

The Impact of Research-Based Spin-Offs Companies as Knowledge Conveyers in Innovation Networks

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Abstract: The increase in the number of spin-offs has led to the growth of the research to understand the performance of these companies and to assess their impact. The literature shows that RBSOs are characterized by the science-based nature of the knowledge being exploited, the close relationship with the parent organisation, and specific firms' internal features. Given the particular characteristics of these firms measuring their impact by traditional indicators, such as employment and turnover, are insufficient. The various empirical studies focus on the one hand on the impact of spin-offs firms on research organizations, in particular on Parent institution and on the other hand on its economic and regional impact. It is considered that the RBSOs impact is more clearly expressed through the value they create in knowledge and innovation networks, as agents of knowledge acquisition, transformation and diffusion. However the potential role of RBSOs as an intermediary between academia and industry is much less discussed. The objective of this paper is to address this gap, contributing to understand whether RBSOs are effectively acting as knowledge dissemination mechanisms, through their position in innovation networks. For this purpose, the paper investigates the innovation networks established by RBSOs, at national and European level. In order to address this question, we conduct an analysis of the formal innovation networks established by Portuguese RBSOs in the context of collaborative research, technology and product development (RTD) projects, between 1992 and 2014, drawing on two sets of data: collaborative RTD projects funded by national support programmes and conducted in Portugal (Innovation Agency database) and joint RTD projects conducted in the context European Framework Programmes (CORDIS database). All the projects with spin-off involvement were identified; totalling 453 projects identified which represent 504 participations by RBSOs, (278 participations in Portuguese projects and 226 participations in European projects). The analysis addresses the formal innovation networks formed in the context of these projects, focusing on partner composition. It compares the composition of the national and European knowledge innovation networks (overall and for specific industries) in order to understand: i) whether they differ and along which dimensions; ii) whether it is possible to discern specific patterns of behaviour among RBSOs that suggest the presence of different strategies and roles. The results provide some indications towards the extent and nature of RBSOs role as knowledge conveyors and the forms this role assumes in national and international innovation partnerships.

Keywords: spin-offs, innovation networks, knowledge dissemination, inter-firm relationships

1. Introduction

Research-based spin-off companies (RBSOs) - i.e. companies set up for the commercial exploitation of knowledge produced in research organisations - have recently become one focus of S&T and innovation policies (Mustar et al, 2008; Perez and Sanchez, 2003; Wright et al, 2007).

The increase in the number of spin-offs has led to a growing research to understand the performance of these companies and to assess their impact (Mustar et al, 2006; O'Shea et al, 2008; Wright et al, 2007). The literature shows that RBSOs are characterized by the science-based nature of the knowledge being exploited, the close relationship with the parent organisation, and specific firms' internal features, such as the high scientific qualifications of the human capital and a frequent absence of business competences and experience (Djokovic and Souitaris, 2008; Helm and Mauroner, 2007; Mustar et al, 2006; Phan and Siegel, 2006).

Given the particular characteristics of these firms, measuring their impact by traditional indicators, such as employment and turnover, are insufficient. The various empirical studies focus on the one hand on the impact of spin-offs firms on research organizations, in particular on parent institution, assessing their entrepreneurial competences and reputation (Slavtchev, 2013; Semadeni and Cannella, 2011) and on the other hand on its economic and regional impact (Bathelt et al, 2010; Buenstorf and Geissler, 2011).

It is considered that the RBSOs impact is more clearly expressed through the value they create in knowledge and innovation networks, as agents of knowledge acquisition, transformation and diffusion (Autio, 1997; Fontes, 2005; Harrison and Leitch, 2010; Perez and Sanchez, 2003; Walter et al, 2006). However the potential role of RBSOs as an intermediary between academia and industry is still underexplored.

The objective of this paper is to address this gap, contributing to understand whether RBSOs are effectively acting as knowledge dissemination mechanisms, through their position in innovation networks, and which is the organisational reach of their activities.

For this purpose, the paper investigates the innovation networks established by RBSOs, both at national and international levels. Previous research focusing exclusively on national innovation networks, linked to national funding programmes, has found that Portuguese RBSOs often played a role as bridges between academia and industry, by partnering with organisations located downstream in the value chain, or connecting between these and research organisations, in tripartite relationships (Conceição et al, 2015). Thus one central objective of this paper is to understand whether and to what extent this role also takes place in international networks, namely those resulting from EU funding programmes.

In order to address this question, we conduct an analysis of the formal innovation networks established by Portuguese RBSOs in the context of collaborative research, technology and product development (RTD) projects, between 1992 and 2014. The research is based on a self-collected data set that encompasses the known population of RBSOs created in Portugal until 2007 (327 firms). To identify the formal networks established by the RBSOs, the paper draws on two sets of data: collaborative RTD projects funded by Portuguese support programmes (Innovation Agency database) and joint RTD projects conducted in the context European Framework Programmes (CORDIS database). All the projects with spin-off involvement were identified; totalling 453 projects identified which represent 504 participations by RBSOs, (278 participations in Portuguese projects and 226 participations in European projects).

The analysis addresses the formal innovation networks formed in the context of these projects, focusing on partner composition. It compares the composition of the national and European innovation networks (overall and for specific industries) in order to understand: i) whether they differ and along which dimensions; ii) whether it is possible to discern specific patterns of behaviour among RBSOs that suggest the presence of different strategies and roles.

2. From academia to Industry – the role of spin- offs

2.1 The nature of RBSOs technological relations: “Bridging” between organisations?

Research-based spin-offs perform an important role in the transfer of academic knowledge to the society (Bathelt et al, 2010; Helm and Mauroner, 2007). In fact, RBSOs are set-up to commercially exploit the results of academic research, transforming it in technologies, products or services and making them accessible to the society. Moreover, if successful in their endeavour, RBSOs are likely to continue to co-create knowledge for innovation with research organisations, due to the fact that their competitiveness is dependent on high-level scientific capabilities and on the renewal of their knowledge base (Owen-Smith and Powell, 2004), and to act as sources and disseminators of new knowledge over time.

For analytical purposes, the transfer process enacted by RBSOs can be thought as a two-stage process. The first stage involves the interaction between the research organisation and the new firm, to support the further development of the knowledge that is being commercialised as part of the spin-off process; or to joint-develop new or complementary knowledge in areas relevant for the firm. Therefore it involves upstream relations with research organizations. The second stage involves the search for and interaction with potential users of the technology or its applications, and therefore downstream relations, in order to gain a better understanding of market needs and requirements; and/or to gain access to complementary competences and resources. Although the latter are more frequently related with business and market development, relationships may also concern the development of new technological knowledge in areas that are critical for the success of the innovation and that go beyond the spin-off frequently specialised competences (Colombo et al, 2006).

These stages can overlap, i.e. these processes may take place simultaneously in the context of tripartite relationships that involve research organisations, spin-offs and other firms. Research conducted on this type of alliance has found the existence of some division of work between these actors (Stuart et al, 2007). For instance, Hess et al (2013) concluded that in alliances between spin-offs, industry and academic partners, the members had well-defined roles in the innovation process. In fact, product needs, access to markets and industrialisation ability were brought into the alliance by the industry partner, while the spin-off delivered the agility and speed connected to in-depth technology know-how, plus its academic network, providing access to laboratories and relevant technology expertise.

The effectiveness of RBSO as a "bridge" between academia and the industry depends on entrepreneurial actions, such as opportunity identification, risk taking, resource mobilisation that can be more effectively achieved through networks (Grandi and Grimaldi, 2003; Walter et al, 2006). The capacity to establish external networks is presented as a competitive advantage of new high-technology firms, supporting the discovery of opportunities, the access to a variety of resources and collaborative learning with partners (Grandi and Grimaldi, 2003; Sousa and Fontes, 2012; van Geenhuizen et al, 2014).

The analysis of the role of RBSOs in innovation networks requires not only the consideration of interactions in the vicinity, namely with the parent organisation, but also the consideration of their eventual international technological relationships (Capaldo et al, 2015). This is true both for upstream relations and downstream relations. In the first case, research has already shown that RBSOs source knowledge from geographically distant locations (Fontes, 2005; Fontes and Sousa, 2016). In the second case, it has been shown that the majority of technology-based firms sells to international markets, requiring interaction with foreign actors to gather knowledge of these markets (Kirwan et al, 2006).

Research also stresses that the need for and the intensity of the technological relationships and the composition of resulting innovation networks can vary between firms, namely that the patterns of interaction between academy and industry depend on the scientific fields (Schartinger et al, 2002). It has also been shown that the innovation process, and thus the type of knowledge and knowledge exchanges required to achieve it, are strongly shaped by firms and industries specific knowledge bases (Asheim and Coenen, 2005; Plum and Hassink, 2011). As a result, the configuration of innovation networks established by new technology-intensive firms was found to differ between industries (Salavisa et al, 2012). These differences are likely to be pertinent in the case of RBSOs, which are not necessarily a homogeneous group (Cunha et al, 2013), affecting both the relevance of a continued collaboration with research organisations, and the intensity and type of technological relationships they establish with downstream organisations.

Despite the extensive literature on the role of networks in technological entrepreneurship and RBSOs (Elfring and Hulsink, 2003; Slotte-Kock and Coviello, 2010) there is still limited research on the nature of the relationships that are established as part of the bridging process potentially conducted by RBSOs. The literature tends to focus on the interaction between the spin-off and the parent organisation (Audretsch and Lehmann, 2005; Colombo et al, 2006; Heblich and Slavtchev, 2013; Semadeni and Cannella, 2011), giving much less attention to the downstream relationships established with other types of organisation, to further develop and commercialise the technology, despite their relevance for this type of firm (Conceição et al, 2012).

Considering the above, it is possible to raise the following hypothesis, in what concerns the composition of the innovation networks established by RBSO, and therefore their role in innovation networks:

H1- *The composition of innovation networks arising from the national projects involving RBSOs is distinct from the composition of innovation networks arising from European projects;*

H2- *The size and composition of RBSOs innovation networks is influenced by the characteristics of the industry where the RBSO operates, in both national and European projects:*

H2A – *The national projects established by the RBSOs translate into network compositions that differ across industries.*

H2B – *The national projects established by RBSOs translate into network sizes that differ across industries.*

H2C – *The European projects established the RBSOs translate into network compositions that differ across industries.*

H3B – The European projects established by RBSOs translate into network sizes that differ across industries.

3. Data and method

3.1 Data sample: The Portuguese RBSOs

The analysis uses a self-collected dataset composed of the known population of RBSOs created in Portugal until 2007, totalling 327 firms (Conceição et al, 2017). Although there is not, in the literature, a single definition of the concept of academic or research-based spin-offs, it is possible to describe them as firms whose creation is based on the formal and/or informal transfer of knowledge or technology generated in public research organisations (Djokovic and Souitaris, 2008; Mustar et al, 2006; Pirnay et al 2003).

For this study we considered firms created by entrepreneurs who have some stable connection with a university or other research institution - such as faculty members, researchers and graduate students - and who are applying knowledge obtained or technology developed as part of their research activity; and firms created by external entrepreneurs based on the transfer of technology developed by a research organisation (Conceição et al, 2017).

With regard to the spin-off population in Portugal, it should be noted that although the first spin-off identified was established in 1979, there was an increase in the creation of spin-offs in the 1990s, which was consolidated in the 2000s. Regarding the industry distribution of the Portuguese RBSOs, the information & communication technologies (ICT) represent 40.67% of the population with 133 RBSOs, followed by the Biotechnology with 64 firms (19.57%). The smaller proportion corresponds to Engineering with 19 RBSOs (5.81%) (Conceição et al, 2017).

3.2 Innovation networks: Data and analysis

To identify the formal innovation networks established by the RBSOs, the paper draws on data on collaborative projects established by Portuguese RBSOs, at national and European level, in the context of all public programmes that funded research and pre-competitive technology, and product development and/or demonstration activities. Given RBSOs reliance on public funding for research and development activities (Wright et al, 2007), this data is expected to offer a good coverage of the formal technological relationships established these firms in this domain.

The National data, regarding the collaborative RTD projects funded by national support programmes, was obtained from the Innovation Agency (AdI) database and covers the period 1992-2014. The European data, regarding the joint RTD projects conducted in the context European Framework Programmes, was obtained from the CORDIS database and covers the same period. All, national and European, projects with Portuguese spin-off involvement were identified; totalling totalling 453 projects identified which represents 504 participations by RBSOs, (278 participations in Portuguese projects and 226 participations in European projects).

The data was collected (in May 2016) on the characteristics of each project and on the partners. Then, the organisations were characterised along three dimensions: location, type and area of activity. RBSOs were also classified according to the industry where they conducted their principal activity. The “parent” research organisations of the RBSOs were identified and their presence in the same project of their spin-offs was signalled.

4. Portuguese project vs. European projects

The 453 projects identified involved 504 participations by RBSOs, with 278 participating in Portuguese projects and 226 participating in European projects.

A detailed analysis of the national projects compared to the European projects reveals that they have very different teams, and therefore translate into different network composition.

Considering the composition of the project team, the data shows that more than ¾ of the projects involve at least one Research Organisations (table 2). Although the Research Organizations are effectively an important partner in the network, we have found statistically significant differences between the national and European projects, which are reflected in higher frequency with which the ROs are included in the European projects (table

1 and table 2). In the specific case of the Parent institution, we have also found statistically significant differences between the national and European projects (table 1). In fact, half of Portuguese projects integrate the Parent institution in the project team compared to 22% in European projects (table 2). Therefore, upstream relations seem to be more relevant in the context of national projects, when compared to international/European ones.

Analyzing the collaboration between spin-offs and other firms, the data also shows that, more than half of the partnerships analyzed involved RBSO and firms (table 2). Even so, we have found statistically significant differences between the national and European projects (table 1). In fact, almost all European projects integrate firms in the team compared to 57% in the case of Portuguese projects (table 2). Therefore, downstream relations seem to be more relevant in the context of international/Euroepan projects, when compared to national ones.

Regarding if the project have a tripartite team, which includes of spin-offs, research organizations and other firms, the data shows that 3/5 of the projects analyzed involve in fact a tripartite team. This result points to an intermediation role played by the RBSO in the network. Comparing the Portuguese and the European projects, we have found statistically significant differences. In more than ¾ of the European projects the team is composed by tripartite teams, while this number rises to 41% in Portuguese projects. Analyzing whether the team includes another spin-off firm, we have found statistically significant differences between the national and European projects - only 8% of European projects include another spin-off, in 22% of the Portuguese projects the team includes another spin-off (table 1 and table 2). Therefore, tripartite relations seem to be more relevant in the context of national projects, when compared to international/European ones.

Table 1: Test of differences between Portuguese and European projects

Team	Value
Project includes the Parent	0.9180*
Project includes a firm	0.8166*
Project includes a Research Organisations	0.9812*
Tripartite Project (Spin-offs + Research Organisations + Firms)	0.7892*
Project includes another RBSO	0.9661*
Number Partners	0.8913*
Spin-off Coordinator	0.6455*

Source: Own calculations.

* significant at 1% level

Analyzing the size of the teams, it was also verified statistically significant differences between the Portuguese and the European projects (table 1). The European projects include, on average, twice as many partners as Portuguese projects, 13 and 6 partners respectively (table 2).

Considering the role of RBSO as project coordinators, we have also verified statistically significant differences between the projects under analysis (table 1). In almost 2/3 of the Portuguese projects RBSOs are the coordinators, but in the case of European projects, this number decrease to 6% (table 2).

Table 2: Descriptive of Portuguese projects vs. European projects.

	Portuguese Projects	European Projects
Project includes the Parent	50%	22%
Project includes a firm	57%	95%
Project includes a Research Organisations	83%	92%
Tripartite Project (Spin-offs + Research Organisations + Firms)	41%	86%
Project includes another RBSO	22%	08%
Number Partners	06	13
Spin-off Coordinator	64%	06%

Source: Own calculations.

Considering the industry, there is a similar trend if we compare the Portuguese and the European projects: the majority of collaborative projects identified are in the information & communication technologies (ICT), followed

by electronics and biotechnology (Table 3). However, considering the weight of each industry in the population of Portuguese spin-offs, we can see that the ICT, Energy & environment and services have a number of projects (national and European) below their weight in the RBSO population. It should be noted that the electronics presents a number of projects (national and European) higher than its registered weight in the RBSO population.

Table 3: Distribution of projects by Industry

Industry	Spin-offs Population	Portuguese Projects	European Projects
Biotechnology	20%	20%	24%
Energy & environment	12%	6%	8%
Electronics	10%	20%	26%
Engineering	06%	4%	4%
ICT	41%	46%	34%
Services	11%	4%	4%

Source: Own calculations.

We have statistically significant differences across the industries, in the composition of the teams in national projects, namely regarding the involvement of ROs (Table 4) The presence of ROs in the project is higher in Services and Biotechnology (100% and 94%, respectively) and relatively lower in Electronics (Table 5). There are also statistically significant differences in what concerns the presence of parent organization, it is higher in Services (100%) and lower in Energy & Environment, Electronics and Engineering (Table 5).

Table 4: Test of differences between 6 Industries

	Value	
	Portuguese Projects	European Projects
Project includes the Parent	0.8779*	0.9126*
Project includes a firm	0.9723	0.9890
Project includes a Research Organisations	0.9578**	0.9893
Tripartite Project (Spin-offs + Research Organisations + Firms)	0.9817	0.9840
Project includes another RBSO	0.9725	0.9896
Number Partners	0.9682	0.9314*
Spin-off Coordinator	0.9682	0.9732
Start up period	0.9559**	0.9225

Source: Own calculations.

* significant at 1% level; ** significant at 5% level

Table 5: Descriptive of Portuguese projects by Industry

	Spin-offs + Research Organisations	Spin-offs + Firms	Tripartite (Spin-offs + Research Organisations + Firms)	Spin-off Coordinator	Project includes the Parent	Number partner (mean)	Project includes another RBSO
Biotechnology	94%	41%	35%	76%	74%	05	13%
Energy & environment	80%	60%	47%	53%	33%	06	20%
Electronics	73%	58%	33%	64%	53%	06	20%
Engineering	79%	58%	36%	79%	36%	05	14%
ICT	81%	63%	47%	58%	38%	07	29%
Services	100%	55%	55%	82%	100%	03	09%

Source: Own calculations.

Regarding the relationships established by the Portuguese RBSOs in European projects, we have also found statistically significant differences across the industries in terms of the network composition (Table 4). The

presence of Partner, it is higher in Energy & Environment and lower in Electronics and Engineering (Table 6). However, the presence of ROs in European the project teams does not show statistically significant differences between industries because they present fairly high values in all sectors – values between 88% and 95% (Tables 4 and 6). Similarly, all sectors have a high presence of firms in the projects (values above 93% in all sectors) and a high frequency of tripartite projects (values between 75% and 89%), and therefore do not show statistically differences across industries (Tables 4 and 6).

Table 6: Descriptive of European projects by industry

	Spin-offs + Research Organisations	Spin-offs + Firms	Tripartite (Spin-offs + Research Organisations + Firms)	Spin-off Coordinator	Project includes the Parent	Number partner (mean)	Project includes another RBSO
Biotechnology	94%	94%	89%	11%	24%	13	07%
Energy & environment	95%	100%	86%	11%	100%	10	00%
Electronics	88%	93%	81%	02%	09%	10	10%
Engineering	88%	100%	75%	00%	13%	14	13%
ICT	94%	94%	87%	07%	23%	17	09%
Services	89%	100%	89%	00%	67%	09	11%

Source: Own calculations.

In the case of European projects, we found statistically differences in the team size across industries (Table 4). In this case, ICT has an average of 17 partners, while services have an average of 9 partners (Table 6). In the case of Portuguese projects, the networks dimension do not present statistically significant differences between industries, all sectors have on average 3 to 7 partners. This suggests differences between RBSOs in different industries, both regarding the need to establish relationships and the nature of the knowledge that is exchanged in these relationships in accordance to Salavisa et al. (2012).

5. Conclusions

This paper presented an analysis of the formal relationships established by Portuguese RBSOs in the context of collaborative projects, at National and European levels, whose goal was to explore the role played by these firms in innovation networks. In particular, we explored whether RBSOs effectively act as “bridges” between research organisations and organisations located downstream in the knowledge value chain.

Regarding the comparison between national projects and European projects established by spin-offs Portuguese the results show that, as established in our hypotheses, they are statistically different with respect to the network composition. In what concerns the inclusion of research organisation in the team, the results show that Portuguese projects have a more frequent participation of the Parent institution, than European projects. In fact in 50% of the Portuguese projects the Parent is included.

Comparing the European projects with the Portuguese ones, the results show that informer the RBSO establish more frequently, tripartite partnerships (86%), connecting both with academia and other firms - potentially facilitating the circulation of knowledge across them.

With regard to the composition of innovation networks established by Portuguese spin-offs, the results show significant differences between industries (both in National and in European projects).

In relation to Portuguese Projects the frequency of the relationship with research organisation is different across industries. The industries with the highest research organisation inclusion are Services and Biotechnology, and the lowest is the Electronics (although it has a high value - 73%). The presence of parent is also quite distinct across industries. While all Services projects include Parent, in only 33% of the Energy & Environment projects the Parent is integrated into the network.

For European projects, the industry is statistically different only in the case of the Integration of Parent institution. In fact Parent is included in 100% of the projects in Energy & Environment, 13% in Engineering and

09% in Electronics. In tripartite networks, the results show that the industries are not statistically different. All industries have a high frequency of tripartite networks.

Regarding the network size, only in European projects, the sectors are statistically different. In fact in European projects, ICT has on average 17 partners, while in services the average is 9 partners.

The in-depth analysis of the configuration of the networks in terms of actor position and structure, considering the network reconstruction at sectoral level, both for national and European project will be addressed in forthcoming research.

References

- Asheim, B.T. and Coenen, L. (2005) "Knowledge bases and regional innovation systems: comparing Nordic clusters", *Research Policy*, Vol. 34, pp 1173-1190.
- Asterbo, T. and Bazzazian, N. (2011) Universities, entrepreneurship and local economic development., in: M. Fritsch (ed) *Handbook of research on entrepreneurship and regional development*. Cheltenham: Edward Elgar.
- Audretsch, D. and Lehmann, E. (2005) "Does the knowledge spillover theory of entrepreneurship hold for regions?", *Research Policy*, Vol. 34, pp 1191-1202.
- Autio, E. (1997) "New, technology-based firms in innovation networks symplectic and generative impacts", *Research Policy*, Vol. 26, pp 263-281.
- Bathelt, H., Kogler, D. and Munro, A. (2010) "A knowledge-based typology of university spin-offs in the context of regional economic development", *Thecnovation*, Vol.30, pp 519-532.
- Capaldo, G., Fontes, M., Rippa, P., Cannavacciuolo, L. and Sousa, C. (2015) "Networks mobilized to access key resources at early stages of biotech firms: A comparative analysis in two moderately innovative countries", *European Planning Studies* (in press) DOI:10.1080/09654313.2014.934206.
- Colombo, M., Grilli, L. and Piva, E. (2006) "In search of complementary assets: the determinants of alliance formation of high-tech start-up", *Research Policy*, Vol. 35, pp 1166-1199.
- Conceição, O., Fontes, M. and Calapez, T. (2012) "The commercialisation decisions of research-based spin-off: targetting the market for technologies", *Technovation*, Vol. 32, No. 1, pp 43-56.
- Conceição, O., Sousa, C. and Fontes, M. (2015). "Research-based spin-offs as agents of knowledge dissemination: evidence from the analysis of innovation networks" in *Proceedings of the 10th European Conference on Innovation and Entrepreneurship* p. 130-138. ISBN:978-1-910810-49-1
- Conceição, O., Faria A. and Fontes, M. (2017) "Regional variation of academic spinoffs formation", *The Journal of Technology Transfer*, Vol. 42, No. 3, pp 654-675.
- Cunha, D., Silva, S. and Teixeira, A. (2013) "Are Academic Spin-Offs necessarily New Technology-Based firms" *FEP Working Papers*, n. 482, Faculdade de Economia da Universidade do Porto.
- Djokovic, D. and Souitaris, V. (2008) "Spinouts from academic institutions: a literature review with suggestions for further research. Success of research-based spin-offs. State of the art and guidelines for further research", *Journal of Technology Transfer*, Vol. 33, No. 3, pp 225-247.
- Elfring, T. and Hulsink, W. (2003) "Networks in Entrepreneurship: The case of high-technology firms", *Small Business Economics*, Vol. 21, pp 409-422.
- Fontes, M. (2005) "The process of transformation of scientific and technological knowledge into economic value conducted by biotechnology spin-off", *Technovation*, Vol. 25, pp 339-347.
- Fontes, M. and Sousa, C. (2016) "Types of proximity in knowledge access by science-based start-ups", *European Journal of Innovation Management*, Vol. 19, No. 3, pp 298-316.
- Grandi, A. and Grimaldi, R. (2003) "Exploring the networking characteristics of new venture founding teams", *Small Business Economics*, Vol. 21, No. 4, pp 329-370.
- Harrison, R. and Leitch, C. (2010) "Voodoo Institution or Entrepreneurial University? Spin-off Companies, the Entrepreneurial System and Regional Development in the UK", *Regional Studies*, Vol. 44, No. 9, pp 1241-1262.
- Heblich, S. and Slavtchev, V. (2013) "Parent universities and the location of academic startups", *Small Business Economics*, Vol. 42, pp 1-15.
- Helm, R. and Mauroner, O. (2007) "Success of research-based spin-offs. State of the art and guidelines for further research", *Review of Managerial Science*, Vol. 1, No. 3, pp 237-270.
- Hess, S., Suhrbeer, S. and Siegwart, R. (2013) "The impact of collaborative innovation between established industry and academic technology spin-offs", *Business and Management Research*, Vol. 2, No. 3, DOI:10.5430/bmr.v2n3p1
- Kirwan, P., van der Sijde, P., & Groen, A. (2006). "Assessing the needs of new technology based firms (NTBFs): An investigation among spin-off companies from six European Universities". *International Entrepreneurship and Management Journal*, Vol. 2, No. 2, pp 173-187.
- Mustar, P., Renault, M., Colombo, M., Piva, E., Fontes, M., Lockett, A., Wright, M., Clarysse, B. and Moray, N. (2006) "Conceptualising the heterogeneity of research-based spin-offs: A multi-dimensional taxonomy", *Research Policy*, Vol. 35, pp 289-308.
- Mustar, P., Wright, M. and Clarysse, B. (2008) "University spin-off firms: lessons from ten years of experience in Europe", *Science and Public Policy*, Vol. 35, No. 2, pp 67-80.

- O'Shea, R., Allen, T., Chevalier, A. and Roche, F. (2005) "Entrepreneurial orientation, technology transfer and spinoff performance of U.S. universities", *Research Policy*, Vol. 34, No. 7, pp 994-1009.
- Owen-Smith, J. and Powell, W. (2004), "Knowledge networks as channels and conduits: the effects of spillovers in the Boston biotechnology", *Organization Science*, Vol. 15, No. 1, pp 6-21.
- Perez, M. and Sanchez, A. (2003) "The development of university spin-offs: early dynamics of technology transfer and networking", *Technovation*, Vol. 23, pp 823-831.
- Phan, P. and Siegel, D. (2006) "The effectiveness of university technology transfer", *Found Trends Entrepreneurship*, Vol. 2, No. 2, pp 77-144.
- Plum, O. and Hassink, R. (2011) "Comparing knowledge networking in different knowledge bases in Germany", *Papers in Regional Science*, Vol. 90, No 2, pp 355-372.
- Salavisa, I., Sousa C. and Fontes, M. (2012) "Topologies of innovation networks in knowledge-intensive sectors: sectoral differences in the access to knowledge and complementary assets through formal and informal ties" *Technovation*, Vol. 32, No. 6, pp 380-399.
- Sousa, C. and Fontes, M. (2012) "Networks and Technological entrepreneurship", in: Salavisa, I. e Fontes, M. (eds), *"Social networks, Innovation and the Knowledge Economy"*, London and NY: Routledge.
- Schartinger, D., Rammera, C., Fischer, M. M. and J. Fröhlich (2002) "Knowledge interactions between universities and industry in Austria: sectoral patterns and determinants", *Research Policy*, Vol.31, pp 303-328.
- Semadeni, M. and Cannella, A. (2011) "Examining the performance effects of post spin-off links to parent firms: should the apron strings be cut?", *Strategic Management Journal*, Vol. 32, pp 1083-1098.
- Shane, S. (2004) *Academic entrepreneurship: University Spinoffs and wealth creation*. Cheltenham: Edward Elgar.
- Slotte-Kock, S. and Coviello, N. (2010) "Entrepreneurship Research on Network Processes: A Review and Ways Forward", *Entrepreneurship Theory and Practice*, Vol. 34, No. 1, pp 31-57.
- Stuart, T. E., Ozdemir, S. Z. and Ding, W. W. (2007) "Vertical alliance networks: the case of university–biotechnology–pharmaceutical alliance chains", *Research Policy*, Vol. 36, pp 477–498.
- van Geenhuizen, M., Taheri, M. and Soetanto, D. (2014) "Triple Helix Interaction: Importance of Spin-off Firms' Networks and the University as Partner" ", in: *Proceedings of the Asia Triple Helix Society Summer Seminar*, 25 June 2014, Daegu South-Korea.
- Walter, A., Auer, M. and Ritter, T. (2006) "The impact of network capabilities and entrepreneurial orientation on university spin-off performance", *Journal of Business Venturing*, Vol. 21, pp 541-567.
- Wright, M., Clarysse, B., Mustar, P. and Lockett, A. (2007) *Academic Entrepreneurship in Europe*. Cheltenham: Edward Elgar