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**Knowledge Spillovers, knowledge filters and entrepreneurial university ecosystems.
Emerging role of University-focused Venture Capital firms**

ABSTRACT

In this study, we analyse the role played by investment managers from University-focused Venture Capital firms (UVCs) in knowledge spillovers in Entrepreneurial University Ecosystems (EUEs). Data from fifteen in-depth interviews with key agents of the EUEs in England was examined through the lens of the Knowledge Spillover Theory of Entrepreneurship, using Social Network Analysis and qualitative analysis. We identified the emerging role of UVCs as key knowledge intermediaries in developing and sustaining EUEs, concluding that UVCs are key to overcoming knowledge filters and maintaining dynamic relationships over time between entrepreneurial universities and University Spin-off companies. In this paper, we describe how UVCs act as social connectors, facilitating a two-way knowledge and technology exchange necessary in the development and sustainment of EUEs.

Keywords: Knowledge spillover, Entrepreneurial University Ecosystems, University-focused venture capital firms, surrogate entrepreneurs.

1. Introduction

Universities have been the focus of several economic development policies due to their ability to stimulate the production and diffusion of new knowledge. In this way, they act as catalysts of innovations in their regions (Audretsch, Hülsbeck, & Lehmann, 2012) and as key agents in knowledge transfer to enterprises (Robertson, McCarthy, & Pitt, 2019; Teixeira, Veiga, & Fernandes, 2019). Different lines of research have been developed to analyse these roles, such as the *Triple Helix* approach of university–government–industry relations

(Etzkowitz & Leydesdorff, 2000), the *Quadruple Helix* (Carayannis & Campbell, 2009), the *national innovation system* (Freeman, 1987), and the *ecosystem* approach (Spigel, 2017). Among these studies, the idea of the *entrepreneurial ecosystem* has generated increasing interest in recent literature (Autio *et al*, 2014; Harrison & Leitch, 2010), with two major branches of research being developed (Clarysse *et al*, 2014), *business* or *innovation* ecosystems and *knowledge* or *regional* ecosystems (Agrawal & Cockburn, 2003; Graham, 2014). The literature identifies Universities as good anchor tenants in the development of *knowledge ecosystems* (Agrawal & Cockburn 2003) and in the emerging concepts of the *entrepreneurial universities* (Etzkowitz, 1983, 2017; Clark, 1996) and the *entrepreneurial university ecosystems* (EUEs) (Graham, 2014).

University Spin-off companies (USOs) are a mechanism used by entrepreneurial universities to exploit the new knowledge generated from their research results (Grimaldi *et al*, 2011) in the formation of *regional* EUEs (Graham, 2014), as an application of their stated third mission (Secundo *et al*, 2017). Subsequently, recent research demonstrates that the contribution of entrepreneurial universities to their ecosystem, in terms of USOs success, depends on the existence of interrelated and well-coordinated knowledge intermediaries guided by a strong collective ethos to encourage and support academic entrepreneurship (Hayter, 2016a, b). The intermediaries' organizational resources provide a strong foundation; however, they are not enough to make these networks a success, as key individuals must also perform vital functions (Larty, Jack, & Lockett, 2017). A recent literature review (Hossinger, Chen, & Werner, 2019) commented on the relevance of individual factors in explaining the entrepreneurial behaviour of academics, but one must understand that this venturing process is influenced not only by these micro-level factors, but also strongly depends on factors at the meso and macro-levels, such as relationships with parent organisations and regional contexts.

Thus, among knowledge intermediaries, venture capitalists have been highlighted as important financial intermediaries (Munari & Toschi, 2010) for the development and success of USOs in entrepreneurial universities (Lawton Smith & Bagchi-Sen, 2012). In addition, further research identifies the emergence of new *venture capital teams* interested in investing in new technologies emerging from university research (Graham, 2014). Investment capital is also considered to be one of the social attributes of entrepreneurial ecosystems (Spigel, 2017). In this study, these financial intermediaries are referred to as *University-focused Venture Capital firms* (UVCs), as they are located close to universities, focus on research exploitation, and are continually looking for new potential technologies in which to invest.

Little is known about these new financial intermediaries as knowledge intermediaries (Hayter, 2016a), and more research is needed to understand the emerging role of UVCs (Graham, 2014) in knowledge spillover and their relationships in sharing knowledge and resources for supporting new successful ventures in the context of EUEs (Siegel & Wright, 2015).

To address this research gap, we need to provide insight about the network formation, helping us to better understand how actors interact and how knowledge dissemination occurs (Acs, Audretsch, & Lehmann, 2013; Hayter, 2013a). We must also consider the connections between the participants in an EUE (Clarysse *et al*, 2014; Hayter, 2016a), as these interactions create a supportive regional environment that increases the competitiveness of new ventures (Spigel, 2017). To do so, we use the *Knowledge Spillover Theory of Entrepreneurship* (KSTE) (Acs, Audretsch, & Lehmann, 2013; Acs, & Sanders, 2013; Ferreira, Ratten, & Dana, 2017; Ghio *et al*, 2015; Plummer, & Acs, 2014; Qian & Acs, 2013; Wennberg, Wiklund, & Wright, 2011) in combination with a social network approach (Kauffeld-Monz & Fritsch, 2013; Fuster *et al*, 2019). This study thus seeks to increase knowledge on the dynamic between participants in EUEs and to identify the role of UVCs in analysing key participants of the network at the individual level. We analyse investment managers, CEOs of USOs, and managers of *Technology Transfer Offices* (TTOs) in order to understand the full dynamics of these ecosystems, using the KSTE theoretical framework to perform our analysis. In doing so, we answer the Research Question (RQ): *What is the role of UVCs in knowledge spillovers in EUEs?*

We carried out an exploratory study based on in-depth interviews of key agents of the ecosystem. Specifically, we interviewed a relevant population of academic entrepreneurs and key stakeholders in England. As for other qualitative studies, the *how* and the *why* were more interesting than the *what* in understanding the complex phenomenon of EUEs. Our study makes a relevant contribution, as it reveals, from a KSTE perspective, the emerging role of UVCs as knowledge intermediaries in developing and sustaining EUEs in the context of EUEs. Focusing on knowledge spillover, we found that UVCs' role is key in overcoming knowledge filters and maintaining dynamic relationships over time between universities and USOs. In addition, we identified two surrogate roles played by investor managers, namely surrogate entrepreneur in USOs and surrogate technology transfer intermediaries in Universities. We describe how they are acting as social connectors, facilitating two-way knowledge and technology exchange metaphorically conceptualised as a *tidal effect*.

2. Theoretical background

2.1. *Knowledge Spillover Theory of Entrepreneurship and EUEs*

Knowledge ecosystems are defined as a network of interconnected firms located around universities, public research organizations, or large firms with an established research and development (R&D) department, acting as focal institutions that co-evolve over time to generate, diffuse, and use new knowledge (Clarysse *et al*, 2014). An EUE is a knowledge ecosystem in which this network of interconnected organizations is located around entrepreneurial universities as the anchor tenant (Agrawal & Cockburn, 2003; Graham, 2014).

In order to understand how actors interact and how knowledge dissemination occurs, one must comprehend the dynamics of EUEs (Clarysse *et al*, 2014). A recent review of the empirical entrepreneurship network literature suggests studying these dynamics by investigating entrepreneurship networks employing a KSTE lens (Hayter, 2013a). KSTE focuses on the individual “agent of knowledge” and their role in knowledge spillover. It embraces the assumption that new knowledge is the source of innovation, productivity and economic growth (Grant, 1996; Romer, 1990). However, it takes issue with traditional theoretical assumptions that all knowledge is economically useful or spills over “automatically” to other organizations. In KSTE, knowledge is instead subject to institutional, geographic, and financial constraints known as the *knowledge filter* and defined as *the gap between the investment in new knowledge and its commercialization* (Audretsch, Lehmann, & Wright, 2014: 316) which leads to innovative activity and growth of the economy. This knowledge is usually generated by research organizations, such as universities, but it often goes unexploited. Although it has been recognised that cooperation between companies and universities plays a particularly important role in the performance of companies at both financial and organizational level (Teixeira, Veiga, & Fernandes, 2019), it is difficult to analyse this knowledge transfer. This is mostly due to the fact that knowledge transfers in R&D projects differ in terms of the characteristics of the projects (Hermans & Castiaux, 2017) and in the measure of the effect knowledge spillover has across and within regions and industries (Xu *et al*, 2019). In thinking about these university-industry knowledge transfer strategies, one must also note the key role that social capital plays (Robertson, McCarthy, & Pitt, 2019).

KSTE suggests filling this gap by starting new firms, a process which commercializes knowledge as a conduit for the spillover of new knowledge, thus, proposing that

entrepreneurship is an important vehicle for the spillover of new knowledge and therefore is critical for economic growth (Acs, Audretsch, & Lehmann, 2013; Hayter, 2013a). Consequently, investment in university research alone is not sufficient to generate innovative activity and economic growth—due to the *knowledge filter*—and Universities must become more entrepreneurial in order to facilitate knowledge spillovers for commercialization out of the universities (Audretsch *et al*, 2014). Therefore, we apply the KSTE to link the micro-level (the entrepreneurial behaviour of the ecosystem participants), with the macro-level (the dynamics of the connectivity between the participants in a EUE) (Hayter, 2013a).

2.2. Entrepreneurial University and USOs

We define an entrepreneurial university (Etzkowitz, 1983, 2017; Clark, 1996) as a university which is, in addition to teaching and research, also focused on the support of entrepreneurial activities as an application of its third mission (Secundo *et al*, 2017). These universities have strong connections with R&D centres, incubators, firms, science and technological parks, governments, and institutions. Therefore, the entrepreneurial university acts as a natural incubator providing a supportive ecosystem to the university community and its surroundings in order to produce, diffuse, absorb, and use new knowledge that can become entrepreneurial initiatives (Guerrero *et al*, 2014). These projects are usually developed using USOs as mechanisms (Siegel & Wright, 2015).

USOs are for-profit firms based on university research (Philpott *et al*, 2011). They are the mechanism most commonly used by universities to exploit the new knowledge generated from their research (Grimaldi *et al*, 2011). However, in order for these USOs to be successful, an interrelated and well-coordinated network of knowledge intermediaries must exist (Hayter, 2016a), bearing in mind that universities are one of the most relevant knowledge brokers in regional innovation systems (Kauffeld-Monz & Fritsch, 2013).

2.3. UVCs

Knowledge intermediaries are defined as *organizations that facilitate knowledge exchange between universities and external stakeholders through the creation of bidirectional, value-added network relationships* (Hayter, 2016a:636). There are four distinct categories of knowledge intermediaries (Hayter, 2016a): *general purpose*, *specialized*, *financial*, and *institutional*. Financial intermediaries have been highlighted as key elements in the entrepreneurial university structure for the USOs success (Lawton Smith & Bagchi-Sen, 2012). Examples of financial intermediaries are venture capitalists, angel investors, or governments.

This link to venture capital companies has proven to be a significant predictor of USO performance (Lee *et al*, 2001). In fact, given the success of this new agent as a USO developer in the US, the financial intermediary model was rapidly replicated in many other countries in Europe, such as the UK (Wright *et al*, 2006) and Spain (Ortín-Ángel & Vendrell-Herrero, 2010), among others. Since then, the role of Venture Capitalists (VCs) has been increasingly identified in the literature to be an important element of the infrastructure required for entrepreneurial universities (Lawton Smith & Bagchi-Sen, 2012). VC investors provide not only financing, but also mentoring, expertise, and industry contacts, thus improving the firm's chances to succeed. VCs are also seen as catalysts for commercialisation because they help to develop the pool of entrepreneurial talent in an area (Samila & Sorenson, 2010), attesting to how investing firms can go from basic existing research to commercial products with increased R&D expenditures, ensuring a path of continuous innovation. In addition, recent literature identified the emergence of a new type of venture team which was created to invest in technology developed by universities (Graham, 2014), termed as UVCs. UVCs are located close to universities and actively seek new technologies in which to invest, working as both investors and surrogate entrepreneurs for the development of new USOs. However, little is known about these new agents, and more research is needed to clarify their role in developing entrepreneurial universities in the dynamics of EUEs (Graham, 2014). In fact, in spite of the existence of VCs and UVCs involved in EUEs, many USOs still lack the financial means to acquire the resources and develop the capabilities they need in order to fully exploit the commercial potential of their technologies (Harrison & Leitch, 2010). One explanation for this phenomenon is that the nascent technology of USOs is characterized by uncertainty and information asymmetry (Widding *et al*, 2009), which makes it difficult for investors to evaluate the profitability of that technology. Additionally, previous research has shown that in the early-stages of investment, VC funds consider the business experience and the commitment of the entrepreneurial team as the main criterion for providing funds (Mueller *et al*, 2012). However, academic entrepreneurs frequently lack the necessary business knowledge and experience (Franklin *et al*, 2001), and university demands make full commitment difficult. Once an academic entrepreneur decides to run a USO, they have two options: leave the university to run the company or run the company in tandem with their academic responsibilities, having to share their time with their core functions of researching, teaching, and administration, preventing them from being full-time entrepreneurs (Franklin *et al*, 2001). Consequently, many USOs attract a *surrogate entrepreneur* (Lundqvist, 2013) into the new venture to fill these gaps, acting as an individual (or organization) from outside

the university who assumes the role of entrepreneur while the technology originator, the academic, maintains their position at the university.

According to this review, this RQ is proposed: *What is the role of UVCs in knowledge spillovers in EUEs?*

3. Data collection and research methods

3.1. Research approach

To address the proposed RQ, this study investigates the knowledge spillover process of entrepreneurship in a critical economic and scientific context, Yorkshire in England (UK). The reasons for selecting Yorkshire were threefold. Firstly, it was in the UK where these intermediaries were first identified in the context of EUE (Graham, 2014). Secondly, it was considered a homogenous context in which to study the knowledge spillover process of entrepreneurship, as an exemplar of an ecosystem with common University legal regulations, financial support, and similar culture, thus allowing differently obtained data to be comparable. Third, the researchers involved had access to different agents of these ecosystems with different roles that would provide enough rich data to analyse the phenomenon. We chose to focus specifically on the Universities of Leeds and Sheffield because they are the longest established and largest Russell Group universities in the region of Yorkshire (Russell Group, 2020). Furthermore, we intentionally decided to use this context as a way of better answering the aim of the research and thereby exploring the emerging role of UVCs in relation to different *entrepreneurial universities*.

We used a mixed-method approach (Creswell, 2013). First, we performed a quantitative exploratory Social Network Analysis (SNA) (Borgatti *et al*, 2002; Borgatti & Foster, 2003), to show the general structure of the network and the relationships among the agents. Second, we conducted a deeper and relevant qualitative analysis of in-depth interviews with key participants (Eisenhardt & Graebner, 2007; Yin, 2011). Then, we used the concurrent triangulation strategy to cross-validate the two databases (Creswell, 2013; Jick, 1979). Specifically, we used two levels of triangulation of secondary data, using *LinkedIn* profiles on the individual level, and university websites at institutional level.

As for instrument design, two different tools were used to interview the same participants: a SNA survey and an interview protocol. The initial theoretical framework informed the questions proposed in the survey (Eisenhardt & Graebner, 2007), and an introduction and

open questions were used to ensure that the interviewee was able to participate in this research (Yin, 2011).

3.2. *Research setting*

The interviewees of this study were located in Leeds and Sheffield. Both universities are members of the Russell Group, which is a group of 24 research-intensive, world-class universities, committed to publishing the very best research, providing an outstanding teaching and learning experience, and maintaining/establishing unrivalled links with the business and public sectors (Russell Group, 2020). Both universities are in the region of Yorkshire and were selected as representative of the region (South and West Yorkshire). Some relevant statistics about both regions are shown on Table 1.

The *Leeds City Region* is a functional economic area. It is the largest city region in the UK, home to 2.3 million people and 100,000 businesses, and generating €60 billion per year – 4 percent of the UK's economic output. Leeds City Region is an internationally renowned education centre offering direct access to an annual talent pipeline of 38,800 graduates. The City Region is home to two world class business schools, 9 universities and 14 further education colleges, and one of Europe's largest teaching hospitals (Leeds City Region Enterprise Partnership, 2019). The City Region also houses the White Rose University Consortium, a strategic partnership between three of the UK's leading research universities located in Leeds, Sheffield, and York (White Rose Consortium, 2020).

The *Sheffield City Region Combined Authority* is the combined authority for South Yorkshire in England, with powers over transport (public transport and major trunk roads only), economic development, and regeneration. With an economic output of more than €31 billion per year and world-class specialisms in advanced manufacturing (e.g., the University of Sheffield Advanced Manufacturing Research Centre - AMRC), the city region is at the forefront of innovation and a major driver of economic growth. It is home to 1.4 million people and 68,000 businesses (Sheffield City Region, 2020).

Table 1: Main statistics

Code	EU28	South Yorkshire (<i>Sheffield</i>)	West Yorkshire (<i>Leeds</i>)
Gross domestic product (Purchasing power standard, PPS per inhabitant)	30000	21,500	26,500
Gross domestic product, Euro per inhabitant	30000	24,000	29,500
Gross domestic product, Euro per inhabitant in percentage of the European Union average	100	80	98
Gross domestic product, PPS per inhabitant in percentage of the European Union average	100	71	88
Gross value added at basic prices (million EUR)		29,647	60,491
Real growth rate of regional gross value added (% change on previous year)		0,8	1,4
Population (persons)		1,389,426	2,301,000

Source: Data of 2017 NUTS 2 level. Eurostat (2019).

3.3. *Data selection*

All of the participants interviewed were selected using pre-determined criteria. As there is no official database of the agents, we developed a database of companies, including USOs, in consultation with regulatory bodies from the public sector (TTOs), USO owners and managers, and the TTOs of Yorkshire Universities. Consequently, a snowball convenient sample of USOs was developed, and a total of 30 agents were identified and contacted in Yorkshire (15 were finally interviewed, response rate 50 percent). The selection criteria were based on the following USO characteristics (see Table 2): the USOs must (i) have been created through a formal mechanism (a signed contract with the university); (ii) come from a variety of technological fields; (iii) have different funding sources; and (iv) have existed for at least one year at the time of the interview. Regarding the last criterion, we collected data from USOs in different stages of development. This way, we represented the dynamics of a EUE, and enriched the study by taking into consideration the role of knowledge intermediaries at different stages in USOs development, which is key to their success. These key knowledge intermediaries involved in the EUE were also identified and interviewed during our research process. In doing so, we compared and completed the data collected from the USOs, thus ensuring correct interpretation through data analysis (Yin, 2011).

As a result, a combined database was constructed. 15 agents (4 TTOs, 3 UVCs, and 8 entrepreneurs from different USOs (ENTREPs) were identified and contacted by email with information about our research, receiving a message explaining our objectives and emphasizing the importance of participation in the study. In order to avoid identification of the intermediaries used in this study, only the ENTREPs are numbered (see Table 2). Most of the interviewees were male CEOs of USOs from the IT and Health sectors and senior managers of the knowledge intermediaries.

Table 2. Summary of the analysed cases

Agent	City Region	Gender of the interviewee	Position of the interviewee	Sector
TTO	Leeds	Male	Manager	Multi-sector
TTO	Leeds	Female	Manager	IT-health
ENTREP1	Leeds	Male	CEO	Military Industry
TTO	Leeds	Female	Manager	Multi-sector
TTO	Leeds/Sheffield	Male	Manager	Multi-sector
UVC	Leeds	Male	Manager	Multi-sector
ENTREP2	Leeds	Male	CEO	IT-health
ENTREP3	Leeds	Male	CEO	IT-health
ENTREP4	Sheffield	Male	CEO	IT-health
UVC	Sheffield	Male	Manager	Multi-sector
ENTREP5	Sheffield	Male	CEO	IT-health
ENTREP6	Sheffield	Male	CEO	IT-health
UVC	Sheffield	Male	Manager	Multi-sector
ENTREP7	Sheffield	Male	CEO	IT-health
ENTREP8	Sheffield	Male	CEO	Services

3.4. Data collection and coding

Data was collected through direct contact with participants, in person or by phone, and from secondary resources, during a period of seven months (in 2014). For the phone interviews, we ensured that the participants met the environmental conditions so the dynamics of the interview would not be affected. Interview length ranged from 45-90 minutes. All participants were assured of the confidentiality of their interview, both for their firm/institution and for the individual. In addition to interviews, archival data (web pages, *LinkedIn*, etc.) was searched until a point of saturation was reached (Yin, 2011), guaranteeing the depth and relevance of the data required (Jick, 1979; Stake, 2010; Yin, 2011).

We used SNA (Borgatti & Foster 2003) to explore the complex network structures and the cross-network alignment of their participants in the EUE. As in previous studies (Clarysse *et al*, 2014), UCINET (version 6) bundled with NetDraw was used; first to visualise the network structure (see Figure 1), and then to calculate some relationship indexes (Borgatti *et al*, 2002).

The data was codified according to the following intensity: (0) no relations at all or very rarely, (0.5) rarely, (1) occasionally, (2) frequently, (3) very frequently. Next, a relationship matrix was built on an Excel file. Once all the transcriptions were codified, the relationship matrix was introduced to the UCINET software. This relationship matrix was square and identical, meaning that it had the same number of rows as columns, both of which represented

the same actors. The rows and columns showed the relationships among the actors (Borgatti *et al*, 2002). With this matrix, we constructed an exploratory EUE network (see Figure 1) which represents the relationships between different TTOs, UVCs, and ENTREPs.

3.5. Interview analysis

According to Wolcott (1990), the key to good qualitative work is identifying and presenting the most relevant data which contains enough contextual information to allow the reader to understand the situations in which the individuals are immersed. Following this principle, we used the five-phase cycle proposed by Yin (2011) for the analysis of the qualitative interviews: compiling, disassembling, reassembling, interpreting and concluding.

First, all responses were recorded and transcribed, then compiled into a formal database together with the archival data. In doing so, we ensured the triangulation of the different data sources used (Jick, 1979; Yin, 2011). Secondly, all responses were coded inductively. For each participant, we composed a list of the benefits and challenges related to the relationships mentioned in the SNA survey. Next, all participants were compared, thus yielding multiple emergent themes and allowing us to discover different perspectives regarding the contribution of the network contacts and the context in which the ecosystem is embedded (Miles & Huberman, 1994). Four researchers then discussed the interpretation of the reassembled data, their different backgrounds and countries of origin enriching the data analysis. Finally, we carefully agreed upon selected quotations that supported each finding, deciding to use a narrative approach to present the results of the qualitative data (Wolcott, 1990).

4. Findings

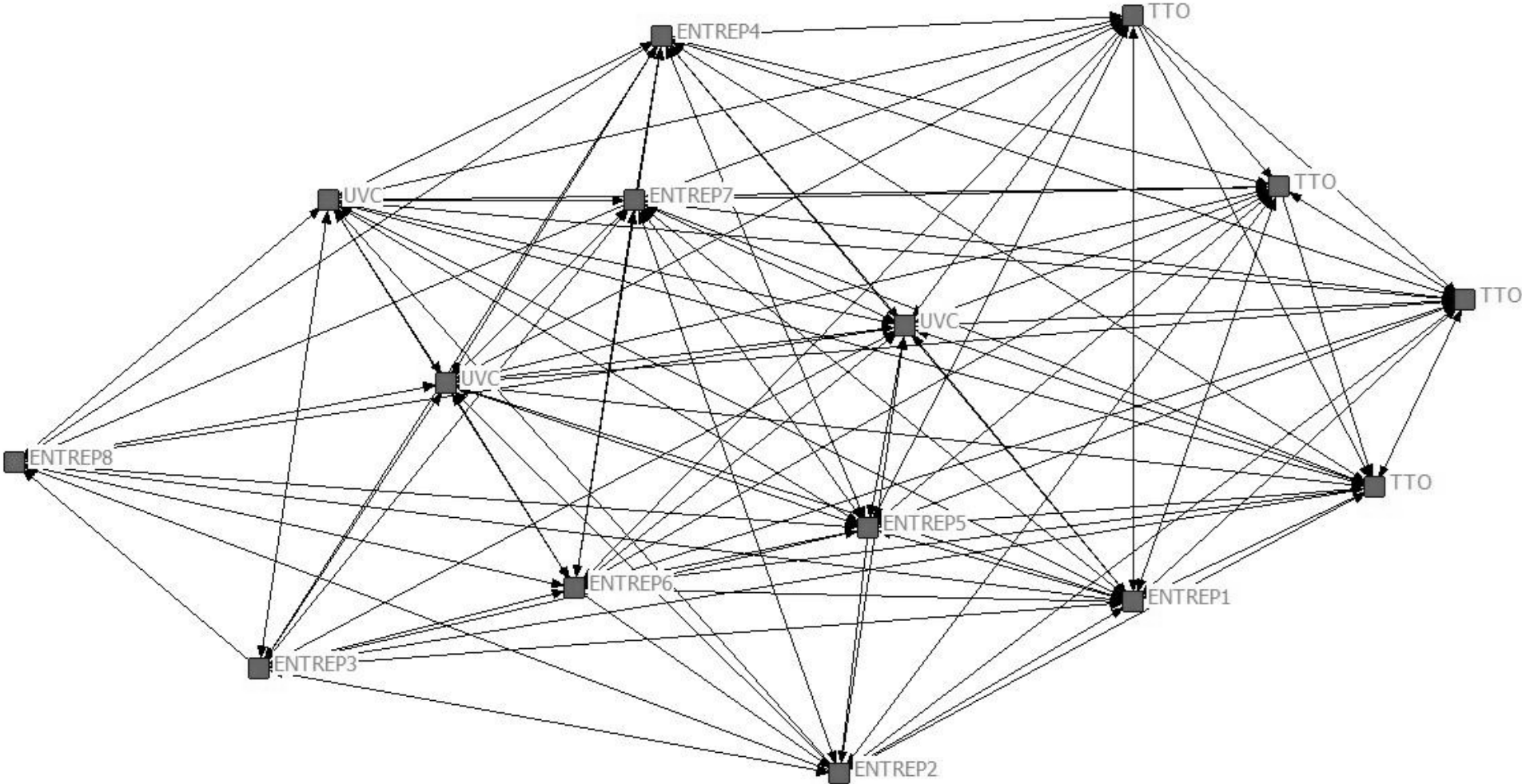
4.1. Identification of the network

Figure 1 identifies the main actors in regional EUEs and the relationships among the key agents analysed. It shows the position each participant occupies in their ecosystem. As Figure 1 demonstrates, the English *EUE* is well connected through knowledge intermediaries such as UVCs. These UVCs are located in the middle of the network and act as anchor tenants, playing a key role in knowledge spillover, while the USOs which appear around these UVCs

create strong networks. In contrast, TTOs are not centred in the network and instead occupy the periphery, reflecting more of a reactive than proactive role.

INSERT FIGURE 1 ABOUT HERE

Figure 1. Social network of the *entrepreneurial university ecosystem*



In addition to the networks, three different indicators of centrality were calculated (*Centrality Degree*, *Closeness Centrality*, and *Betweenness Centrality*) in order to provide a deeper explanation of the network structure, both as a whole and regarding each individual agent.

4.2. Social network analysis: Connectivity between participants and role of UVCs

The *Degree Centrality* was measured using Freeman's approach, based on the out-degrees and the in-degrees of the network (Hanneman & Riddle, 2005) (see Table 4). The *Degree Centrality* is defined by two separate measures: Indegree (number of ties directed to the node) and Outdegree (number of ties that the node directs to others). As the data is valued, the degrees (in and out) consist of the sums of the values of the ties (Borgatti *et al*, 2002). This *Degree Centrality* measures to what extent a node is highly degree-central, or directly connected to many other nodes. Therefore, if network agents are ordered from the greatest to the lowest centrality, we can obtain a ranking of the best-connected individuals in the network. Using this method, we found that among the first ten positions of the Indegree at the individual level were 1 entrepreneur and 3 UVCs. This ranking points to how these intermediaries receive more communications in order to collect information, advice, etc. In addition, among the first ten positions of the Outdegree were three UVCs, reflecting how these agents are some of the most active, behaving proactively when they look to communicate with other agents. Regarding the *Degree Centralization* of the network, this is relatively low (1.53 percent), so the network is far from a *star* shape (centralization closes to 100 percent), showing that there is not an intermediate agent that connects the other agents in the network (Hanneman & Riddle, 2005).

Table 4. Degree Centrality of the network (only the first five included)

Order Indeg	Agent	Indeg	Outdeg
1	ENTREP5	33.000	27.000
2	UVC	32.000	32.000
3	UVC	32.000	32.000
4	UVC	31.000	32.000
5	ENTREP7	31.000	23.000
Order Outdeg	Agent	Outdeg	Indeg
1	UVC	32.000	32.000
2	UVC	32.000	32.000
3	UVC	31.000	32.000
4	TTO	18.000	31.000

5	TTO	23.000	29.000
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Note: Indeg: indegree; Outdeg: outdegree.

The *Closeness Centrality* refers to what extent a node is highly close-central, meaning it is connected by short paths to most other nodes, while the *Closeness Centralization* is a measure of the extent to which the network is dominated by a few of these close-central nodes (see Table 5). The node with the highest closeness centrality has the shortest distance to the other nodes on average, so it is useful to know the nodes that are best placed to influence the entire network the quickest. Unsurprisingly, taking into account the existing relations between ENTREPs and TTOs, taken as a selection criterion of USOs, strong links exist between both agents, and, in the ecosystem analysed, the nodes with the highest closeness centrality regarding in and out communications are TTOs in the case of in communications, and UVCs in the case of out communications.

Table 5. *Closeness Centrality*

Agents ranking	InClose	Agents ranking	OutClose
ENTREP5	0.933	ENTREP1	0.933
ENTREP6	0.933	UVC	0.933
TTO	0.875	UVC	0.933
TTO	0.875	UVC	0.933
ENTREP1	0.875	TTO	0.824

Finally, the *Betweenness Centrality* refers to the nodes one given node must go through in order to access other nodes, and it considers a node highly between-central when it lies on many geodesics (shortest paths) between nodes. The *Betweenness Centralization* is a measure of the extent to which the network is dominated by a few between-central nodes. By locating the individuals who influence the flow of communication around a system, the *Betweenness Centrality* is useful in considering what a node gains from bridging between different nodes, for example, thus brokering between different types of nodes. Therefore, the *Betweenness Centrality demonstrates* the ability of an actor to mediate communications between pairs of other agents, known as *agent communication control*. In the ecosystem analysed (see Table 6), the three UVCs are shown in the first positions of the ranking are intermediaries good at connecting agents of the network in terms of knowledge spillover and entrepreneurial activities of the ecosystem. Interestingly, UVCs appear high up in the ranking together with some entrepreneurs, who have a relevant presence in the first position of the *Betweenness Centrality*, thus reflecting the active role USOs have in the network as

individuals who influence the flow of communication around the ecosystem. Regarding the whole network studied, the *Betweenness Centralization* is relatively low (39.054 percent), reflecting that the network is not dominated by a few between-central nodes.

Table 6. *Betweenness Centrality*

Agents ranking	Betweenness	nBetweenness
ENTREP5	5.137	2.822
ENTREP6	5.137	2.822
UVC	4.419	2.428
UVC	4.419	2.428
UVC	4.419	2.428

Note: The normalized betweenness centrality is the betweenness divided by the maximum possible betweenness expressed as a percentage.

4.3. *Analysis of the interviews*

In this section, we provide a deeper explanation of the social network interactions among participants in the selected EUE and how the knowledge dissemination leading to USO success occurs.

4.3.1. *The role of UVCs*

Regarding UVCs, we summarise the most relevant information from the interview analysis using two main categories: the concept of the UVC and its functions (knowledge spillover, EUs support, opportunity recognition and market gap, surrogate entrepreneurs, incubation services, and financial support).

Concept

Concerning the concept of University-focused Venture Capital firms, one UVC expressed, '*We, as a company, are a way to exploit and develop university knowledge*'. According to the interviews conducted, the main role of the UVC is to provide external support to universities looking to exploit entrepreneurial opportunities. UVCs were created by people with experience in technology and business development who, once they identified a good opportunity, helped academics to develop it as a USO, thus providing them with business support as well as investment for the first stages of development. They are considered strategic partners in developing *entrepreneurial universities*.

Knowledge spillover

The first function of a UVC relates to the idea of academic entrepreneurship: contributing to *knowledge transfer* from Universities. UVCs work together with universities in order to promote an entrepreneurial culture and create an environment where university research can be developed through USOs. One UVC interviewed stated that, *'When you think that the brightest ideas are inevitably often in universities, the challenge is to pull it out the universities and creating spin-offs that can actually take form into the economy to have an impact'* (UVC). Another commented, *'we invest in early stage technologies, particularly technologies that come out from the universities'* (UVC).

Entrepreneurial university support

During the interview process, TTOs were identified as very efficient agents in the knowledge sharing process for developing USOs, one USO noting that *'many universities have a commercialisation business function - maybe a department of the university or a separate company which works in the market'* (USO), and UVCs were named as one of those *'separate companies'*. According to the interviews, UVCs work closely with TTOs in continually looking for new emerging technologies in which to invest, thus creating new USOs and therefore supporting entrepreneurial universities and developing EUEs.

Opportunity recognition and market gap

Once an opportunity is identified, a UVC invests in this early stage of technology. As one UVC manager stated, *'my main responsibility is working within the universities, to identify IP [Intellectual Property] that we feel has the potential to become a USO and really it can be incubated and developed to build the business case'* (UVC).

According to the UVCs interviewed, once a new company is formed, the UVC carries out all the management activities involved in developing the research opportunities. This includes incubation and direction of the research, bringing in both commercial people to validate the technology and new management teams, getting the technology out of the university, making agreements with universities, and employing people in the USO. Thus, UVCs bring to the USO all the skills that academics may not have but need in order to run the company.

Regarding the market gap, UVCs recognise the difficulties of taking this research into the real market, stating that *'there is a gap in terms of translating these ideas into real solutions in the market'* (UVC). UVCs work within universities to identify IP that have the potential for exploitation in a new company. *'[In England] I think we should be a lot better because if you look at the science base, it's probably one of the best in the world and surely we are*

doing less than perfect in terms of commercial success turning in the entrepreneurial success' (UVC).

Surrogate entrepreneur

During interviews, one UVC mentioned that, *'Universities and academics don't have the experience and the skills for running companies... We are within the university trying to provide that help. That is the way in which we go'* (UVC), further commenting that they can do this by providing them with an experienced CEO (surrogate entrepreneur). However, not all the USOs studied had access to this choice, *'because, due to the maturity of the company, they did not have the resources to hire managers'* (USO). Another way to obtain these managers is to connect with UVCs, which bring to the USO all the skills that academics do not possess but need to run the company, and once the initial investment is made and the company is established in the market, the UVC still sits on the board of the company to ensure that it is developed. In this way, the USO keeps in contact with UVCs and TTOs over time, thus ensuring they are linked to the revenues of the established company, which will be invested back again in new emerging technologies at universities. Therefore, UVCs in England are key in sustaining university IP commercialisation.

Incubation services

As one UVC interviewee stated, *'Our activities regarding incubation are: bringing commercial people to validate the technology, bringing management teams, getting the technology out to the university, making the agreement with universities, and employ people into the spin-off company'* (UVC).

Financial support

Another UVC we interviewed mentioned: *'Our UVC has a number of venture capital investments that try to get funds that come out of some government initiatives to create enterprise within the university sector'* (UVC).

5. Discussion

This paper addresses the RQ: *What is the role of UVCs in knowledge spillovers in EUEs?* Our research shows distinct contributions regarding the role of UVCs in the emergent ecosystem approach.

First, this paper provides evidence of the role of UVCs in developing *entrepreneurial universities* in the emergent ecosystem approach, and expands upon the evidence found within the existing literature. Furthermore, it shows the role of UVCs in regional development (Larty *et al*, 2017), and details how USOs access adequate resources in terms of finance, skilled personnel, advice, and business development support (Harrison & Leitch, 2010). We also contribute to the entrepreneurship literature in the area of social networks and knowledge spillover approaches by empirically analysing the social network interactions among participants in EUEs and thus demonstrating how actors interact (Hayter, 2013b) and how the knowledge dissemination necessary for USO success occurs (Hayter, 2013a). Thus, it sheds light on the dynamics of the EUE and the role of UVCs. The results presented in this paper highlight the importance of building a connected ecosystem with a variety of participants for new venture success (Hayter, 2013b). In doing so, the agents mentioned in the academic entrepreneurship literature, such as TTOs and financial intermediaries, such VC or business angels (Audretsch *et al*, 2014; Hayter, 2016a) are identified, as well as their role in knowledge spillover from universities.

In addition, we study the creation of USOs, finding that universities act as facilitators which provided a supportive ecosystem in which the members of the community are able to start and develop entrepreneurial initiatives (Guerrero *et al*, 2014, 2016). However, in order to fulfil their economic and social impact, these universities require the help of knowledge intermediaries (Guerrero *et al* 2016; Siegel and Wright 2015). This study highlights the role of these knowledge intermediaries (Audretsch *et al*, 2014) in promoting the development of *entrepreneurial universities* and as a relevant participant in EUEs for USOs success (Hayter, 2016a).

According to the SNA conducted, our research shows that UVCs act as central agents of the ecosystem. From the perspective of the KSTE, this research also outlines the role played by UVCs, participating in the process of knowledge transfer as support to the entrepreneurial university. They contribute to reduce the gap between the university and the market by recognising opportunities and providing the support, incubation, and financial funding necessary for the creation of USOs. According to the interviews conducted during our research, UVC managers and USOs consider that these intermediaries work closely with TTOs by continually looking for new emerging technologies in which to invest, thus creating new USOs and therefore supporting entrepreneurial universities and developing EUEs.

In this vein, the major contribution of this study is the identification of the importance of UVCs (Graham, 2014) in developing and maintaining dynamic relationships between TTOs

and USOs. They provide support to the USOs as well as knowledge and resources during a long cycle that we call the *tidal effect*, rather than a one-off event in EUEs. UVCs favour USOs relationships with TTOs and enable repeated access to emerging technologies within universities, thus acting as key participants in the ecosystem. USOs tend to reduce their contact with TTOs over time, and UVCs play a critical role beyond simply company formation by helping maintain dynamic relationships between TTOs and entrepreneurs in USOs, thus giving rise to this *tidal effect* that sustains university IP commercialisation in EUEs. This effect means that the general investment made in research at universities returns to these institutions when USOs commercialise the university IP, promoting the EUE. The revenues generated are then reinvested in new technology in the university - metaphorically, they act as a *tide* that comes back.

6. Conclusion

The paper has identified the roles played by investment managers from UVCs in knowledge spillover in EUEs. Through social network analysis, we identified the central position of investment managers from UVCs connecting TTOs with ENTREPs. Additionally, through qualitative analysis, we discovered that these investment managers act, in addition to their previously recognised role of providing access to finance, as surrogate entrepreneurs on the board of USOs and also as surrogate technology transfer intermediaries co-located in the Universities. This places investment managers in the unique role of social connectors, as they enable more continuous knowledge and technology exchanges between Universities and USOs. We also identified the two surrogate roles played by investment managers, namely surrogate entrepreneurs in USOs and surrogate TTOs in universities. Thus, investment managers act as social connectors, facilitating two-way knowledge transfer exchanges, a process metaphorically conceptualised as a *tidal effect*.

Practical implications of our study include the idea that policymakers should bear in mind that investment managers from UVCs play a proactive role at the centre of a EUEs, the identification of the ongoing interactions between ENTREPs in USOs, and that investment managers in UVCs also play a significant role in reconnecting ENTREPs with TTOs in universities, thus providing further opportunities for university IP commercialisation.

However, our research has its limits, as it is an exploratory study that investigates the different ways of approaching academic entrepreneurship promotion involving UVCs and other knowledge intermediaries. The sample size may be considered small (two city regions,

15 interviews). Consequently, as a future line of research, an analysis of a larger number of observations coming from more regions and countries might improve the generalization of the results. In addition, the use of more quantitative methodologies would enrich the knowledge about the causal relations between different agents and their effects on the success of whole ecosystems, measured, for example, with the longevity of USOs supported by the UVCs.

7. References

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