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Shareholder Networks of University Spinoff Companies: Firm Development and Regional Characteristics

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Abstract

This paper contributes to the understanding of university spinoff (USO) development by analysing structural properties of their shareholder networks over time and across different regions. Theoretically, we propose a new stage-based typology of USO development across regions. Empirically, the study utilises a sample of 1033 academic spinoffs founded by 87 universities across 12 unitary regions in the UK considering the diversity of spatial contexts in the USO development. We undertake a social network analysis of relations USOs form with their parent universities and shareholders by adopting ‘betweenness centrality’ and ‘structural holes’ as two key measures. By employing this novel network-based view of firm development across regions, this study builds on the development model of USOs by identifying three key phases of USO development: 1) *organisation phase*, 2) *exploitation phase*, and 3) *maturity and reorganisation phase*. Second, we observe differences in USOs in terms of shareholder network development across diverse regional contexts. We propose a novel typology of entrepreneurial regions to better understand the diverse spatiality of USOs: *peripheral lock-in*, *entrepreneurial periphery*, *rigid core*, and *entrepreneurial core*. We call for further research to capture the long-term development and variable growth paths of USOs.

Keywords:

Academic spinoffs, universities, networks, network evolution, firm growth, regional economic development

1. Introduction

University spin-off (USO) is a unique type of firm (Prokop 2021a) characterised by high levels of innovation (Bagchi-Sen et al. 2020), attraction of venture capital funding (Mueller et al., 2012), and factors related to their survival (Prokop et al. 2019). While much of the research attention devoted to USOs tended to focus on their formation (e.g. Ramaciotti and Rizzo 2014), in recent years, there has been increasing interest in the performance of these ventures (Bolzani et al. 2021), and the influence of spatial (Bagchi-Sen et al. 2020) and institutional contexts (Marzocchi et al. 2019) on their activity and performance.

Networks with a range of actors can be clearly recognised as critical to a USO's success (Vohora et al. 2004). In particular, a USO's network capability is significant for its growth, performance and sustainability (Walter et al. 2006), suggesting that networks are equally important at every stage of the USO's development. Although much of the USO literature stresses the role of networks (e.g. Bourellos et al. 2012), the majority of studies on the networks of USOs have centred around qualitative small sample approaches (e.g. Vohora et al. 2004) where networks are merely recognised as part of firm development. Consequently, the evolution of USOs has been left under-theorised.

This paper asks the following research questions: 1) how do USO shareholder networks evolve and what do they reveal about firm development?; 2) are the USO shareholder networks different across regions? In order to answer these research questions, we use a sample of 1033 USOs from 87 universities across 12 unitary regions in the UK. The paper undertakes social network analysis of relations USOs form with their parent universities and other shareholders to describe network positions of USOs at different firm development stages. We then examine whether USO shareholder networks show the same characteristics across different spatial contexts. Based on the analyses, a typology of regions is constructed to better understand the nature of the USO networks.

The following parts of the paper review the USO development and network literatures in section 2, outline the methodology in section 3, report and discuss findings in section 4, while section 5 concludes the article with policy recommendations.

2. USO Development and Networks

2.1. Networks and USOs

Networks are critical to understanding USOs in a university-centred environment, as indicated by much of the academic entrepreneurship literature (e.g. Hayter 2016a) highlighting the importance of networks developed as part of university support for USOs (Patzelt and Shepherd 2009). For example, networks are provided by Technology Transfer Office (TTO) professionals (Lockett et al. 2003), especially those

linked to venture capitalists, entrepreneurs (Franklin et al. 2001), university alumni (Berggren, 2011), senior management talent (Shane 2004), or other university TTOs (Lockett et al. 2003). In particular, the UK universities that were more successful in developing USOs had greater ‘network capital’ (Huggins 2010) and existed in better connected university ecosystems (Prokop 2022), due to a more open-minded approach to technology transfer (Franklin et al. 2001). This resonates with Roper and Hewitt-Dundas's (2013) research that identified universities holding more central positions in networks. It is important to note that different types of universities pursue diverse entrepreneurial pathways and USO formation strategies reflect their own resource and capability limitations, but also their geographical focus (Sanchez-Barrioluengo et al. 2019).

These networks accessible to USOs could be strongly related to their university’s reputation effect endowing USOs with credibility (Mueller et al., 2012). Thus, the university’s internal characteristics, related to the volume of potential entrepreneurial opportunities, are interlinked with the university’s ability to equip a USO with more intangible characteristics crucial to its future success. Furthermore, Grandi and Grimaldi (2003) point out that the first networks that USOs build are in fact inherited from their parent organisations, indicating how critical university resources are for these companies.

Networking allows firms to overcome the liability of newness (Chan et al. 2010), build credibility (Bower 2003), access resources (Kitagawa and Robertson 2012), secure necessary funding and further opportunities for growth (Chan et al. 2010) and survival (Prokop et al, 2019). In other words, USOs develop networks primarily to access resources otherwise not available to them (Grandi and Grimaldi 2003). This is, however, far from an exhaustive list of what networks bring to USOs. Vohora et al. (2004) stress that networks with industry and external entrepreneurs play a key role in opportunity recognition, at the very early stage of USO formation. This is further supported by Landry et al. (2006), who found that the likelihood of USO formation is significantly influenced by the academic’s social capital.

Since proximity of firms induces networks, and networks lead to opportunities (Huggins, 2008; Fini et al. 2011), it is clear that the spatial character of networks is critical. This importance of local social capital has played a fundamental role in the development of the high-tech cluster, exemplified by the cases in the UK such as Cambridgeshire (Garnsey and Heffernan 2005), and Oxfordshire’s biotechnology cluster with distinct entrepreneurial culture and local networks (Lawton Smith et al. 2008). Similarly, studies in Sweden show that the successful development of USOs is linked to the continuing generations of networks developed by the USOs (Berggren and Lindholm Dahlstrand 2009), thus ensuring a continuous stream of knowledge-based entrepreneurship contributing to the local/regional economic development. These examples clearly indicate that evolutionary aspects play a central role in academic entrepreneurship considerations (Lawton Smith et al. 2008), as networks are built over time (Siegel et al. 2007). Benneworth and Charles (2005) go even further, describing the university as a central regional innovation agent, which could utilise USOs to diffuse knowledge in

underperforming regions, transforming its innovative capability. Thus, USOs could play the role of regional knowledge brokers.

The crucial difference between the networks at different stages of development is found in its orientation, where they transition from academically- to more commercially-oriented networks (Pérez Pérez and Sánchez 2003). This evolutionary aspect of inter-firm networks signifies that small firms switch from reliance on more personal-level social capital towards network capital, depicting inter-organisational connections of more calculative and deterministic character (Huggins 2010). It is critical to recognise that such connectedness transformation is not a uniform process across all USOs. In fact, USOs need to adapt their networks by building and restructuring their network position, aligning it with changing needs and expectations over time (Rasmussen et al. 2015), especially as their strong network position is related to performance (Scholten et al. 2015). Furthermore, USO productivity is related to academic entrepreneurs having stronger links with external entrepreneurs or industry (Bourellos et al. 2012). Prokop et al. (2019) in their study of UK USOs report that USOs' survival is dependent on their shareholder network structure, with those holding less constrained positions characterised by lower failure rate. Networks clearly play a critical role in the development of USOs and require further exploration to build on the existing development models.

2.2. USO Development

The USO growth model has been inspired by the original growth model of high-technology firms (Galbraith 1982) in general. However, the academic entrepreneurship literature so far has predominantly focused on the early stages of USO firm development, typically before the initial public offering (IPO) (Vohora et al. 2004; Rasmussen 2011; Parmentola and Ferretti 2018). Consequently, the importance of long-term contribution of USOs to the economic development (Vincett 2010) has been under-represented in the literature. To better understand the USO performance, an examination of the USO development over time is critical, as each stage of development poses a different set of challenges for these ventures. For instance, 'goal conflicts' between venture capital and USOs constitute one of the challenges for early stage of USO development (Sandstrom et al., 2016) as venture capitalists are less likely to invest in the starting phase of the USO (Wright et al. 2006).

Within the early stage, more specifically, four distinct phases of USO development have been identified (Ndonzuau et al. 2002; Shane 2004; Vohora et al. 2004; Rasmussen 2011; Parmentola and Ferretti 2018): 1) "research", providing a clear link of the to-be-developed intellectual property (IP) to the university it originated from; 2) "opportunity recognition", in which theoretical IP is assessed against possible applied or commercial purposes; 3) "proof of concept", in which the theoretical IP has been developed to a level where it can be proved to be a workable/practical IP; and 4) "start-up", in which various core resources are accumulated/assembled to create a separate legal entity to develop the IP into a finished product or service and generate revenue.

Even the ‘late-stage’ models (e.g. Parmentola and Ferretti 2018) end immediately after the firm starts selling the product, breaks even or attracts major investment. One could argue that this is a point at which the firm, however inflated by venture capital investments, is still in its infancy as it has not achieved the required scale of operations (Bigdeli et al. 2015) and therefore is still subject to a high degree of risk, where the company's status could change. Similarly, the Ndonzuau et al.’s (2002) final stage of creating economic value is quite broadly defined that it could depict any moment in USO’s post formation existence. This is especially paradoxical when taking into account the studies that focus on a USO’s IPO (Bonardo et al. 2011), or those that point out that a USOs’ significant contribution to economic development starts after firms become publicly listed, as this is when they actually start to grow (Lawton Smith et al. 2008). It is worth stressing, nevertheless, that many USOs do not even sell their products/services even after reaching the IPO stage, suggesting considerable heterogeneity (Siegel et al. 2007), and an increased difficulty in capturing their development in a single stage-based model.

Furthermore, while the models focus on the early stages until the USO firm is formed, they only account for a very short and intensive period of time in the life of a USO, leaving a vacuum between company formation and achieving Vohora et al.’s (2004) ‘sustainability’, or ‘creation of economic value’, as per Ndonzuau et al. (2002). There is a clear need to account for the longer term, especially as the dynamic growth period of USOs could take even 30 years (Vincett 2010) before levelling off. This means that for USOs created in the past 10-20 years (and more) the existing theoretical explanations of their development may reach their limits or even become redundant.

2.3. Conceptualising local and regional contexts

USOs are surrounded by specific contextual and institutional conditions facilitating the entrepreneurial climate of the region, underlying variable performance of these ventures across different spatial contexts (Prokop 2021b). Elements that pertain to institutions cannot be easily imitated (Braunerhjelm 2007). Local and regional contexts play a crucial role in USO support (Fini et al. 2011), as universities are immobile entities (Berbegal-Mirabent et al. 2013) and thus need to utilise the available regional resources and capabilities to their best advantage. Universities’ relationships with local economic growth are dynamic and change over time due to both internal and external conditions (Lawton Smith et al., 2014). Consequently, the performance of USOs across regions varies significantly.

Ramaciotti and Rizzo (2014) found that USO formation is greater in Italian regions that have less innovative activity, suggesting a knowledge spillover role for these firms; yet USOs of higher quality (Fini et al. 2017) and characterised by greater performance (Iacobucci and Micozzi 2015) are found in more developed regions, reflecting the complexity involved in spatial aspects of academic entrepreneurship. Rasmussen (2008) notes that actively engaged policymakers stimulate skills development among the TTO staff as well as encourage universities to *experiment with new approaches and initiatives* (p. 515). Nevertheless, it is important not to lose sight of support available to avoid duplicating initiatives at a cost to the taxpayer: in places where regional policies stimulate

entrepreneurship through a certain set of initiatives, e.g. provision of finance or tax incentives, universities focused on USOs should ideally invest their time in developing support initiatives not available at a regional level (Fini et al. 2011). As a result, it is important to understand what type of regional environments USOs occupy and how these relate to their development.

The role played by local industry structures and access to investments, funding and context-dependent entrepreneurial support mechanisms and other resources is further conceptualised in the literature on ‘entrepreneurial ecosystems’ that stresses the relevance of local entrepreneurial assets and networks for start-ups creation and growth (Stam, 2015). Brown and Mason (2017) suggest two types of such contextual characteristics: ‘embryonic’ and ‘scale-up’ ecosystems. The first describing ecosystems with low start-up activity, dependent on established businesses, locally-oriented, and building non-local connections only when necessary to access resources. In contrast, the ‘scale-up’ ecosystems are characterised by a dynamic venture formation activity focused on growth, where successful firms lead to entrepreneurial recycling, and firms integrated into wide-ranging networks of local, regional and international nature. As such, firms finding themselves in such radically different ecosystems may experience diverse growth patterns.

The difference in the characteristics of USOs at different stages of development affect their networks situated in different regional contexts. Based on the review of literature above, the paper aims to better understand how shareholder networks of USOs evolve and what they reveal about the firms and the entrepreneurial characteristics of their regional environments, specifically in terms of network resources available across regions. The remaining parts of this paper examine these networks empirically.

3. Research Design and Methods

3.1 Research context

The sample we employ comes from multiple sources to ensure cross-validation of data. First, we used www.spinoutsuk.co.uk to identify firms listed as USOs formed between 2000 and 2013. As the website lists USOs and other firms linked to universities (i.e. staff and graduate start-ups) we visited websites of all UK universities to validate the names and affiliations of USOs and collect further firms, especially those founded before the year 2000. Our next step involved a FAME (Financial Analysis Made Easy) database search to further confirm the relationship between universities and the firms and collect additional information on USOs, including firm demographics, and their shareholders. Resultantly, the study employs a sample framework of 1331 USOs established by 87 universities across 12 unitary regions in the UK. The data was captured in 2014 and includes USOs of varying ages, between 0 and 55 years with an average age of 9. Within the sample, 1033 firms were still live in May 2014, and these are the focus of our study.

The regional context of USOs in the UK presents a complex picture, as depicted in Table 1. There are twelve NUTS1 regions in the UK with varying characteristics. The regions characterised by

higher levels of economic output with higher concentrations of venture capital firms – London and South East – perform quite well, though not extremely so in terms of USO formation and survival of USOs. In fact, we observe that the region with the highest number of USOs is Scotland, highest number of USOs averaged by the number of universities is Northern Ireland, whilst the greatest survival rate of USOs is in East Midlands. The participation of the USOs in the regional populations of firms is largest in Scotland, whilst well below the national average for regions such as London, East of England or even South East. However, little is known about the evolution of the USO networks in relation to the entrepreneurial characteristics of each of these regions. Specifically, the distinct character of USO companies is not captured particularly well within Brown and Mason’s (2017) taxonomy, with Scotland and London sharing parts of both embryonic and scale-up ecosystems.

Table 1 About here

3.2 Methods

This study examines USOs from UK universities by adopting a network-based view, in particular observing the evolution of the USO networks, with their development in relation to diverse regional entrepreneurial characteristics. It undertakes social network analysis of relations USOs form with their parent universities and other shareholders, in total comprising of 12960 actors. Our network boundary delineation is based on a realist approach (Laumann et al. 1992) – in this case based on membership of those who have ownership of spinoff companies. Such networks are composed of ties where actors acted on connections and formalised them, frequently by exchanging equity in company for support. Given their nature, they also represent ties of trust. Shareholder networks are not exhaustive of all connections spinoff companies have, however, they represent a significant portion of connections that brought benefits to USOs. These also comprise of the key actors that play important roles in spinoff companies (Prokop 2021a). Such delineation and focus on specific network construct is important in the analysis of social networks to uncover meaning (Mitchell, 1969). It is important to highlight the use of shareholder data is common in the study of interorganisational networks (e.g. Li et al. 2016; Prokop et al. 2019).

Whilst several different variables could be used to describe network positions of USOs, we employ two key measures: “betweenness centrality” (Freeman 1977) and “structural holes” (Burt 1992) as the key measures used in many influencing studies (Huggins et al. 2020; Prokop et al. 2019).

Betweenness centrality (BC) is a measure of the extent to which an actor i plays a role of a hub in a network, i.e. the i ’s centrality is based on how many other actors in the network have to communicate with each other (or are linked) through i (Wasserman and Faust, 1994). In other words, betweenness centrality measures the probability that the interaction between actor j and actor k will travel through actor i accounting for all possible connections within the network for actors j and k . Therefore, the betweenness centrality BC of actor i is defined here as:

$$BC(i) = \sum_{j < k} \frac{g_{jk}(i)}{g_{jk}}$$

where g_{jk} is the number of shortest paths (i.e. geodesics) between actors j and k , whilst $\frac{g_{jk}(i)}{g_{jk}}$ is the probability that these paths include actor i (Freeman, 1977). The sum of those probabilities for all network actors for actor i , provides an index of i 's betweenness centrality. It takes a minimum value of 0 when i is not part of any geodesics, whilst it reaches a maximum value when i is part of all geodesics of length greater than 1 (Freeman, 1977). In order to standardise the index so that the measure takes values between 0 and 1 it is divided by the maximum value $\frac{(g-1)(g-2)}{2}$ being the number of pairs of actors excluding i (Freeman, 1977; Wasserman and Faust, 1994). Betweenness centrality indicates USO's importance in a network (i.e. holding central or powerful position) (Borgatti et al., 2018), given that it plays a mediating role between actors in a network, in essence being an information hub/broker. USOs with high levels of betweenness centrality are actors that mediate in greater information/resource transfer between network actors, making such USOs more powerful by the position held, information/resources transmitted, and its ability to disrupt such transmission (Borgatti et al., 2018). Holding such a role may indicate credibility in a network where information/resource flow relies on an actor with higher betweenness centrality.

Structural holes (*SH*) measure the position of an actor i dependent on the proportion of nonredundant ties in its network (Burt, 1992), with i having a stronger position when i 's network includes more actors that are not connected to each other. The i 's relations become redundant from the moment actors j and k form a tie. The measurement of structural holes is expressed as a constraint C of j on i , with i being more constrained in a network characterised by a higher number of redundant ties (Burt, 1992). As such i has limited (if any) opportunities to benefit from structural holes. We first denote aggregate constraint *AG* of actor i as a sum of all constraint of j on i , where constraint C is specified as follows:

$$C_{ij} = \left(p_{ij} + \sum_{k, i \neq k \neq j} p_{ik} p_{kj} \right)^2$$

with:

$$p_{ij} = \frac{a_{ij} + a_{ji}}{\sum_k (a_{ik} + a_{ki})}$$

where p_{ij} stands for the proportion of relation values a from actors i to j , and j to i , divided by the sum of all relation values $\sum_k(a_{ik} + a_{ki})$ of actor i (Burt, 1992). The value of structural holes SH for actor i is simply:

$$SH_i = 1 - AG_i$$

Structural holes signal USO's skilful exploitation of opportunities that enhance its success (Prokop et al., 2019). Since a structural hole depicts lack of a connection between two immediate actors of a USO, it awards the USO with opportunity to play one against the other (Burt, 1992) and explore non-redundant information/resource (Borgatti et al., 2018) – since disconnected actors have no way to share information/resources. In other words, structural holes measure the extent to which an actor is constrained within its most immediate network to utilise existing gaps in other actors' relationships (i.e. opportunities). Actors with high level of structural holes have more such gaps which translate to opportunities that can be exploited.

Each score is then converted into an index with an average value of 100 and standard deviation of 1, with the values of betweenness centrality and structural holes first standardised and then increased by 100 to ease interpretation. Within the data range, each 0.5 value difference constitutes an actual difference of approximately 5% for BC and approximately 9% for SH variables. In order to understand the evolution of the USO, and analyse the firm performance beyond formation, this study takes a longer time framework, in essence building on and extending the stage-based frameworks discussed above.

4. Findings and Discussion

This section presents the results of the social network analysis of the USOs aiming to better understand the interplay between the firm itself, and the USO shareholder network characteristics across different regional contexts. We first focus on the firm (USO) level networks by depicting how USOs at different development stages structure networks with their universities and shareholders, and then consider the regional level of USO networks presenting a typology of *entrepreneurial regions*.

4.1. USO networks – firm level

Figure 1 shows the evolution of the USO networks for firms aged 0-30¹. The network structure is captured with betweenness centrality and structural holes measures which are averaged for each individual firm age-year. There is a non-linearity observed in the development of USO networks, in particular with a clear starting point where USOs present weak centrality positions being strongly constrained in their networks. Over the first few years the situation clearly changes where USOs

¹ The choice of this age group is dictated by the more inconsistent data availability for older USOs across regions.

between ages 5 and 15 achieve peaks in developing their networks across both measures. Older USOs show signs of a greater level of fluctuation.

Figure 1 About here

In order to understand what the USO network evolution data says about USO development we employ a simple measure in the mean average for both BC and SH variables. Reaching the mean value for BC and SH development signifies a start of a new development stage where USOs have configured their networks to optimal or above optimal levels, enabling them to benefit from accumulated social capital (Coleman 1988; Burt 1992; Zaheer and Soda 2009). What this means for USOs is that they are now playing important roles (at least at the average level) in the network – where the reliance of network actors on information and resources travelling through USOs has increased (Borgatti et al. 2018). Equally so, once the USO network characteristics for BC and SH dip below the mean value, it signifies suboptimal network configurations and a different phase in USO development. This can be interpreted as loss of importance of USOs in the network below the average value for the network. The mean value² for BC is 100.05 and for SH it is 99.93.

As such we identify two clear transition stages, first, when USOs reach the mean value for SH (start of the transition) and for BC (end of the transition). We call this transition stage *optimum*, and find that it corresponds with Vohora et al.'s (2004) threshold of sustainability, where a firm transforms its network resources and capabilities into more profitable, reorganising its network structure. This is where we expect the academically-oriented networks of USOs morphing into commercially-oriented ones (Pérez Pérez and Sánchez 2003). Second, when the USOs' networks are in decline and cross the mean value for BC (start of the transition) and SH (end of the transition). We identify this transition stage as *lock-in*. Whilst previous research did not identify this juncture, there is a distinct exhaustion in USO network development where the aggregate constraint increases and betweenness centrality declines. This could lead to failure of the USO (Prokop et al. 2019), as the returns from existing contacts diminish, resulting in increased redundancy of connections and demotion from the previously powerful central position.

These transition stages separate three distinct phases in USO development: 1) *organisation phase*, 2) *exploitation phase*, and 3) *maturity and reorganisation phase*. The *organisation phase* covers the early years of USO development post-formation. The network-based analysis shows that USOs in this phase are characterised by centralising the network position and increased entrepreneurial behaviour (Burt 1992). This phase reflects Vohora et al.'s (2004) 're-orientation' phase, where firms accumulate resources and translate them into new sets of entrepreneurial capabilities. Here, these are

² Whilst the full sample of firms has an average of 100 for each of the measures, because we select a slightly reduced sample (aged 0-30) and average these measures for each individual USO age, the mean value for such a changed sample does not equal 100.00.

network resources that enable USOs to develop their technologies by mobilising their contacts (Parmentola and Ferretti 2018), connecting with investors and growing.

When the USO transforms its network position towards achieving the optimum, it transitions towards the *exploitation* phase, where USOs stabilise their network structure. *Exploitation* phase goes further than Vohora et al.'s (2004) 'sustainable returns' stage. In the *exploitation* phase the USO is characterised by above optimal network characteristics, where the board composition changes in line with required skillsets (Bjornali and Gulbrandsen 2010) and new networks that need accessing. The length of this phase is determined by the firm's observation of the lock-in effect, where previously new and heterophilous relations become homogenised over time by shared experiences, routines and groupthink. This could also be reflected through a tendency for homophilous management team formation in new ventures (Parker 2009) and further additions to the USO's board from founder's networks³ (Bjornali and Gulbrandsen 2010), essentially having a cumulative effect of increasing network constraint. The phase ends when the USO starts losing its centrality and its aggregate constraint increases, essentially leading the USO towards a network *lock-in* characterised by the firm's increased unresponsiveness to market dynamics, limited innovation levels, and an intensified reliance on a smaller network of stronger ties (Capaldo 2007). The end of the *lock-in* transition signifies a start of the next phase: *maturity and reorganisation*. This is observed from both measures crossing their mean values multiple times, indicating a level of dynamism in network positions. Spinoffs at this stage of development form new ties and disband old ones in pursuit of new knowledge and to ensure long term survival (Huggins 2010) by avoiding network lock-in and regaining the optimum. To achieve this, USOs need to become more selective in network development (Walker et al. 1997) in order to increase their levels of opportunities (Burt 1992) that are related to higher probability of success (Prokop et al. 2019). These phases represent a non-linear network development. We depict the USO development model based on the network data in Figure 2.

Figure 2 About here

4.2. USO networks – regional level

We aggregate the network characteristics of the USOs to depict average structural positions of USOs based across twelve unitary regions in the UK (Table 2). There is a clear divergence between regional entrepreneurial conditions as reflected in network attributes. The Greater South East regions, inclusive of London, South East and East of England, are home to USOs with the strongest network positions across both betweenness centrality and structural holes. Whilst USO numbers and their survival in these regions are not exceptional (Table 1), USOs based in these most economically developed regions clearly

³ Whilst at first the new additions increase the USO's structural position, further additions from the same networks of the founders introduce redundant ties.

benefit from accumulated stocks of structural network capital (Huggins and Prokop 2017). This suggests that USOs based in these regions gain access more quickly to more important actors than USOs based elsewhere. This could be due to a presence of well-performing universities and companies in these regions or regional innovative performance, with the causality of the mechanism remaining unknown (Huggins and Prokop 2017). Whilst the data does not allow us to comment on prior informal contacts actors in these regions have, the greater presence of some of the key actors in these regions (e.g. venture capitalists, entrepreneurial talent), past connections, could offer some of the potential explanations for the observed results. Conversely, the most peripheral economic regions of North East and Wales present further diversity in terms of their network positions, with Wales characterised by higher level of survival of its USOs also showing stronger network characteristics (Prokop et al. 2019).

Table 2 About here

Figure 3 depicts these values in a graphical form, where we centre the axes at 100 for both BC and SH. We identify a new variety of entrepreneurial regions. Instead of a typical dichotomy of core versus periphery, four types of regions emerge: a) *peripheral lock-in*, b) *entrepreneurial periphery*, c) *rigid core*, and d) *entrepreneurial core*.

Figure 3 About here

The *peripheral lock-in* regions (e.g. North East) are characterised by constrained network positions of their USOs struggling to access a more diverse pool of actors, which may be either available in scarcity or not available at all. USOs in such regions struggle to build their centrality, as the availability of ecosystem actors is markedly lower (Xu and Dobson 2019). For example, it is possible to observe limited pockets of external entrepreneurial talent to form strong management teams or attract venture capital investment, highly concentrated in London, Cambridge and Oxford (Prokop 2021b). This may be further complemented by the low participation of the USOs in such regions in their respective clusters (Bagchi-Sen et al. 2020).

In comparison, the *entrepreneurial periphery* depicts a type of region (e.g. Wales) where USOs are not well-connected overall, but enjoy access to some key actors channelling entrepreneurial opportunities (Burt 1992). The limited connectedness may stem from locational conditions (Huggins and Prokop 2017) and less developed ecosystems, making access to a large pool of actors difficult. At the same time, USOs in *entrepreneurial periphery* could be better able to catalyse limited local network resources, and where possible connect with the important ecosystem actors from outside their regions (Prokop 2021b). This may be observed through a more strategic orientation towards securing investors and entrepreneurial talent (Huggins 2010), regardless of where it is located.

USOs that reside in a *rigid core* type region (e.g. Scotland) benefit from high levels of connectivity, but have limited entrepreneurial opportunities potentially stemming from network closure effects. Such regions may contain quite well developed and connected local ecosystems reflecting network dynamics of scale-up ecosystems (Brown and Mason 2017), that have a good pool of actors in vicinity. However, the higher level of aggregate constraint indicates a potential homophily and disconnect of such ecosystems (i.e. spatial dynamics of embryonic ecosystems – Brown and Mason 2017), essentially limiting availability of diverse strategic actors and opportunities that come with them (Burt 1992). We may observe that USOs in *rigid core* regions have good access to entrepreneurial talent, investment and markets, but due to high centrality and disconnect they may be characterised by groupthink and limited ability to identify a successful development path (Capaldo 2007).

The *entrepreneurial core* typifies regions (e.g. South East) where USOs hold central positions in the network with access to a greater level of entrepreneurial opportunities. This preferential network structure may be a consequence of network capital accumulated by the local ecosystem actors (Huggins and Prokop 2017), in particular its self-reinforcing character (Minniti 2005). It is important to note that the *entrepreneurial core* is aligned with the regions that are also the most economically developed in the UK, clearly offering an environment rich not only in the numbers of actors but also their higher level of diversity, enabling USOs positioned there to quickly grow their betweenness centrality and benefit from higher proportion of structural holes. This means that such regions have easier access to a wide-ranging entrepreneurial talent, investors and other key ecosystem actors (Hayter et al. 2018).

5. Conclusion

This study employs a novel network-based view of the USO development across diverse regions and regional entrepreneurial environments, resulting in two key contributions. First, we build on Vohora et al.'s (2004) development model by identifying two additional phases: *exploitation*, and *maturity and reorganisation*, capturing the late-stage development and building on previous USO development models (e.g. Parmentola and Ferretti 2018). The *exploitation* phase is when USOs capitalise on their developed networks, further reinforcing them through exploring new opportunities (Burt 1992) and strengthening their centrality position. This is followed by the *maturity and reorganisation* phase when USOs actively respond to a threat of network lock-in, homophily and limited development opportunities. This stage is characterised by greater dynamism in network development that is characterised by more strategic and calculative behaviour (Huggins 2010).

Second, following Hayter (2016b) indicating the importance of the regional characteristics to the performance of USO networks, we observe differences in USO network development across regional contexts, suggesting a novel typology of entrepreneurial regions. Specifically, we identify four such types: a) *peripheral lock-in*, b) *entrepreneurial periphery*, c) *rigid core*, and d) *entrepreneurial core*. *Peripheral lock-in* regions are characterised by their USOs having weaker network positions observed in lower values for betweenness centrality and structural holes of individual USOs compared

to those based in other regions. Such regions offer lower stocks of network capital to their firms (Huggins and Prokop 2017). In contrast, *entrepreneurial periphery* regions show greater level of opportunities being accessible to firms, even though the availability of actors is limited. This may be a result of USOs from these regions developing connections to actors in other regions (Prokop 2021b). USOs based in *rigid core* regions enjoy stronger connectivity with local/regional actors, however suffer from peripherality and limited opportunities for growth. USOs in such regions struggle to access particular types of actors e.g. entrepreneurial talent (Prokop 2021b), important to developing the companies. Finally, *entrepreneurial core* regions offer their firms the best network capital, enabling the USOs based in these regions to grow more central positions and explore a greater level of access to more diverse opportunities, perpetuating success (Minniti 2005).

5.1. Implications

A variety of national and regional policy measures has been put in place to stimulate the creation of university spin-off firms over the last decades. Universities have changed their policies, incentive mechanisms to encourage academic entrepreneurship. In this context, the findings presented here signify a number of policy and management implications.

Managerial implications

The USO development follows a non-linear path, and instead of stability (Vohora et al. 2004) the later stages are characterised by further instability, as visible from our analysis of aggregated data, where the company needs to reorganise its networks to ensure survival. This finding extends the theoretical works on stages of growth of spinoff companies (e.g. Ndonzuau et al. 2002; Gübeli and Doloreux 2005). In particular, our research highlights the continuous challenges even for the established firms.

For university administrators interested in the success of their spinoff companies, our findings suggest a longer-term engagement in supporting the firms, potentially through the technology transfer officers to monitor spinoff companies and be available to engage with them by mobilising their connections to university ecosystem actors (Hayter et al. 2018) and also encouraging USOs to proactively build new unique connections. For investors with equity stakes in spinoffs it is important to recognise that even at later stages they may have to return to a more active role either proactively – recognising the upcoming network lock-in and steering the firm's strategic development, or responsively by tapping into their vast networks to help the spinoffs reorganise their management teams.

Policy implications

This long-term view of spinoff development opens new avenues for policymakers, university administrators, and investors, to better understand the needs of companies for steering and support. In particular, the policymakers need to recognise that business support should not just focus on the initial development phases, but may also be required at later stages, especially when things may appear stable, potentially indicating a network lock-in.

The taxonomy of regions presented here offers a more complex perspective on regional entrepreneurship, and specifically indicates the struggle of poorer connectivity among more peripheral regions (*peripheral lock-in* and *entrepreneurial periphery*), compared to a stronger network capital accumulation available in the *entrepreneurial core* (Huggins and Prokop 2017). The policymakers may consider placing a greater emphasis on building inter-regional networks to at least partially alleviate the issues faced by peripheral regions that lack the necessary connections in their localities.

Finally, the regional network results also present a perplexing nature of academic entrepreneurship, where peripheral regions with weaker network capital observe superior survival outcomes, whilst *entrepreneurial core* regions achieve mediocre survival results at best. A similar picture was observed in Mueller et al. (2012) with regards to venture capital finance. This could be explained by different risk profiles of these regions, with more selectivity taking place in the periphery. It is important for policymakers to observe this ‘efficiency’ in employing network resources, when deciding which regions should receive support and the extent of it.

5.2. Limitations and recommendations

This research is not without limitations, and a more comprehensive picture of networks could be presented if a larger network was captured rather than just shareholder-based one. However, it is extremely difficult to identify the full picture of network with a variety of actors (Hayter, 2016a) and confirm their belonging, which would provide insights on the availability of potential for actions, in addition to network capital acted on (Huggins, 2010). Scholars in the field of academic entrepreneurship may build on the findings presented in this paper by capturing such networks of spinoff companies to examine their evolution. Further to that, future research could focus on the questions of which connections lead to particular shareholders taking equity in spinoff companies and what the connections between individual shareholders are. Whilst this paper employed two social network measures well established in innovation and economic geography literatures (Huggins et al. 2020), a more intricate picture could be captured by observing other network characteristics, which may require additional data – for example specifying the value of each relation. We also recognise that even though the paper captures a large span of USO lifecycle, this is still a relatively short period of development captured, as indicated by Vincett (2010). Future studies would do well to expand on this, especially highlighting the complex interplay between institutional and regional contexts, as the USOs become more established firms.

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Table 1. Regional USO characteristics.

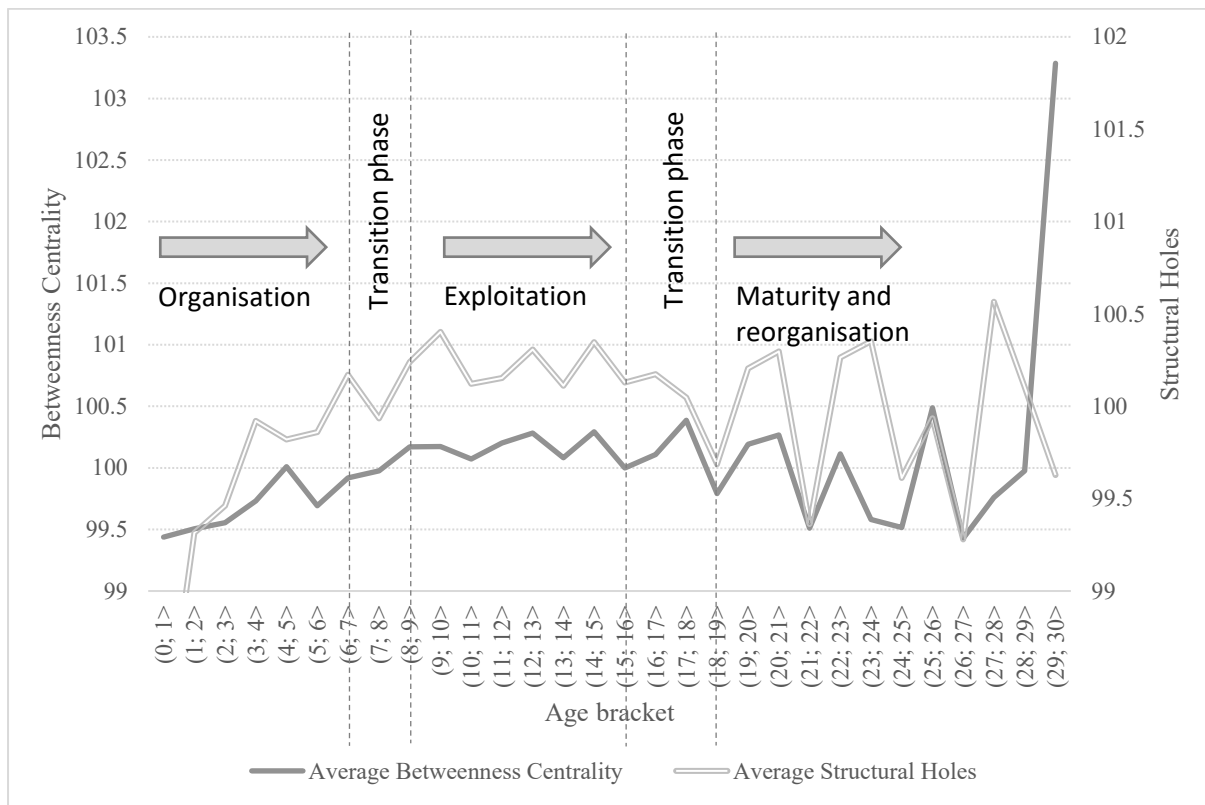
	Number of USOs (2013)	Survival of USOs (2014)	USOs per university (2013)	GVA per capita [£] (2013)	Active spinoffs per 1000 active firms (2013)	University experience in forming spinout firms [years] (2014)	Early-stage VC investment per firm [£m] (2013)	Total VC investment s per firm [£m] (2013)
East Midlands	66	87.88%	13.20	19902	0.36	16.90	0.77	13.50
East of England	111	81.98%	22.20	22137	0.37	15.20	2.00	5.71
London	195	77.95%	16.25	40516	0.33	15.91	0.34	4.32
North East	57	66.67%	11.40	17697	0.58	13.69	0.19	1.59
Northern Ireland	57	80.70%	28.50	18329	0.82	22.52	0.23	0.43
North West	103	79.61%	12.88	20455	0.34	13.06	4.00	5.32
Scotland	280	72.50%	18.67	22174	1.25	24.81	0.27	2.76
South East	189	82.01%	21.00	26276	0.40	19.00	1.29	9.37
South West	61	73.77%	12.20	21644	0.21	16.56	0.36	7.24
Wales	48	87.50%	8.00	17215	0.47	15.53	0.60	2.20
West Midlands	74	66.22%	9.25	19630	0.26	14.50	0.49	2.17
Yorkshire and the Humber	90	80.00%	12.86	19314	0.42	20.24	0.20	9.10
Total	1331	77.61%	15.30	24131	0.42	17.77	1.14	6.16

Note 1: Survival of USOs was tested in May 2014.

Note 2: Venture capital investments include firms that are not USOs.

Note 3: University experience is based on earliest spinout registration date until survival testing.

Figure 1. Stages of USO development.



Note: Data limited to active USOs aged 0-30 years due to inconsistent annual data availability for older spinoffs. The resultant N=1024 spinoffs, with the exclusion of only 9 firms.

Figure 2. USO development model

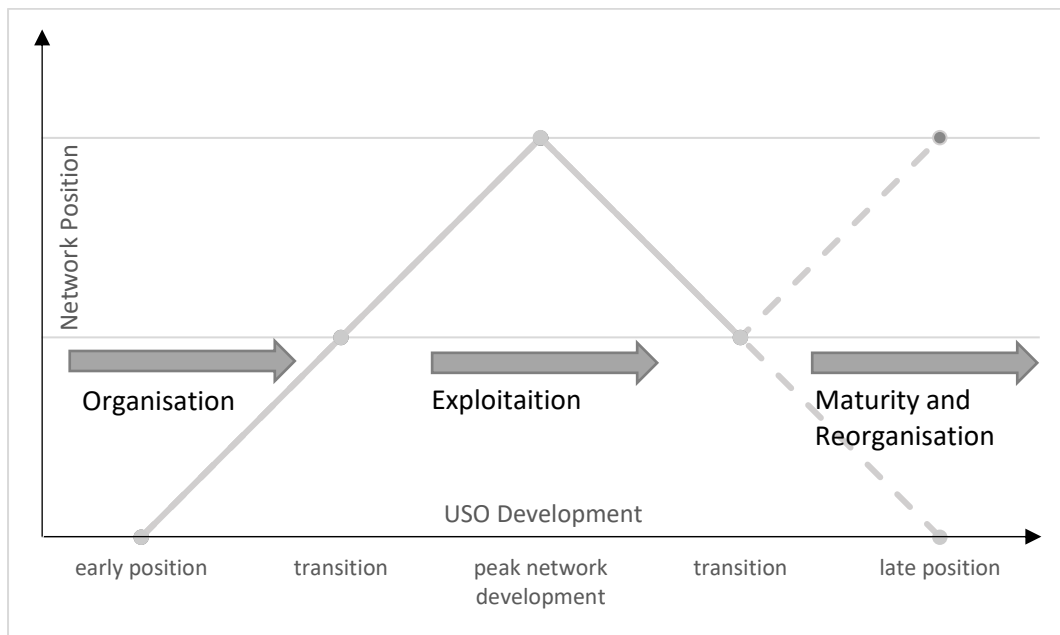


Table 2. Regionalised characteristics of the USO networks.

	Average Betweenness Centrality	Average Structural Holes
East Midlands	99.72	99.60
East of England	100.15	100.28
London	100.15	100.21
North East	99.79	99.77
Norther Ireland	99.97	100.09
North West	99.95	99.92
Scotland	100.01	99.93
South East	100.11	100.16
South West	99.92	99.82
Wales	99.89	100.03
West Midlands	99.90	99.93
Yorkshire and the Humber	99.82	99.69

Note: Active USOs depicted, N=1033.

Figure 3. Typology of entrepreneurial regions.

