&D intensive firms are less likely to cooperate with universities and more likely to cooperate with technology institutes, because they are closer to them in several dimensions (technological, organizational, cultural).

Third, studies have mainly focused on manufacturing industries in developed countries. Very few studies address the services sector independently, despite its growing importance in modern economies. In addition, most studies are concerned with European countries (possibly due to information availability) and, to a lesser extent, USA, Canada and some Asian countries, such as Taiwan, China and Korea. Thus, little evidence was found concerning the impact of the use of knowledge providers for firms from developing countries.

Above results suggest important lines for future research. First, to take in greater consideration methodological issues so that potential biases in the results, caused by sample selection and

endogeneity, are handled properly. Second, to develop comparative analysis of the differential features of different knowledge providers. Third, to pay more attention to the determinants of impact, and fourth, to take into account depth and breadth of collaborations.

To sum up, attention on the utilization and impact of knowledge providers on firms have increased in recent years. This effort has allowed us to develop stylized facts regarding which firms are more likely to use knowledge providers and the average effect of utilization of knowledge providers on technical and economic results of firms, but nor on the characteristics of firms moderating impact neither on the differential effect of different knowledge providers. Empirical evidence is still to be developed on this topic, which is of great practical importance both for guiding managerial decisions and policy initiatives.

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7. Appendix

7.1 List of articles from the Literature Review

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7.2 List of Search String subareas

Agriculture

Automation & Control Systems

Biotechnology & Applied Microbiology

Business & Economics

Chemistry

Communication

Computer Science

Construction & Building Technology

Demography

Education & Educational Research

Energy & Fuels

Engineering

Environmental Sciences & Ecology

Fisheries

Food Science & Technology

Government & Law

Information Science & Library Science

International Relations

Instruments & Instrumentation

Materials Science

Medical Laboratory Technology

Nuclear Science & Technology

Operations Research & Management Science

Physics

Public Administration

Science & Technology - Other Topics

Social Issues or Geography

Social Sciences - Other Topics

Sociology

Sport Sciences

Telecommunications

Urban Studies