The relationship between universities and business: identification of thematic communities[1]

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Abstract

This article analyses the link between universities and business from a neo-Schumpeterian evolutionary theory perspective. It aims to identify the thematic communities present in the literature that deals with the university-business relationship, highlighting the focuses of interest of this literature and currently emerging themes. Social network analysis and text mining tools are used for this purpose. The present contribution differs from other reviews by using large datasets, which made it possible to discern aggregate trends in scientific output. Six thematic communities were detected in the literature: technology parks, entrepreneurial university, triple helix, transfer channels, geographic perspective and open innovation. Once these communities were defined, the characteristics of each one were identified, along with their linkages, differences and limitations, with a view to gaining an understanding of the knowledge transfer processes.

Keywords

Knowledge management, universities and colleges, industrial sector, intellectual cooperation, scientific literature, data analysis, statistical methodology

JEL classification

C80, C88, L20, L24, 032, 050

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I. Introduction

There are many studies of the university-business relationship that address the specific forms in which knowledge transfer occurs (Bozeman, 2000; Siegel and others, 2003), analysing its aggregate impact and role in promoting development (Drucker and Goldstein, 2007; Hessels and Van Lente, 2008).

This article seeks to identify different thematic communities present in this literature, based on a bibliometric analysis. The term "thematic community" is used here to refer to a group of contributions to the field of study that: (i) resemble each other in terms of the set of bibliographic references to which they refer; (ii) are nourished by a shared lexical repertoire; (iii) address the same issue or subject; and (iv) tend to be discursively related to each other by alluding to a distinctive set of dominant ideas or motifs. The study addresses the following research questions: What thematic communities can be identified through a bibliometric analysis of the literature on relations between universities and enterprise? What are the specific (identity) characteristics of each community? What type of communicating channels and dialogues can be identified between them through time?

The article's main contribution relative to previous research in this field is the use of large volumes of data that make it possible to examine aggregate trends in scientific output. Unlike most previous studies, which conduct either reviews (Bozeman, 2000; Perkmann and others, 2013; Drucker and Goldstein, 2007; Geuna and Muscio, 2009; Salter and Martin, 2001; Uyarra, 2010; Smith, 2007; Hessels and Van Lente, 2008), traditional bibliometric analyses (Abramo and others; Calvert and Patel, 2003), or small network analysis (Meyer and others, 2014; Randhawa, Wilden and Hohbergeret, 2016; Teixeira and Mota, 2012), this article draws on a large corpus of literature to identify different thematic communities that emerge from the network of contributions.

Section II of this article describes the theoretical framework in which the study is approached. Section III presents the methods used to detect the emergence of thematic communities in the study of the university-business relationship, namely social network analysis and text mining. Section IV presents the descriptive statistics of the corpus, and section V deploys content analysis to identify the predominant conceptual dimensions in each community. Section VI discusses linkages and differences between the communities in terms of the set of analytical dimensions they give rise to. Lastly, section VII presents the conclusions.

II. Theoretical framework

The aim of this paper is to understand the multiple and varied mechanisms through which knowledge is transferred in the university-business relationship. Given the complex and evolutionary nature of the knowledge generation derived from this linkage, the article is framed by three complementary theoretical approaches: the Schumpeterian and evolutionary approaches and complexity theory.

Specifically, the corpus of the university-enterprise relation can be characterized as a network with multiple nodes (authors and contributions), in which connections are based on the co-occurrence of bibliographic references. There are also hierarchies (the position of contributions in the thematic network) and relationships between epistemic communities.

To understand this dynamic, the concepts of "creative destruction" and "emergence of innovation" will be adopted in the framework of a competitive process derived from the Schumpeterian approach. Analogously, it is posited that the evolution of the different thematic communities in the study of the university-business relationship can be viewed as the result of competition between academic contributions. This dynamic gives rise to a new body of knowledge and diminishes the relevance of other contributions. Within this competitive process, different communities emerge that provide new interpretations and explanations of the university-enterprise relationship, while others lose explanatory power.

This theoretical approach is complemented by the evolutionary legacy perspective (Nelson and Winter, 1982; Langlois, 2003; Metcalfe, 2010; Nelson, 2003), which makes it possible to account for the competitive dynamics that exist between the different interpretations of the relationship between universities and firms. These dynamics, centred on variation, selection and retention processes, foster the emergence of explanations (contributions) that have more followers and greater presence and dynamism in the network.

The two legacies —Schumpeterian and evolutionary— are combined with the complexity perspective, which analyses systems formed by heterogeneous components (in this case, contributions to the literature on the relationship between university and business). The interaction of the different nodes (contributions), located in a network of connections with nonlinear relationships, reveals emergent properties, understood as diverse ways of interpreting the relationship (Kirman, 1997; Dopfer, Foster, and Pottset, 2004; Hodgson, 1998; Potts, 2001; Dosi, 1982; Metcalfe, Foster, and Ramloganet, 2006; Antonelli, 1999; Edquist and Hommen, 1999; Robert, Yoguel, and Lerena, 2017).

In this framework, to understand the emergence of, and changes in, the weights of the different thematic communities studying the university-business nexus, it is necessary to consider the following dimensions specifically: (i) the evolutionary path of institutions and organizations involved in knowledge transfer (Rosenberg and Nelson, 1994); (ii) the deepening of the division of labour in production, the appropriation of knowledge (Langlois, 2003) and the organization of technological knowledge production (Antonelli, 1999); (iii) the strategies deployed by firms to increase internal and external knowledge absorption capacities (Cohen and Levinthal, 1990); (iv) the ability to link with other agents that produce technological knowledge (Robert and Yoguel, 2010); (v) the degree of development of social technologies (Nelson and Sampat, 2001); (vi) the academic capacities of universities (Liefner and Schiller, 2008; Mansfield and Lee, 1996) for establishing linkages with the production sector in innovation projects; (vii) the supply of skilled labour from universities to firms (Salter and Martin, 2001; Lundvall, 2010; Metcalfe, 2010); and (viii) the design of science and technology policy (Rosenberg and Nelson, 1994; Lundvall, 2010; Metcalfe, 2010).

In this context, the characteristics of the linkages between universities and firms, and the way in which each contribution captures, describes and analyses the phenomenon, are fundamental for understanding the emergence of thematic communities. Far from being evident from the outset of the research, these communities emerge from the set of interrelationships that exist between the contributions (nodes) that make up the corpus. This gives rise to the generation of structures that model an idiosyncratic network architecture, which evolves over time and may result in the emergence of new communities. Linkages can also be conceptualized on the basis of relationships between authors and between communities through time. These dynamics relate directly to the "evolution" concept, insofar as they imply the selection and emergence of contributions in the network.

III. Method

The method used to identify thematic communities is based on social network analysis and text mining. Social network analysis is compatible with a complex-systems perspective, since it makes it possible to identify communities in the network of contributions, based on the structure of their linkages. These linkages are derived both from the relational data present in the bibliographic references and from the terminology appearing in the textual content of the contributions. Whenever contributions in the network have incomplete linkages, a structure emerges with a non-trivial configuration. This particular structure makes it possible to detect distinct communities through social network analysis.

Text mining, in contrast, is based on automated analysis of textual data and seeks to extract key concepts or significant relationships from large corpuses. Using these techniques, a bibliometric mapping was performed of the different communities or thematic areas that predominate in research into the university-business relationship.

The data source used was the Scopus repository, which encompasses more than 22,600 journals with external referees, books and publications in other media. A search was made for all contributions that included the university-industry syntagm in any part of the text, or at least one of the following three terms: linkage, transfer and interaction.

The results were restricted to the disciplines of management, economics and social sciences. The disciplinary boundary was determined so as to fit the theory that frames the research question. This was a methodological decision based on three factors. First, the relationship between the university and enterprise is an interdisciplinary research problem; so restricting the search to academic output in economics would be at odds with the nature of what is being studied. Secondly, such a decision would mean denying the strong roots that neo-Schumpeterian evolutionism has in the discipline of management, thus contradicting the theoretical framework that has been adopted. Strictly speaking, neo-Schumpeterian evolutionary economics has been in dialogue with researchers in both economics and management since its origins (Nelson and Winter, 1982; Nelson, 1991). Lastly, inclusion of the social sciences among the selected disciplines not only reflects the authors' quest to build an interdisciplinary corpus of studies on the relationship between the university and business, but is also in conformity with the methodology adopted in this study. This implies the creation of a network that is sufficiently open and complex for unforeseen results to emerge. This is only possible if a more general discipline is incorporated, which includes contributions produced outside the familiar field of economics.

The search yielded a set of 6,794 contributions. For each one, the abstracts, bibliographic references and a set of additional metadata were downloaded, including the title, author, source, publication date, and the number of citations received in Scopus. For this purpose, two Elsevier application programming interfaces (APIs) were used, which provide access to curated data.[2]

Of the 6,794 original contributions, records that did not include bibliographic reference data were discarded. Then, contributions that did not cite, or were not cited by, others were also eliminated, leaving 5,917 contributions published between 1981 and 2017.

Next, the similarity between two contributions i and j was measured using the Salton index (Salton and McGill, 1983):

$$P_{ij} = \frac{C_{ij}}{\sqrt{s_i \cdot s_j}} \quad (1)$$

where C_{ij} is the number of common elements in the references of contributions i and j; s_i is the number of references cited by i; and s_j is the number of references cited by j.

A reference co-occurrence analysis (Kessler, 1963) was performed using the UCINET 6 software for the analysis of social network data (Borgatti, Everett and L. Freeman, 2002). The references-documents matrix consisted of 5,917 contributions and 239,681 unique references, so its processing involved the calculation of nearly 1.5 billion possible combinations and almost 1 million edges.

Communities were detected using the Gephi network analysis software (Bastian, Heymann and Jacomy, 2009), in which the modularity tool is based on the Louvain algorithm. This algorithm seeks to determine the optimal number of partitions, such that the modularity index is maximized (Blondel

[2] The data were downloaded between 18 and 22 September 2017. Further details on the method implemented in this study are provided in Lerena (2019).

and others, 2008). The modularity index of a partition is a scalar between -1 and +1 that measures the density of linkages within communities, versus the density of linkages between them. For a weighted network, the modularity index is:

$$Q = \frac{1}{2m}\sum_{ij}\left[A_{ij} - \frac{k_i k_j}{2m}\right]\delta\left(c_i, c_j\right) \quad (2)$$

where:

A_{ij} represents the weights of the edges between nodes i and j; k_i is the sum of the weights of the edges associated with node i; c_i is the community to which node i is assigned; the function δ takes the value 1 if $c_i = c_j$ and 0 otherwise; and $2m$ is the sum of the weights of all edges. Using this algorithm, six thematic communities were detected in the corpus.[3]

Using the titles and abstracts of the contributions, a word co-occurrence analysis was performed in each of the detected communities. The VOSViewer software and the similarity measure known as association strength (Van Eck and Waltman, 2010) were used for this. The similarity s_{ij} between two items i and j was calculated as:

$$s_{ij} = \frac{c_{ij}}{w_i w_j} \quad (3)$$

where cij denotes the number of co-occurrences of items i and j; and wi and wj denote the total number of occurrences of items i and j, respectively.

IV. Descriptive statistics

Of the 6,794 contributions obtained, 5,231 (77%) are journal articles, 1,155 (17%) are books or book chapters, and 408 (6%) are contributions in other media.[4] The results include articles published in 977 scientific journals. Of the journals identified, 53% are associated with a single contribution. This suggests that more than half of the articles on the relationship between universities and business were not published in journals specialized in this thematic area. The 10 journals with the most contributions account for over 29% of the total number of articles in the database.

Based on social networks and an analysis of the co-occurrence of terms through text mining, six thematic communities were identified: (i) technology parks; (ii) entrepreneurial university; (iii) triple helix; (iv) transfer channels; (v) geographic perspective; and (vi) open innovation.

Just over 13% are contributions that are cited once only. The top five contributions in terms of the number of local citations, weighted by age, are shown in table 1. The term "local citation" means the number of times a contribution has been cited by others in the total network of 5,917, whereas "global citation" is the total number of citations reported by Scopus for each work.[5] As can be seen in table 1, the five contributions with the most local citations have a local-to-global citations ratio above 50%, which indicates that they are referenced more within the network than outside it. This pattern suggests that it is a cohesive network; in other words, the links that the contributions have inside the network are stronger than those that they have outside it.

[3] In this article, the term "corpus" refers to the 5,917 contributions that make up the literature on the relationship between universities and business.

[4] The descriptive statistics refer to the complete set of contributions obtained from the Scopus search.

[5] Local citations were weighted by age to make it possible to compare contributions without penalizing those published more recently.

Table 1
Five contributions with the most local citations, weighted by age
(Number of citations per year)

Classification	Contribution	Journal or book	Citations per year	Local/global citations *(percentage)*
1	"Academic engagement and commercialization: a review of the literature on university–industry relations" (Perkmann and others, 2013)	*Research Policy*	41.2	76
2	"University-industry linkages in the UK: What are the factors underlying the variety of interactions with industry?" (D'Este and Patel, 2007)	*Research Policy*	31.5	87
3	"University entrepreneurship: a taxonomy of the literature" (Rothaermel, Agung and Jiang, 2007)	*Industrial and Corporate Change*	27.8	62
4	"University-industry relationships and open innovation: towards a research agenda" (Perkmann and Walsh, 2007)	*International Journal of Management Reviews*	26.6	74
5	"Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: an exploratory study" (Siegel, Waldman and Link 2003)	*Research Policy*	24.7	68

Source: Prepared by the authors, on the basis of data from the corpus obtained at Scopus.

For each thematic community, table 2 shows, the percentage of contributions with respect to the total corpus, the period of publication, the most frequent researchers, the journal with the highest occurrence of publication, the most cited article and contributions from developing countries.[6]

Table 2
Main features of the thematic communities identified

	Technology parks	Entrepreneurial university	Triple helix	Transfer channels	Geographic perspective	Open innovation
Number of contributions (% of corpus)	210 (4)	757 (13)	1 378 (23)	1 040 (18)	1 291 (22)	1 241 (21)
Period of publication (average length of time in years)	1981–2017 (11)	1995–2017 (6)	1987–2017 (7)	1987–2017 (8)	1981–2017 (8)	1990–2017 (7)
Most frequent researchers (occurrences as first author)	Mian, S. (5) Schwartz, M. (5) Minguillo, D. (4)	Siegel, D. (10) Wright, M. (9) Guerrero, M. (8)	Etzkowitz, H. (30) Leydesdorff, L. (24) Bozeman, B. (8)	Mowery, D. (17) Azagra Caro, J. (10) Thursby, J. (10)	Huggins, R. (13) Cooke, P. (13) Leydesdorff, L. (11)	Carayannis, E. (12) Santoro, M. (11) Wang, Y. (9)
Most frequent journal (occurrences)	*Technovation* (32)	*The Journal of Technology Transfer* (70)	*Scientometrics* (96)	*Research Policy* (129)	*Research Policy* (81)	*Research Policy* (64)
Main contribution by degree of entry (indegree)	"Science parks and university-industry interaction: geographical proximity between the agents as a driving force" (Vedovello, 1997)	*Academic entrepreneurship: University Spinoffs and Wealth Creation* (Shane, 2004)	"The norms of entrepreneurial science: cognitive effects of the new university-industry linkages" (Etzkowitz, 1998)	"Assessing the impact of organizational practices on the relative productivity of university technology transfer offices: an exploratory study " (Siegel, Waldman and Link, 2003)	"Science-based technologies: university–industry interactions in four fields" (Meyer-Krahmer and Schmoch, 1998)	"Knowledge networks as channels and conduits: the effects of spillovers in the Boston biotechnology community" (Owen-Smith and Powell, 2004)
Authors from developing countries	Zhou, Xu and Manyike (2013)		Cassiolato and Lastres (1997), Brisolla (1998), Arocena and Sutz (2001), Eun, Lee and Wu (2006)	Giuliani and Arza (2009), Arza (2010), Dutrénit, De Fuentes and Torres (2010)	Sutz (2000), Corona, Doutriaux and Mian (2006), Lenger (2008)	López-Martínez and others (1994), Prabhu (1999), Numprasertchai and Igel (2005), Caetano and Amaral (2011), Guan and Zhao (2013)

Source: Prepared by the authors, on the basis of data from the corpus obtained at Scopus.

[6] The human development index (HDI) (UNDP, 2018) was used to identify developing countries. Developed countries were those with an HDI of at least 0.847. Thus, the list comprises 42 developed countries (the last of which is Portugal) and 147 developing ones.

V. Content analysis: thematic communities of the university-business relationship corpus

This section analyses the content and conceptual dimensions that predominate in each thematic community, based on the results of the bibliometric study.

1. Technology parks

This community, although the oldest on average, is also the smallest in terms of volume of contributions (see table 2). Technovation articles predominate. The oldest contribution (Brown and O'Brien, 1981) was published when some universities in the United States and Europe began to venture into the incubation of technology-based enterprises to participate in territorial economic development (Mian, 1997).

Technology parks are conceived as a defined space for interaction between universities and firms, where the latter —consolidated businesses, spin-offs or start-ups— are key agents for the commercialization of basic and applied research generated by universities. In this sense, the parks are considered important spaces (Vedovello, 1997) for firms to access research results through informal links that enable them to valorize the knowledge generated by researchers.

After the 1990s, this thematic community lost relevance in studies on the university-business relationship. This can partly be explained by the criticism of technology parks as relevant sources of technology transfer, and the questioning of their effectiveness in promoting innovation or joint research between scientists and entrepreneurs.

2. Entrepreneurial university

The entrepreneurial university community draws on contributions from strategic management, economics and network theory (Rothaermel, Agung and Jiang, 2007). Despite being the community with the youngest average age in the corpus (see table 2), it enjoyed rapid dissemination in the late 1990s.

The entrepreneurial university phenomenon was boosted in the United States by the enactment of the Patent and Trademark Amendments Act 1980 (the Bayh-Dole Act), which had significant effects in terms of the commercialization of intellectual property and other forms of university technology transfer (Siegel and Wright, 2015).[7] The emergence and expansion of this thematic community was largely due to a defensive strategy in the absence of formal research funding.

Although university technology transfer offices focused initially on issuing licenses and patents, this model influenced the emergence of start-up firms (Shane, 2004) and had positive effects on basic research in universities (Siegel and Wright, 2015). Interaction with biotechnology, nanotechnology and information and communication technology (ICT) start-ups located at the technological frontier kept the academic agenda up to date.

More recently, the entrepreneurial university model has evolved from a role based on technology transfer offices, in which the main objective was to commercialize the intellectual property generated at the university, to the formation of a new institutional framework known as the "entrepreneurial ecosystem". This shift involves a greater weight of incubators or business accelerators and science and technology parks to support technology transfer and the emergence of entrepreneurship centres (Siegel and Wright, 2015). Thus, there has been a shift from visualizing the university-enterprise relationship in terms of affiliates and intellectual property revenues, to considering it in terms of start-up businesses.

[7] The Bayh-Dole Act gave universities and research and development institutions in the United States the right to retain ownership of inventions.

3. Triple helix

In the framework of a new form of interaction between universities, firms and government, external funding for university research has increased since the 1980s, as part of a paradigm known as the "triple helix" (Etzkowitz and others, 2000). This is the community with the most contributions and the oldest average age (see table 2). The triple helix refers to a government strategy aimed at stimulating cooperation between universities and firms in creating and commercializing intellectual property, based on joint research and development (R&D) processes.[8]

It is postulated that the circulation of scientists, professionals and technicians belonging to each of the helixes is a key factor for the creation, circulation and appropriation of knowledge; and that it represents a new division of labour that requires specialists to act as interfaces.

From this standpoint, university research teams involved in interaction processes can be viewed as quasi-firms. These endeavour to capitalize knowledge by converting research results into a "club" type of good that allows its members to access rents. The helixes generate alliances and consortia, as well as a continuous division of labour among them, which manifests itself in out-of-equilibrium dynamics (Etzkowitz and others, 2000).

This new type of cooperation goes beyond the traditional function of the university, centred on research and human resource training. Changes in the financing of basic and applied research —in conjunction with budget constraints and increased private funding— are accompanied by a retargeting of research projects towards solving problems of industry and society. This change in the social contract is reflected in a loss of autonomy for researchers, and has given rise to differing views of the validity of the triple helix: both critical (Rosenberg and Nelson, 1994) and optimistic (Feller, 1990; Kleinman and Vallas, 2001).

4. Transfer channels

This community addresses the issue of knowledge transfer, also called the universities' "third mission" (Cohen and others, 2002; D'Este and Patel, 2007), and it studies the channels of public-private interaction. The most frequent channels are informal contacts, professional mobility, attendance at conferences, consultancies, technical assistance and joint research projects.[9] This transfer dynamic requires organizational changes and technological integration processes in both universities and firms.

In the seminal works of this line of research, the idea of academic engagement represents inter-organizational collaboration between universities and firms, involving direct interactions between actors (Rosenberg and Nelson, 1994; Srinivas and Viljamaa, 2008; Perkmann and others, 2013). This type of collaboration, which can be traced back to the American universities of the mid-nineteenth century, was confined to transfer, human resource training, consulting, training courses, research contracts, and problem solving.

In addressing the determinants of transfer, several contributions highlight the importance of non-institutionalized relationships; and they suggest that direct linkage with individual researchers may be more effective than transfer through research teams. The academic characteristics —both environmental and institutional— and the organizational practices of the universities to which they belong are key factors in explaining their performance (Siegel and others, 2003; Siegel, Waldman and Link, 2003; D'Este and Patel, 2007).

[8] The distinctive term "research collaboration" expresses these interactions.

[9] The publication of scientific texts should be added to this list of transfer channels, since "publication" is a distinctive term in the scientific community.

Much of this literature (Mansfield and Lee, 1996; Schartinger, Schibany and Gassler, 2001; Mowery and Sampat, 2004) argues that the set of channels used is biased in terms of the number of participating researchers: while most researchers are not linked, a small proportion collects most of the transfers.

Some contributions from this community (Rosenberg and Nelson, 1994; Dasgupta and David, 1994) approach the transfer from the perspective of different modes of organizing scientific research. The former provide a critical discussion of the literature that had proposed aligning knowledge from academia with the needs of industry, on the basis of institutional reforms that in practice restricted the researchers' independence from the firms.

Dasgupta and David (1994), meanwhile, analyse the institutional and normative features that characterize open science, and show that, although the reward system based on college reputation worked reasonably well, it entails various inefficiencies in the allocation of basic and applied scientific resources.

5. Geographic perspective

This literature uses a systemic approach to address the various modalities of technology transfer from universities to firms, which take place in geographically defined environments: local districts, regions or nations. The specifics of local environments shape the knowledge transfer process and influence its potential to promote systemic development.

Although this thematic community proclaims the proximity between university and business, the proximity to which it refers extends beyond the geographical dimension to also encompass cognitive aspects (Boschma and Frenken, 2010). Thus, a critical mass of firms in science-based sectors interacting with universities can lead to the formation of a regional system based on specific analytical knowledge (Asheim and Coenen, 2005).

At the same time, some contributions warn of problems that could potentially arise from excessive proximity between universities and business. For example, when analysing the capital goods industry in Germany, Meyer-Krahmer and Schmoch (1998) detect lock-in effects, which result in reduced openness to new technologies and are attributed to the stability of the sector and the long-standing links between firms and universities.

There is also evidence that regional knowledge spillovers occur depending on the number of firms, proximity to universities and local research capabilities (Audretsch and Lehmann, 2005). Despite the widely accepted idea that the economic benefits of public funding for research generate spillovers and localization effects, these can only be appropriated under specific technological, sectoral and knowledge-type conditions (Salter and Martin, 2001). Although advocates of the university focused on basic research see a trade-off between entrepreneurial activities and the volume of scientific texts published, Van Looy and others (2004) report experiences in which these activities complement each other.

6. Open innovation

This thematic community is the second most recent in the corpus of literature analysed. The thematic affinity between the older contributions of the group and the more recent literature on open innovation is evidenced by a distinctive set of terms.[10]

The increasing mobility of knowledge workers, the rise of the Internet, venture capital and the greater availability of potential external suppliers are some of the factors invoked to explain the emergence of open innovation (Giannopoulou and others, 2010; Lee, Ohta and Kakehi, 2010).

[10] Conceptually, this literature is closely intertwined. Some contributions highlight its "outward" linkages with other more traditional currents, such as those of regional innovation systems (Cooke and Leydesdorff, 2006) and national ones (Cooke and Leydesdorff, 2006).

This literature highlights the permeable nature of enterprise boundaries, which enables a constant knowledge flow. Within this framework, it analyses linkages with external sources of knowledge, based on cooperation with partners. This can take various forms, such as bilateral collaboration, innovation ecosystems and networks. The valorization of knowledge and its subsequent commercialization depend on endogenous business capabilities, the incorporation of external knowledge and collaboration networks.

The practice of open innovation brings with it a specific division of labour: it requires firms to valorize their formal innovation projects and make them available to other actors, such as competitors, suppliers, customers, venture capitalists and public research organizations. Although the focus is often on larger firms and knowledge-intensive sectors such as biotechnology (Owen-Smith and Powell, 2004), relationships can also involve small and medium-sized enterprises (SMEs) (Lee, Ohta and Kakehi, 2010) and traditional sectors (Spithoven, Clarysse and Knockaert, 2010).[11]

These dynamics require actors to have a minimum threshold of absorption capacities (Lane, Koka and Pathak, 2006) to be able to make linkages. Thus, the presence of intermediary institutions can be decisive (Spithoven, Clarysse and Knockaert, 2010) for small firms and traditional sectors, which often need support to establish linkages. The creation of new linkages can expand absorption capacities in these firms and trigger a virtuous feedback loop.

Intellectual property is a central pillar in this community; so open innovation enables firms to benefit from the assets of their partners, including their reputation and their relationships with investors. Thus, as participation in inter-firm alliances becomes increasingly important, distributed co-creation practices and collaboration with customers increase trust between actors and become a core value (Santoro and Saparito, 2003; Giannopoulou and others, 2010). However, contracts are often insufficient to ensure that the firm can appropriate the value of its innovation. In particular, firms no longer leave their inventions on the shelf simply because they cannot commercialize them themselves (Giannopoulou and others, 2010). On the contrary, they must engage in careful management of intellectual property in order to strategically exploit their own knowledge and the innovations of other firms (Giannopoulou and others, 2010).

VI. Discussion

This article has identified six thematic communities in the literature on the university-business relationship: technology parks, entrepreneurial university, triple helix, transfer channels, geographic perspective and open innovation.

Table 3 schematically displays the main differences and similarities between these thematic communities in terms of the research question, the prevailing theoretical framework, the focus of analysis, the lead actor in the relationship, the conceptual linkages between communities, and the role played by the new division of labour in the type of cooperation that is established.

In each of the thematic communities, dominant theoretical approaches coexist with a minority of critical contributions. In the case of the technology park community, the prevailing theoretical framework reflects neoclassical assumptions because the development of these parks can be understood as a response to the generation of spillovers in the context of market failures. For its part, the entrepreneurial university community has a pragmatic approach and bases its proposals on an eclectic theoretical perspective. The triple helix community involves a third actor —the government— the analysis of which requires a systemic theoretical framework, such as the innovation systems approach.

[11] The term "coopetition" is often used to refer to cooperation strategies that include participation by a competitor as a partner (Carayannis, Alexander and Ioannidis, 2000).

Table 3
Thematic communities: similarities and differences in several key dimensions

	Technology parks	Entrepreneurial university	Triple helix	Transfer channels	Geographic perspective	Open innovation
Research question	Limitations of spillovers generated by universities	Role of the university in economic development	Role of the actors involved in the new division of labour	What are the relevant transfer channels?	Regional and sectoral specifics explaining the transfer process	Role of stakeholder capabilities in an open innovation process
Theoretical framework	Neoclassical	Pragmatic, eclectic	Innovation systems	Evolutionary	Evolutionary economic geography	Evolutionary
Focus of analysis	Market failures	University involvement in the development	Interaction between university, business and government	Capabilities and connectivity in the university-industry relationship	Technology transfer based on geographic, cognitive, social, institutional and organizational proximity	Openness of research and development (R&D) projects of companies with partners
Actor assuming leadership	Technology parks and universities	Universities	Universities, business and government	Universities and companies	Regions and sectors	Firms
Conceptual linkages between communities	Entrepreneurial university	Technology parks, triple helix	Entrepreneurial university	Open innovation, entrepreneurial university	Open innovation	Transfer channels, geographic perspective, triple helix
Role of division of labour	Not relevant	Intellectual division of labour	Changes in the functions of each helix	Not relevant	Geographically bounded	Centralized in the firm and partners

Source: Prepared by the authors, on the basis of data from the corpus obtained from Scopus.

The other communities (transfer channels, geographic perspective and open innovation) are closer to the evolutionary theoretical framework discussed. In the transfer channels community, the contributions inquire about the presence or absence of capabilities and linkages between universities and firms. This community suggests that the predominant channels are not based on the generation of start-ups, licences or patents. The geographic perspective community, in contrast, is interested in technology transfer based not only on geographic proximity but also on cognitive, social, institutional and organizational proximity. Lastly, the open innovation community studies the co-evolution and synergy between the capacities of organizations, the connections between them and the mechanisms of open innovation. In all three communities (transfer channels, geographic perspective and open innovation), the spillovers generated by economic engagement —materialized in transfer mechanisms or in the generation of research activities themselves— are not considered a market failure. On the contrary, spillovers are a positive aspect of the generation and circulation of knowledge and rent capture by firms in the competition process.

Much of the evolutionary literature stresses the need to view the link between the university and the firm as a deepening of the division of labour, in a context in which the generation and appropriation of knowledge are becoming increasingly important for developing competitive advantages and appropriating quasi-rents (Nelson and Sampat, 2001; Langlois, 2003). However, these issues are not discussed in all communities. For example, since technology parks are designed to take advantage of knowledge spillovers, the analysis of the division of labour is not a frequent approach. In the entrepreneurial university community, another perspective on the division of intellectual labour is raised, focused on bringing universities and firms closer together, by virtue of the former's new entrepreneurial role. The triple helix community, for its part, highlights the importance of synergies in the division of labour and the interaction between university, business and government, as well as the geographical and entrepreneurial aspects that condition them. This issue is not considered in the community transfer channels because it focuses on the predominant types of channel. Lastly, the division of labour is bounded regionally in the geographic perspective community and acquires a new central role in the open innovation community, owing to the significant weight of the firms that open their research and development (R&D) projects to the partners.

With respect to developing countries, from the perspective of the technology park community, there is a weak link between national innovation systems and production structures. In the case of the entrepreneurial university community, the main constraints are underestimation of the importance of forming skilled human resources to improve enterprise capacities (Nelson and Sampat, 2001; Salter and Martin, 2001; Lundvall, 2010) and the failure to consider the importance of teaching and research as pillars of university modus operandi.

For its part, the triple helix community has been addressed by the literature of developing countries, especially in Latin America, since the mid-1990s (Arocena and Sutz, 2001; Brisolla, 1998; Casas Guerrero, 1997; Cassiolato and Lastres, 1997; Sutz, 2000; Vessuri, 1995). Criticisms of this approach can be summarized as follows: (i) there is a weak demand from firms for knowledge-intensive activities, partly owing to the nature of the predominant pattern of production specialization; (ii) under these conditions, the university-helix may have more linkages with helixes located in developed countries than with national ones; and (iii) the reduction in the public budget for science and technology, the increase in private financing and the pressures for universities to earn income from intellectual property have impaired the interaction between universities, government and enterprise in Latin America.

In contrast, the transfer channels community describes transfer processes in developing countries that go beyond patents, start-ups and licensing. The contributions originating in this community include Giuliani and Arza (2009), Arza (2010) and Dutrénit, De Fuentes and Torres (2010), who analyse transfer channels as a contribution to the design of institutional policies. The focus of interest is on issues such as the determinants of the formation of "valuable" links, the risk-benefit calculus associated with the different channels of public-private interaction, the relationship between the channels of interaction involved and the differential benefits perceived by the agents (researchers and firms) in the transfer processes.[12]

The geographic perspective community emphasizes that the relationship between universities and enterprise is mediated by the characteristics of the production specialization profile and by the small share of knowledge-intensive activities. Lastly, the open innovation community notes the reduced absorption capacities of firms in developing countries, the limited connectivity and the scant development of open innovation activities, which is compounded by the weakness of the networks to which the firms belong.

VII. Closing remarks

This article has explored the main trends in the literature on the relationship between universities and business in the last 20 years. Using a methodology based on social network analysis and text mining, it considers recent developments through a large corpus of literature. Six thematic communities are identified and analysed on the basis of a neo-Schumpeterian evolutionary conceptual framework extended with complexity. As stated in the theoretical framework, major differences and heterogeneities were found among the six communities identified. The study focused on a set of key characteristics in each community, to expose the linkages, counterpoints and constraints that these communities reveal, in order to understand the processes of knowledge transfer, both globally and in developing countries.

The set of communities, and especially the open innovation, triple helix and geographic perspective communities, make it possible to consider the relationship between universities and business from the neo-Schumpeterian evolutionary theory framework. These analyse the relationship as mechanisms of exchange, transfer and diffusion of knowledge through non-linear linkages that generate positive exchanges between the parties, beyond the production of spillovers, or as a strategy for universities to allocate funds to their research projects.

[12] In contrast to the dominant literature, which considers university-business linkages as beneficial per se, "valuable" linkages are those with the greatest potential to disseminate knowledge to other firms in the regional economy (Giuliani and Arza, 2009).

Another common characteristic of these communities is that they allude to processes of deepening the division of labour that give rise to the appropriation of knowledge and the obtaining of quasi-rents from innovation. Moreover, these transfer mechanisms require the development of social technologies to enable the flow of knowledge between the university and the firm.

The identification of thematic communities makes it possible to understand knowledge transfer between universities and firms, and, at the same time, to highlight the different science and technology policy guidelines that could emerge in each community. While the technology parks community prioritizes the need to foster the appropriation of knowledge spillovers generated in the link between universities and firms and in start-up incubation, the entrepreneurial university community recommends the creation of universities that emphasize entrepreneurial functions related to basic research. Especially since the passage of the Bayh-Dole Act in the early 1980s, these trends have been accentuated; and participation by scientists in the commercialization of patents and licenses, and in the emergence of start-ups, has become central.

The triple helix community highlights the need for a systemic approach, in terms of the capabilities of the helixes and their connections and in relation to the overlap between the functions of each one. In contrast, the transfer channels community shows the need to connect research groups, stimulate informal channels and focus on channels that are not centred on patents, start-ups and licenses. Lastly, the technology parks community focuses its recommendations on the need to increase capacities and linkages at the regional and sectoral levels; while the open innovation community proposes to operate on the determinants of capacities, encouraging open innovation processes and network formation.

Much of the literature on the university-business relationship has emerged and disseminated since the mid-twentieth century in developed countries. The results of this research indicate that in the last two decades an uncritical adoption of these contributions has prevailed in developing countries, although some exceptions can be identified.[13] In general, the literature has not considered the specifics of emerging countries, which tend to have patterns of production specialization characterized by weak interaction between firms, universities and public agencies, as well as low thresholds of technological knowledge. There is also large cognitive distance between the university and the private sector, weaknesses in science and technology infrastructure, and firms with low R&D-oriented absorption and linkage capacities.

The identification and evolution of the different thematic communities that represent the link between the university and enterprise express the evolutionary path of the institutions and organizations involved in the dynamics of technological change. Thus, each community contains its own questions regarding the way in which universities and firms address the demands of competition and institutional change. One of the distinctive aspects of each community is the role assigned to technological and organizational capacities, and the type of linkages that exist among of the agents involved in generating and appropriating knowledge. The degree of complexity of the relationship depends, in turn, on the predominant specialization profile, the regime of incentives facing the universities and firms, and the resources and dynamic capacities that both actors develop over time.

[13] See, for example, Suzigan and Motta and Albuquerque (2008).

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