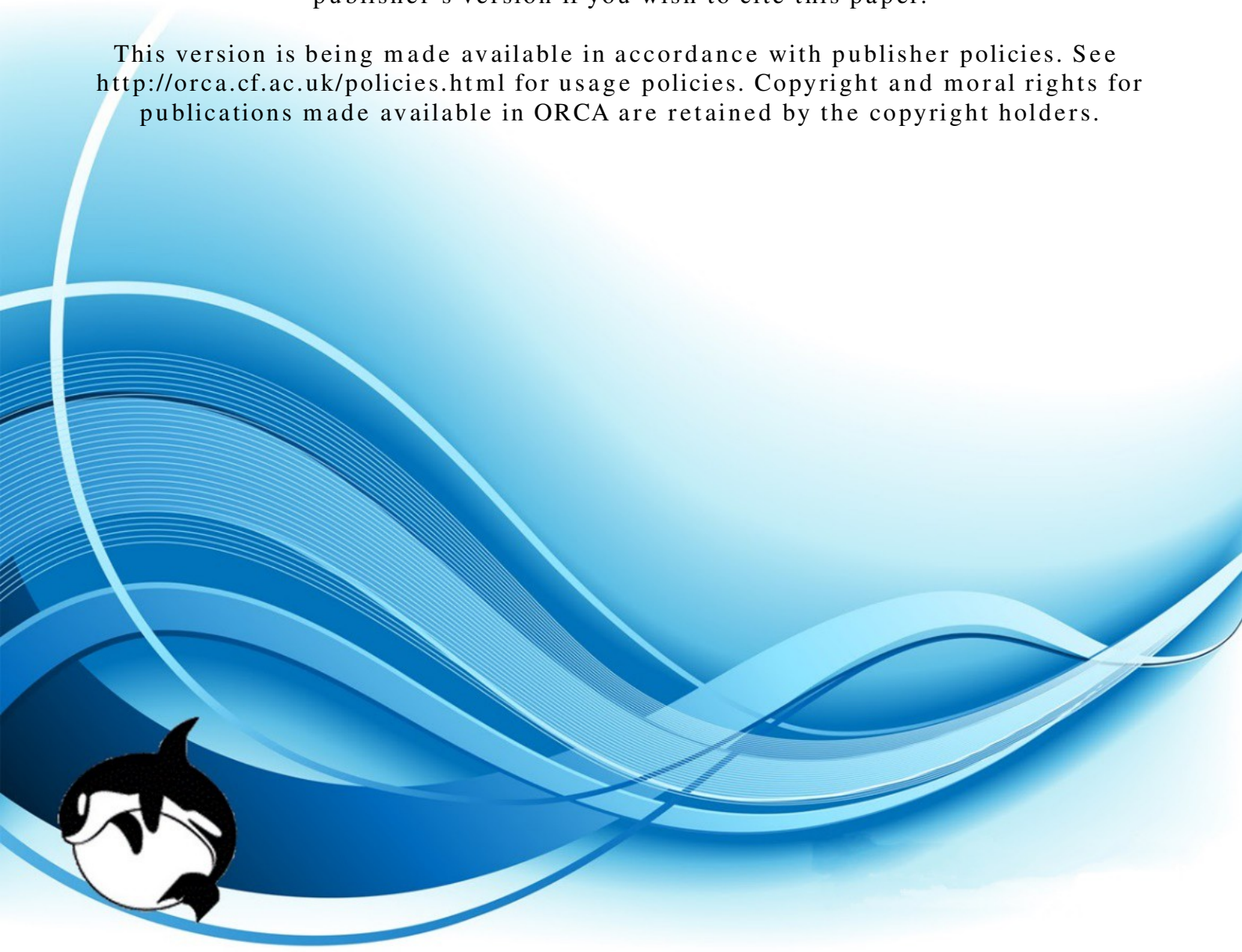

The Composition of University Entrepreneurial Ecosystems and Academic Entrepreneurship: A UK Study

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Abstract

The paper examines the link between the composition of university entrepreneurial ecosystems and performance of higher education institutions (HEIs) in academic entrepreneurship, specifically founding academic spinoff companies. The paper studies a sample of 160 UK HEIs and their university entrepreneurial ecosystems related to formation of 784 academic spinoffs. It employs social network analysis to inspect the composition and connections between university entrepreneurial ecosystems. It finds that HEIs based in better developed university entrepreneurial ecosystems are associated with formation of greater numbers of academic spinoff companies. The best performing ecosystems are based in the Greater South East region. It is concluded that policymakers need to recognise the importance of the composition of the university entrepreneurial ecosystems and the role it plays in academic entrepreneurship.

Keywords: *academic spinoffs, entrepreneurial ecosystems, universities, networks, knowledge commercialisation*

Introduction

As the demand for university knowledge commercialisation has grown in significance (Etzkowitz et al., 2000; Compagnucci and Spigarelli, 2020), universities are more frequently engaging in Third Mission activities, in part through their own initiative to improve institutional budgets (Chiesa & Piccaluga, 2000; Giuri et al., 2019) and/or due to government initiatives to support the generation of wealth and competitiveness (DTI, 1993; HM Government, 2017). Across many university knowledge commercialisation modes - e.g. licensing patents, consultancy, and collaborative research - a growing attention is being paid to the academic spinoff companies by both institutional investors (Chiesa & Piccaluga, 2000; Bank of England, 2001; Library House/UBS, 2006; Lenzer and Kulczakowicz, 2021) and economic development policymakers (Lambert, 2003; Shane, 2004), especially from a regional perspective (Huggins et al., 2008).

The role played by universities in securing the success of academic spinoffs goes beyond considerations of IP protection, and involves the provision of access to business incubators (Library House/UBS, 2006) and science parks (Link & Scott, 2005), as well as networks of investors (Mosey and Wright, 2007; Munari et al., 2018; Bonardo et al., 2011) and experienced entrepreneurs (Lockett et al., 2003; Library House/BVCA, 2005) that can be considered as a university's network capital (Huggins, 2010). These actors, inclusive of Technology Transfer Offices (TTOs), which play important roles in university knowledge commercialisation through spinoff formation (Fini et al., 2011) and

contribute to their longer-term success (Prokop et al., 2019), constitute the core components of the university entrepreneurship ecosystem (UEE) (Hayter et al., 2018).

The current development of knowledge concerning the role of the UEE in the success of academic spinoffs is largely fragmented (Phan & Siegel, 2006; Hayter et al., 2018) and focused on internal institutional or spinoff characteristics (Jensen & Thursby, 2001; Di Gregorio & Shane, 2003; Lockett et al., 2003; Shane, 2004; Debackere & Veugelers, 2005; Clarysse et al., 2011), with the recent qualitative evidence pointing to the importance of configurations of the UEEs (Prokop, 2021). Furthermore, the literature concerning the critical perspectives and problems of academic spinoffs and spinoff company formation has been growing in strength (Lambert, 2003; Siegel et al., 2007; Swamidass & Vulasa, 2008; Harrison & Leitch, 2010; Markman et al., 2008; Gianiodis et al., 2016; Lindholm Dahlstrand et al., 2016), emphasizing the evident need for a more holistic approach to researching the topic. Specifically, little is known whether a more developed UEE composed of most of these actors, i.e. business incubators, science parks, investors, experienced entrepreneurs, TTOs, is linked to greater spinoff numbers.

The paper systematically reviews the importance of the university entrepreneurial ecosystem indicated above in the process of university spinoff creation by applying a network perspective. It has an exploratory character and attempts to shed light on the following question: Is the composition of the university entrepreneurial ecosystems associated with supporting spinoff company creation? The paper is based on an empirical study of 160 HEIs and their ecosystems in the UK. It leads to the consideration of structural disparities between spinoff company formation performance across the UEEs, and offers recommendations on reducing these disparities. The key contribution of the paper is in recognising a link between the spinoff formation and the composition of the university entrepreneurial ecosystems, with those that are more developed generating a greater number of firms. Specifically, HEIs that intend to focus on the academic spinoff formation activity require an ecosystem composed of business incubators, science parks, investors, and external entrepreneurs.

Academic Entrepreneurship and University Entrepreneurial Ecosystems

Academic Spinoffs and Economic Development

The ‘Third Mission’ extension of the key roles (i.e. teaching and research) of the universities has drawn an increased and intensified interest from academia (Goldstein, 2010) and government (e.g. Lambert, 2003) to the now officially ascribed responsibility of universities for a significant part of economic development (Lawton Smith, 2007; Wong et al., 2007, Etzkowitz & Dzisah, 2008; Lopez et al., 2009; Goldstein, 2010). The fact that the university contribution to the economic development has been formalised does not mean there was no such contribution before. The difference between the two is the recent focus on the university research commercialisation as playing the more important role in the economic development, rather than typical university inputs, e.g. employment, expenditure, quantity of students (Goldstein et al., 1995; Garrido-Yserte & Gallo-Rivera, 2010) which do not capture the full

scale of economic contribution of the university (Thanki, 1999). These effects could also be observed from the creation of academic spinoff companies (Berggren & Lindholm Dahlstrand, 2009), accredited with greater economic potential (Lambert, 2003; Shane, 2004; Phan & Siegel, 2006; Siegel et al., 2007; Huggins et al., 2008).

As the academic spinoff firms are based on specific innovation (Etzkowitz, 1998; Shane, 2004), it is important to note that the size of those companies – predominantly small – (Harrison and Leitch, 2010) may not necessarily act against them in the competitive markets, as small firms have been reported to experience better rates of innovation than their larger counterparts (Gellman Research Associates, 1976; The Futures Group, 1984; Audretsch, 1991; Chakrabarti, 1991; Audretsch, 1995). Furthermore, small innovative firms attracted by university R&D intensity are found to contribute positively to the local/regional economic development both directly and indirectly through related multiplier effects (Kirchhoff et al., 2007). However, these localised effects could migrate outside if the local/regional absorptive capacity and resources to support the innovative firms are not adequately developed (Christopherson & Clark, 2010).

The studies that focused on the contribution of the university through academic spinoffs have demonstrated positive effects on economic development (Chrisman et al., 1995; Lawton Smith, 2000; Dahlstrand & Jacobsson, 2003; Shane, 2004; Clarysse et al., 2005; Vincett, 2010). In the UK some of the economic contribution of the academic spinoffs could also be observed via exits, either through IPOs (Initial Public Offerings) (Wright et al., 2007) or acquisitions, with over 80 having taken place thus far (Prokop et al. 2019). It is important to note that these contributions become more significant in scale over a longer time frame (Vincett, 2010). However, not all evidence is large enough in scope to provide a clear and robust picture of the spinoffs' contribution to the economy. Thus, some doubt could be observed as to the economic value of the university spinoffs (Harrison & Leitch, 2010). Lambert Review (2003) already highlighted a problem of quality versus quantity orientation in university strategies towards academic entrepreneurship, with the evidence suggesting the second to be dominant. This is in many instances a result of focusing support activities on creating rather than developing the spinoffs (Siegel & Wright, 2007). However, this does not necessarily diminish the importance of spinoffs as an economic development mechanism, as the quantity-orientation follows the logic of intensification of economy-developing activities performed by the universities. Similarly, although based on HEFCE's (Higher Education Funding Council for England) HE-BCI (Higher Education-Business and Community Interaction) survey data and their own research Harrison and Leitch (2010) argue that the spinoffs' contributions to the economic development are rather insignificant, it is important to note that their contributions require broader consideration in terms of the role played in the local ecosystem (Benneworth and Charles, 2005) and through their non-local links (Prokop, 2021).

University Entrepreneurial Ecosystems

The concern of many researchers in a recent decade was focused on the effectiveness of the academic spinoff company creation (Meoli and Vismara, 2016; Neves and Franco, 2018), but also performance (Corsi et al., 2017; Fini et al., 2017; Prokop et al. 2019). However, recent developments in the field suggest that a wider university environment is critical to academic entrepreneurship (Boh et al., 2016). Specifically, the studies identified a number of key actors that play important roles in supporting academic entrepreneurship that constitute the university's entrepreneurial ecosystem: universities, technology transfer offices, business incubators, science parks, investors, and external entrepreneurs (Hayter et al., 2018; Prokop, 2021). Each of these actors is examined individually below.

Technology Transfer Office

The primary development in the university commercialisation activities and the commitment to its increased economic role is expressed in the establishment of an internal unit/department concerned with the knowledge transfer – Technology Transfer Office (TTO) (Etzkowitz et al., 2000; Siegel et al., 2007). The role of the TTO is principally concerned with administrative burden of technology/knowledge transfer with a focus on legal aspects (IP – Intellectual Property) and commercial exploitation (Huggins et al., 2008; Goldstein, 2010) through, for example, creating a company or licensing the university IP. This administrative function is not definitive as can be found in Siegel et al. (2007) who discussed a much wider role of TTOs in relation to strategic decisions concerned with invention disclosure and commercialisation, and institutional responsibility. Lockett et al. (2003) also stress the importance of TTOs in relation to identifying the commercial opportunities at the universities. In addition to that, Shane (2004) also points at another role – providing the 'network of stakeholders' (p.76), in particular the providers of 'human and financial resources' (p.78). In essence, the TTO needs to play a role of a boundary spanning actor (Alexander and Martin, 2013) between the university, the spinoff company, and the rest of the UEE.

Business Incubators and Science Parks

Business incubators are in essence institutions created to aid new firms, particularly technology-based, by providing a range of business support services, for example office space, equipment and business advice (Grimaldi & Grandi, 2005) to increase their initial survival chances (Sun et al., 2007). As noted by Sun et al. (2007) there is little doubt in the effectiveness of business incubation, proving it to be a vital element of UEEs for academic spinoff companies. The concept of science parks is very close to that of business incubators (Tamasy, 2007), with the difference in scope of support and profile of tenant firms – typically being a mix of startups and subsidiaries of large firms. Thus, science parks still 'facilitate commercialisation of technologies, stimulate development of technology-based SMEs and promote regional development' (Malairaja & Zawdie, 2008, p.729; Zeng et al., 2010) to as much a degree as business incubators do (Wynarczyk & Raine, 2005). However, this may come at a different price point for the tenant firms (Tamasy, 2007). Importantly, whilst these incubating components of the

UEE clearly have an important role, there is only limited evidence of their use by academic spinoff companies (e.g. Hewitt-Dundas, 2015), which typically incubate within university departments. However, notably business incubators and science parks may contribute to the availability of entrepreneurial networks for spinoff companies (Prokop, 2021).

Investors

The investors in the format of public funds (Huggins, 2008), university venture funding (Munari et al., 2018), business angels (Mosey and Wright, 2007) and venture capital (Bonardo et al., 2011), endow spinoffs with critical start-up resources that typical new firms lack. In 2006 approximately 19% of the UK Venture Capital market's portfolios consisted of university spinoffs or start-ups, with average investment of £3.6m per company, which was below the average for similar investments in independent start-ups (£4.1m) and corporate spinoffs (£7.0m) (Library House/UBS, 2006). This could be related to the fact that academic ventures are often perceived as high-risk investments by venture capitalists (Harding, 2000; Oakey, 2003; Shane, 2004), due to their very early stage of technology development and the consequent long time of product-to-market delivery (Shane, 2004). As a result, it is often hard for the inventors to fund their ventures due to inherent information asymmetry issues, especially considering the low availability of early-stage funding (Murray, 1999; Lockett et al., 2002; Wright et al., 2006; Huggins, 2008; Pinch & Sunley, 2009). This, in particular, emphasises the need for the university TTOs to develop links with investors which may often mean 'life or death' for the new ventures (Shane, 2004). Such cooperation is typified by very early engagement of specialist spinoff-focused investors that select the most prominent disclosures (Prokop, 2021).

External Entrepreneurs

Another important part of the UEE is concerned with external entrepreneurs (Franklin et al., 2001; Lockett et al., 2003; Shane, 2004; Library House/BVCA, 2005; Wennberg et al., 2011). The Library House/BVCA (2005) report specifically stresses the importance of TTOs engaging with experienced entrepreneurs in order to develop academic spinoffs, as these contribute commercial (Wennberg et al., 2011) and management (Grandi and Grimaldi, 2003) experience as well as their own networks (Franklin et al., 2001). As such, they play important roles in spinoff company formation, both passive – expressed in enhanced commercial credibility of the spinoffs (Wright et al., 2006) – and proactive – reflected in fund-raising (Vohora et al., 2004). This is especially important, as venture capitalists assess a company's investment attractiveness by focusing strongly on its management team (Gompers et al. 2020). Hayter (2013) finds that spinoff formation is associated with the presence of the external entrepreneur in the management team. In fact, academic spinoffs that have a management team composed of academic and non-academic individuals achieve greater early-stage performance (Visintin and Pittino, 2014), highlighting the post-start-up role of external entrepreneurs. In fact, this mixed background is related to firm's innovative capability (Arvanitis and Stucki, 2012). This is further

evidenced in Lundqvist (2014), who found that spinoffs with external entrepreneurs performed better than those run by academic founders only. Additionally, having more external entrepreneurs in the management team is found to contribute to greater entrepreneurial orientation of the spinoff company (Diánez-González and Camelo-Ordaz, 2016).

Networks

The actors discussed above form networks (Hayter, 2016) which underpin the organisation of entrepreneurial ecosystems (Spigel, 2017). As such it is important to refer to the concept of social capital which is concerned with the value of links between different social actors (Lin, 1999). As the social capital concept originates from the focus on social actors, it may be over-stretched in the considerations of more institutionalised ones, i.e. organisations or firms. A more adapted to organisational character concept has been proposed in a form of network capital (Huggins, 2010). Huggins (2010) argues that network capital can be managed, unlike social capital being based on individual actors difficult to control at an organisational level. This paper acknowledges the two concepts, as the UEEs involve both human and institutional actors.

Within the network considerations there is a clear relationship between densely populated networks and better performance of firms or organisations (Fleming et al., 2007; Hochberg et al., 2007; Schilling & Phelps, 2007), as better connectedness increases the flows of knowledge. This paper explores whether academic entrepreneurship activity differs across UEEs of different composition (i.e. having more or less of the key actors/ being more or less connected).

The University Entrepreneurial Ecosystem Model

The university entrepreneurial ecosystem is composed of the following key actors: universities, technology transfer offices, business incubators, science parks, external entrepreneurs, and investors. Whilst this is not a comprehensive list of actors (more detailed work is offered in Hayter et al. 2018), they have been identified as critical in the functioning of the UEEs (Prokop et al. 2021). We posit that the TTOs hold central ecosystem positions in the UEEs, as they make decisions whether the entrepreneurial activity, reflected through academic spinoffs, would take place or not. As such, they also employ their extensive networks and resource access to endow a spinoff company and enable its development. Figure 1 captures these actors diagrammatically.

Figure 1 About here

Methodology

The data sources used to construct the sample are available in the public domain, specifically consisting of all UK HEIs' websites, research reports, and have been collected from sources published between 2005-2008 period of time. Many universities list spinoff companies for reputational reasons,

showcasing their commercialisation successes. This step identified 784 spinoff companies formed across 73 HEIs. The firm data was complemented using the MINT (Bureau van Dyke) database, which holds financial and other descriptive data on UK companies. Whilst it holds data on many incorporated companies, the financial and employment type data availability is inconsistent, largely due to UK Companies House regulations on filing, where small and medium sized firms enjoy different types of exemptions, allowing them to report very basic information (normally key items from balance sheet such as capital, liabilities, etc.). As most of the UK spinoffs are small (Hewitt-Dundas 2015; Prokop et al., 2019), this limits greatly availability of such information. For the purpose of this paper data on the firms' incorporation date and status was mainly collected. The status of firms that were found to be in receivership, liquidation, dormant or ceased trading is referred to as 'inactive'.

The final sample focuses on 160 HEIs, inclusive of those that generated spinoffs (73) and those that did not (87). The dataset includes ecosystem information on the following elements: business incubators, science parks, and venture capital investors (i.e. institutional investors) identified in HE-BCI survey (HEFCE). Additionally, by using the data on venture capital investors, the external entrepreneurs element was identified by classifying the links of universities with external venture capital firms as indicative of having links with the entrepreneurs. The data from HE-BCI survey relates to 2007-08 academic year for the analysis of university entrepreneurial ecosystems, and refers back to 2002-03 to present trends in technology transfer surrounding the spinoff activity.

The analysis presented in this paper focuses on the social network analysis (SNA), which is performed using open-source software Pajek. The SNA provides not only statistical but also graphical perspective that enhances the understanding of relations between the ecosystem actors. The links between the components of the UEE based on Figure 1 are constructed into a network. The graphical exploration of the network links between the components of the UESI allows to analyse the interactions from a range of perspectives. The paper first explores the networks graphically by presenting all UEEs and how they relate to each other, followed by extracting a *k-core* cohesive subgroup (Borgatti et al., 1990). Cohesive subgroups identify the core structures within networks, importantly so tied by similar structural properties expressed in the same number of connections to each other. The data is then explored with two additional network measures: betweenness centrality (Freeman, 1977) and structural holes (Burt, 1992). The former relates to a specific property of an actor in a network, where it essentially plays a role of a network hub with its centrality calculated on the basis of ties having to pass through that actor. The latter assesses the redundancy of immediate contacts, with the redundancy present if actor *i*'s ties are connected. When the immediate contacts are not linked to each other, the lack of a network tie signifies a structural hole, as actor *i* gains an advantage in mediating between them.

Findings

HE-BCI survey

The HE-BCI survey data provides an overview of UK HEIs' spinning out activity from 160 institutions. Figures 2 – 5 capture a 6-year period and paint an interesting picture of academic spinoff formation. From Figures 2 and 3 it can be observed that the number of spinoffs established each consecutive year was growing since 2004/05[1] period (Figure 2), however this increase was not attributed to a greater participation of the UK HEIs in creating spinoffs (Figure 3), but rather intensified activities of the HEIs already actively involved in academic entrepreneurship. It is quite known from the case study research (e.g. Braunerhjelm, 2007; Harrison and Leitch, 2010; Fogelberg and Lundqvist, 2013) that certain HEIs are more prominent in spinoff formation than others, signifying a variable availability of resources and dissimilar commercialisation capabilities of HEIs.

Figure 2 About Here

Figure 3 About here

When considering the 'survival' of academic spinoffs, it is observable that nearly each year consistently (excluding 2004/05) the number of active spinoff firms was increasing (Figure 4). This trend seems again unrelated to a greater participation of UK HEIs in 'developing' firms (Siegel & Wright, 2007), and draws attention to only a certain (decreasing) amount of universities that appear to be successful in having created sustainable (i.e. surviving) firms (Figure 5). This evidence compared with the average of 15 years (n=145) that the UK TTOs have been established for could be indicating that the accumulated experience in technology transfer is not utilised by all HEIs that have such a unit or department. In fact, there may be a variable set of approaches adopted by TTOs to academic entrepreneurship (Prokop, 2021). Furthermore, Figures 2 and 3 suggest that the fact that new spinoff company creation started to fall in numbers whilst the experience of TTOs is theoretically growing (subject to staff rotation) suggests 5 explanations: 1) TTOs have reached a plateau in their productivity, 2) TTOs are shifting from quantity to quality orientation in spinoff formation (as noticeable in Figure 4), or 3) there was significantly less research that could be commercially exploited in 2007-08 than in the previous years, 4) there has been a change in recording the disclosures either driven through administrative changes (policies) or revision of resource endowments, 5) a shift away from academic entrepreneurship mode has been observed, with other knowledge commercialisation routes becoming more prominent.

Figure 4 About here

[1] The annual spinoff company generation does not follow a linear path, annual variations are to be expected, as observed in Prokop (2021) who studied a longer time frame.

Figure 5 About here

Table 1 depicts the percentage of HEIs with access to each particular element of the UEE. It suggests that many HEIs already operate within a more developed ecosystem for commercialising their knowledge through creating spinoff companies. Specifically, over 80% of UK HEIs have access to business incubators, either on campus or provided by a partner organisation. This suggests that the majority of UK HEIs are capable of providing some sort of facilities for their new innovative firms. However, it remains unknown as to what composition of the UEE (which elements together) signifies that HEIs are well equipped for spinning out firms. This is especially important as academic entrepreneurship is a result of a combination of factors (e.g. Krabel and Mueller, 2009; Hayter, 2013; Fini et al., 2017), not least related to the development of each UEE. As HE-BCI survey data captures only those spinoffs that are still active it does not give a clear picture of absolute spinoff rates (as it excludes firms that ceased trading). Thus, in the next section the data collected on 784 academic spinoffs is utilised, complemented with HE-BCI survey data.

Table 1 About here

The composition of UEEs

Table 2 below depicts the regional character of the sample, based on the region of the HEI a spinoff originated from. From the table it is evident that the East of England is the most 'productive' region in spinoff company formation, and when considering the average lifespan (both active and inactive) of the academic spinoffs from the region it appears the universities located in the East of England are characterised by more experience in academic entrepreneurship. The explanation for this could be sought in the presence of Cambridge University and the general entrepreneurial culture in the locality (Garnsey and Heffernan, 2005). The typical prevalence of the Greater South East regions (in many economic activities) is disrupted by high performance of the Scottish universities in the creation of academic spinoffs. This could be partly explained by the higher level of commitment from the Scottish Government to supporting spinoff companies, with over 60% of them being in receipt of public funding (Hewitt-Dundas, 2015). Surprisingly, a similar proportion of Northern Irish spinoffs reported such support, however this is not reflected in the academic entrepreneurship outcome for the region. It is also interesting to observe that regions responsible for lower proportions of spinoff companies differ quite substantially on the average lifespan measures. For example, HEIs from North East and Wales formed a similar number of spinoffs, yet spinoffs in North East tend to stay active for longer than those in Wales, even those that become inactive survive longer than Welsh firms.

Table 2 About here

From merging two datasets: the data on 784 academic spinoffs and the HE-BCI survey (2007-08) a clearer picture is observed on the role played by the UEE components. As Table 3 depicts it appears there is a strong link between the UEE's completeness and spinning out rates. The higher spinoff creation rates are observable among the HEIs that have a TTO and a more developed UEE, with the HEIs that have a complete 4-element UEE having created on average more than 10 spinoff firms. This is approximately 2.25 times more than those HEIs with the TTO that have a 3-element UEE, circa 4.79 times more than those HEIs with the TTO that have a 2-element UEE, and circa 22.03 times more than those HEIs with the TTO that have a 1-element UEE. Furthermore, it appears that 61 HEIs with TTOs and up to 2 elements in their UEEs are responsible for spinning out approximately 6.27% of firms, whilst a lower number of universities (50) with complete UEEs are responsible for nearly two thirds of all spinoffs. This finding provides two key interpretations: 1) TTOs need to be better connected with access to all elements of the UEE to increase their spinoff rates (importance of building networks), 2) it appears that the average experience of the TTOs of 15 years shows that fairly many TTOs did little academic entrepreneurship activity, suggesting either institutional struggles (e.g. top-down management of knowledge commercialisation that may prove to be counterproductive (Philpott et al., 2011)) or other commercialisation modes pursued.

Table 3 About here

Social Network Analysis

Figure 6 presents a macro perspective on the links of the components of UEE of 160 UK HEIs. The network was energised using Kamada-Kawai Separate Components algorithm. The light blue vertices represent HEIs, the yellow vertices TTOs, green vertices academic spinoffs, red vertices business incubators, dark blue vertices science parks, pink vertices investors, and the white vertices represent external entrepreneurs. In the dataset of 784 spinoffs some of the firms have originated from more than one HEI, thus this is also captured in the graph. Although the network appears to be densely populated, its actual density is very low – 0.00215 (Table 4), and resembles the isolation of most of the HEIs and their UEEs built into the network, further emphasised by the low average degree (1.66537) and clustering coefficient (0.00594). The UEEs linked together forming the largest component in the network are represented by the following HEIs: Royal Veterinary College, Universities of Birmingham, Nottingham, Newcastle, Cambridge, Oxford, School of Pharmacy, Imperial College London, University College London, King's College London, Queen Mary (University of London), Birkbeck College, and Institute of Cancer Research. Although many of them are located in relatively close proximity (e.g. London), their network originates from more than one collaboration in creating a spinoff company (e.g. University College London is found to have worked with 9 other HEIs in the process of creating spinoff companies).

Figure 6 About here

Table 4 About here

The network shows that on average each HEI has at least 2 elements in its infrastructure, with the most frequent being: business incubators (16.7% of the network elements), then institutional investors (12.6%), external entrepreneurs (12.2%), and finally science parks (8.7%). In order to depict the most interlinked element of the network a cohesive subgroup is extracted from the network (Figure 7). This cohesive subgroup consists of a 3-core sub-network (each vertex has at least 3 links, or its degree is 3). The identified cohesive subgroup consists of those actors most highly involved in spinoff-creating interactions with at least 3 different other actors. The actors forming the 3-core cohesive subnetwork are TTOs of Universities of Cambridge, Newcastle upon Tyne, Oxford, and College London, with a clear Greater South East concentration. Such well-connected actors form a network of trust, where each of them has the same or similar access to opportunities (Burt, 1992), here considered as commercial exploitation of university knowledge.

Figure 7 About here

After exploring the most interlinked component of the network it is essential to consider the concept of centralisation of the network by looking at its betweenness (Freeman, 1977), which treats as central the vertices that are the main, in this particular consideration, technology transfer hubs. In this network, it appears that the 3 key ‘hubs’ are University College London, Imperial College London and University of Cambridge TTOs (Table 5). This is consistent with the findings of Bagchi-Sen et al. (2020), who point out that the research-intensive HEIs are responsible for larger numbers of spinoff firms. Consequently, such institutions would tend to hold more central positions in their networks. It is also important to stress that those key 'hubs' have at least 3 elements in their respective UEEs.

Table 5 About here

Since the technology transfer is very related to the commercial opportunities it is important to consider the structural holes (Burt, 1992) in the network. Structural holes could be best described as actors linked indirectly by another actor – the lack of direct link is regarded as a structural hole, and thus an opportunity for the linking actor to convey information between the two (or more actors). When considering the structural holes present in the network University College London appears as one that can benefit the most in the network (Table 6), suggesting it holds a superior structural network position. Given it is London-based its spinoffs have access to a network rich in connections with key businesses

(Huggins and Prokop, 2017), endowing them with greater levels of network capital (Huggins, 2010). Furthermore, all of the HEIs in Table 6 have a UEE consisting of at least 3 components.

Table 6 About here

The social network analysis points at structural disparities between HEIs and their UEEs at a national level. Those technology transfer offices that had a chance to work together to commercially exploit knowledge residing at their institutions created links, and thus networks. Being networked provides them with greater opportunities compared to isolation (Vonortas, 2009), as observed from the empirical evidence presented through social network analysis, where none of the isolated TTOs was ranked high on betweenness centrality or structural holes. These inequalities found in the presented network confirm the dominating individualistic approach of UK HEIs to academic entrepreneurship.

Conclusions

The evidence presented in this paper, although subject to certain limitations, outlines major differences in academic entrepreneurship activity related to a variable composition of university entrepreneurial ecosystems. It shows that HEIs with a well-developed ecosystem consisting of multiple actors: business incubators, science parks, investors, and external entrepreneurs, tend to display greater commercialisation activity focused on academic entrepreneurship. This effect persist when controlling for the network characteristics[2].

Furthermore, it is evident that although the dataset did not capture all existing connections, being linked with other technology transfer offices is associated with improved network characteristics of the TTOs, as opposed to being in isolation. In addition to that, as the analysis focused on the links with the UEE components, it is even more essential for the technology transfer professionals to work together forming cross-institutional alliances. The building of such alliances can be seen as accumulating the network capital (Huggins, 2010), and eventually expanding the support offered to academic spinoffs – through a stronger university entrepreneurship ecosystem. This should be especially important for the technology transfer offices (representing HEIs) with less developed UEEs.

Policy implications

The findings presented here indicate a number of important policy implications. At the micro level of the university entrepreneurial ecosystem, those HEIs that do engage in academic entrepreneurship should evaluate the composition of their UEEs. Where weaker configurations are identified, the role of local policymakers needs to be in supporting development of UEEs either through devoting resources

[2] This has been examined with negative binomial regression of academic spinoff rates against university entrepreneurial ecosystem elements and controlled with betweenness centrality variable (both entering the equation at a 1% significance level).

to create its components (e.g. business incubators and science parks) or contributing to stronger connectivity between the UEEs to improve access to better architectures. The challenge to achieve improved academic spinoff company generation through a particular UEE composition is in acknowledging that these cannot be short-term one-off uncoordinated adjustments, but should ideally be aligned with wider cultural reconfigurations (Kirby, 2006).

At the meso level of the higher education sector the attention should be drawn to the prominent HEI isolationism in technology transfer. Both HEI administrators and policymakers should consider the UEEs to have a greater spatial reach rather than being set-up predominantly around individual HEIs. This could enable a more supportive environment to a greater number of HEIs and their academic entrepreneurs. This can be especially important for those HEIs based in more peripheral places (Siegel et al., 2007), where developing UEEs is more difficult due to limited access to a diverse set of actors. At the same time, higher education sector needs to be sensitive to the variable configurations of UEEs (Prokop, 2021), which may lead to different outcomes in terms of spinoff formation, supporting its growth, or later-stage success (Colombo et al., 2012).

At the macro/national level it is important to recognise that not all HEIs engage in academic entrepreneurship activity. This is merely one of the modes of commercialisation, as such the central policymakers need to recognise that not all HEIs may have the necessary knowledge and skills essential for generating spinoff companies. However, they may be engaging in other Third Mission activities, for example focusing on a more extensive graduate start-up activity (Åstebro et al., 2012). Finally, it is important to recognise that policy lessons presented here are drawn from an example of a developed country. Whist many of the recommendations may appear sound within the UK's context, their application and subsequent effectiveness may differ across countries characterised by different development levels, but also and crucially so, varied institutional arrangements (Foss and Gibson, 2015).

Directions for further research

This study focused on a limited structural perspective, which encourages many questions. Therefore, further research is recommended to provide a more robust picture of the university spinning-out activity taking into consideration measures of spinoff success, university characteristics and the existing links formed by all elements of the presented UEE. Specifically, the scholarly attention could be devoted to functional compositions of UEEs, exploring a range of outcomes based on specific configurations, identifying blueprints for organising and managing academic entrepreneurship activities. Furthermore, an interesting avenue of research would be to explain why spinoff numbers have not increased more drastically in line with accumulated experience of technology transfer offices. Finally, future researchers could also investigate a range of cases of UEEs by employing qualitative methods to unpack the complexities of different configurations and their dynamics, especially focusing on the institutional and cultural dimensions.

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Figure 1 University Entrepreneurial Ecosystem

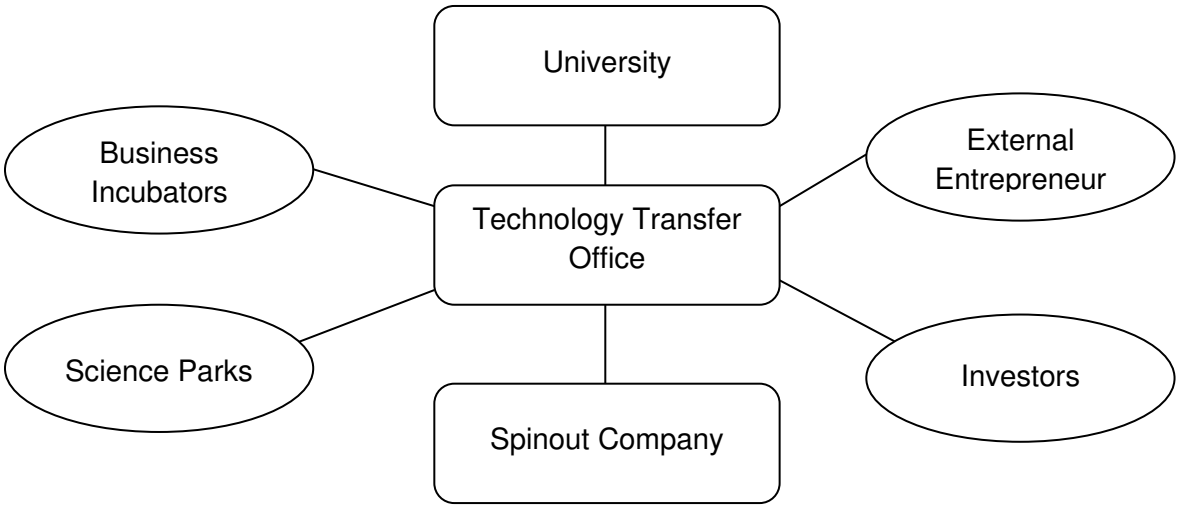

Figure 2 Established Spinoffs: 2002/03 – 2007/08

Figure 3 HEIs that Established Spinoffs: 2002/03 – 2007/08

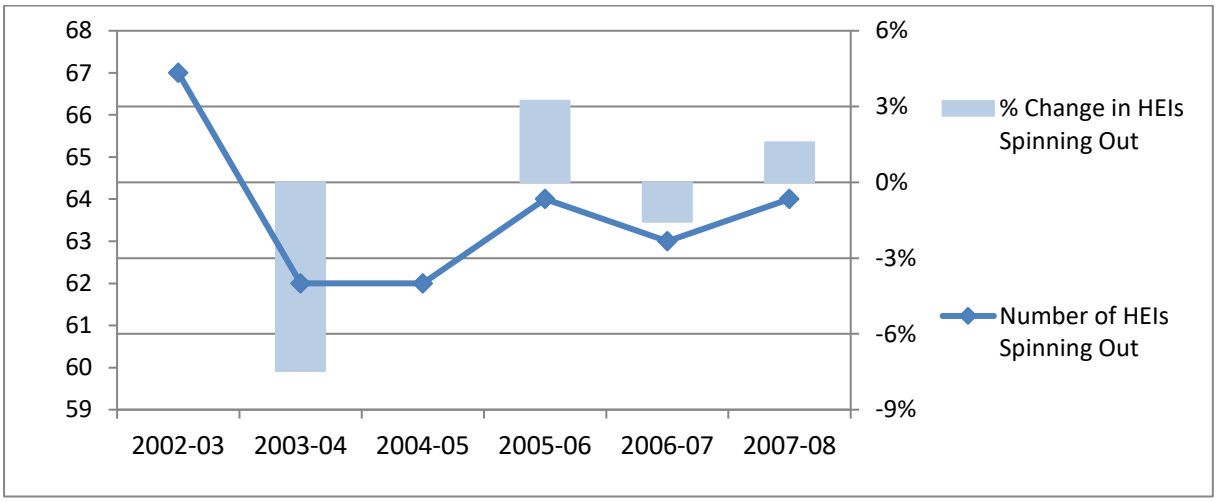

Figure 4 Active Spinoffs: 2002-03 – 2007-08

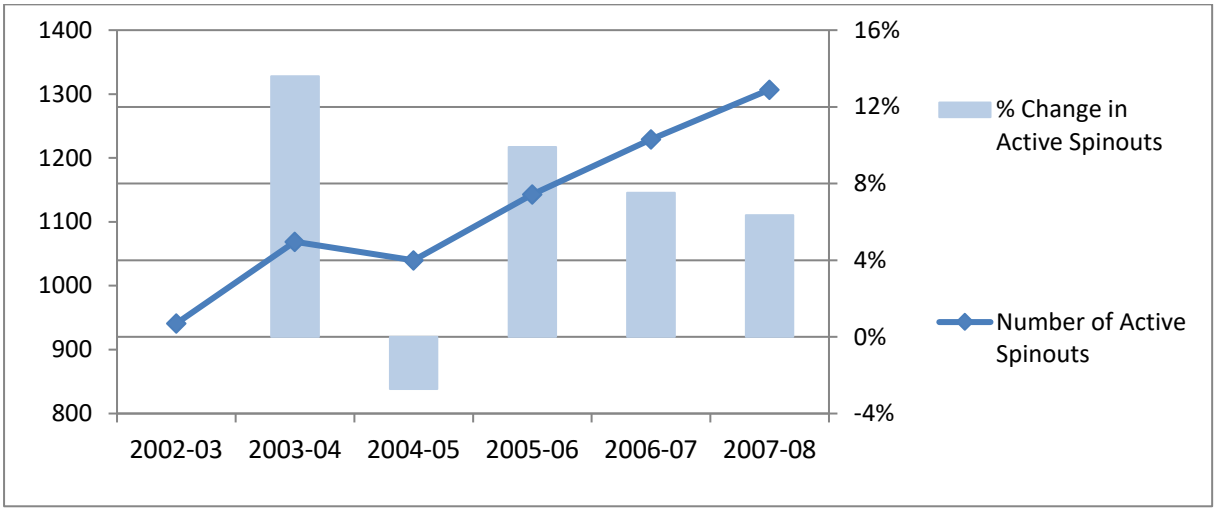

Figure 5 HEIs with Active Spinoffs: 2002-03 – 2007-08

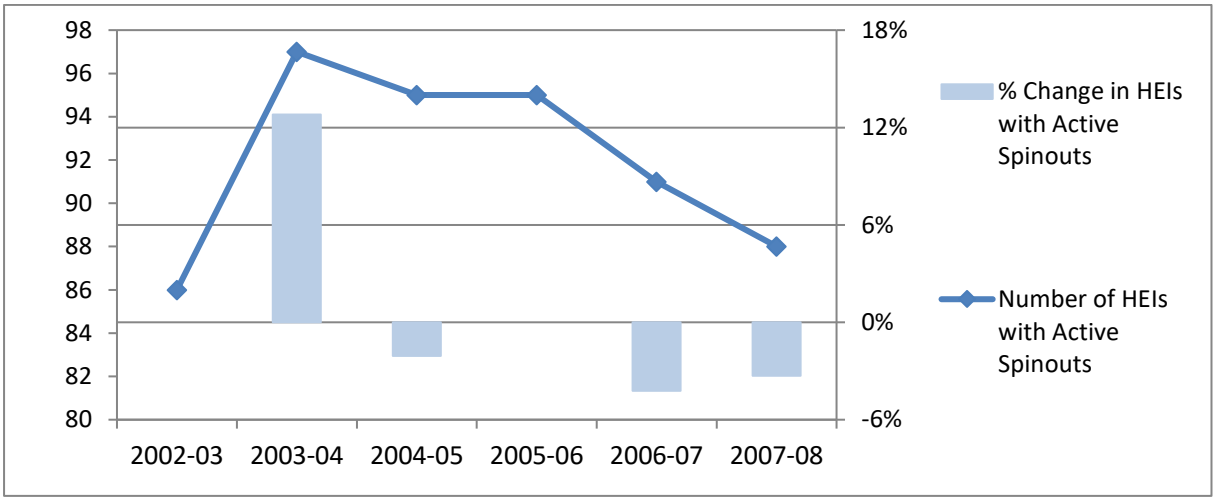

Table 1 HEIs and Infrastructure Elements (HE-BCI survey 2007-08)

Business Incubators	80.6%
Science Parks	41.9%
Institutional Investors	60.6%
External Entrepreneurs	58.8%

Table 2 Regional Distribution of the Spinoffs in the Dataset

N=785*	Number of HEIs in the dataset	% Number of Spinoffs	% Active Spinoffs	% Inactive Spinoffs	Average Lifespan of Active Spinoffs	Average Lifespan of Non-Active Spinoffs
East of England	5	17.5%	14.1%	3.4%	11.7	8.3
London	13	13.6%	11.3%	2.4%	8.2	5.1
Scotland	12	14.6%	12.4%	2.3%	10.6	5.5
South East	8	10.7%	9.3%	1.4%	10.1	6.5
West Midlands	8	8.7%	7.1%	1.7%	10.6	4.8
Yorkshire and the Humber	5	8.5%	6.9%	1.5%	8.1	6.7
East Midlands	4	6.4%	5.6%	0.8%	9.7	8.0
South West	6	6.4%	5.4%	1.0%	10.0	6.5
North East	2	4.4%	3.5%	0.9%	10.6	8.0
North West	3	4.6%	4.1%	0.5%	9.2	5.3
Wales	7	4.5%	3.6%	0.9%	7.9	2.4
Northern Ireland	1	0.1%	0.1%	0.0%	11.0	n/a

*The number of spinoffs used in this table includes John Innes Centre (JIC) and its 1 spinoff, however, as JIC is not listed in HE-BCI survey data, it is excluded from further analysis.

Table 3 Ecosystem Completeness and Spinoff Rates

Number of elements in the UEE	HEIs and TTOs (n=160)		% of Total Number of Spinoffs (n=784)		Average of Spinoff Creation Rates (n=784)	
	TTO	No TTO	TTO	No TTO	TTO	No TTO
0	19	5	0.04%	0.00%	0.02	0.00
1	25	2	1.51%	0.00%	0.47	0.00
2	17	1	4.72%	0.00%	2.18	0.00
3	40	0	23.66%	0.00%	4.64	n/a
4	50	1	66.50%	3.57%	10.43	28.00

Figure 6 Network of University Entrepreneurial Ecosystems

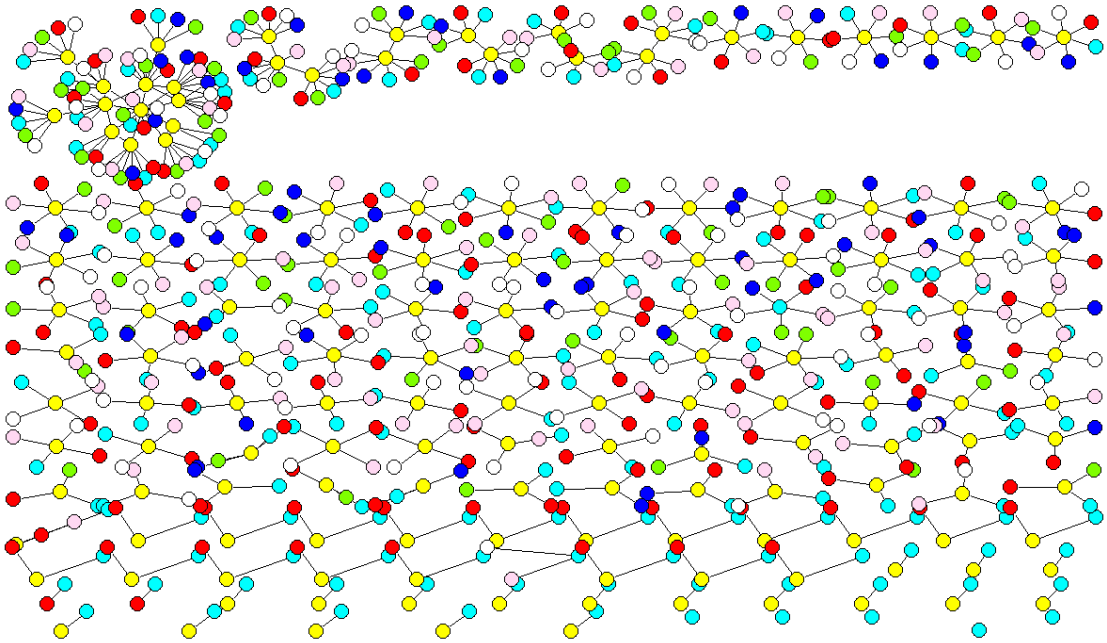

Table 4 Average Regional Network Results of Ecosystems and Network Diagnostics

	Average Betweenness Centrality	Average Structural Holes	Diagnostics
East of England	0.00034	0.32829	
London	0.00047	0.42391	
Scotland	0.00011	0.32178	
South East	0.00011	0.29562	
West Midlands	0.00015	0.33690	
Yorkshire and the Humber	0.00004	0.33182	
East Midlands	0.00019	0.26661	
South West	0.00003	0.36667	
North East	0.00032	0.19845	
North West	0.00002	0.48452	
Wales	0.00005	0.20909	
Northern Ireland	0.00003	0.45556	
Density			0.00215
Average Degree			1.66537
Clustering Coefficient (Watts-Strogatz)			0.00594
Betweenness Centralisation			0.00578
Average Aggregate Constraint			0.86280

Figure 7 3-Core Cohesive Subgroup

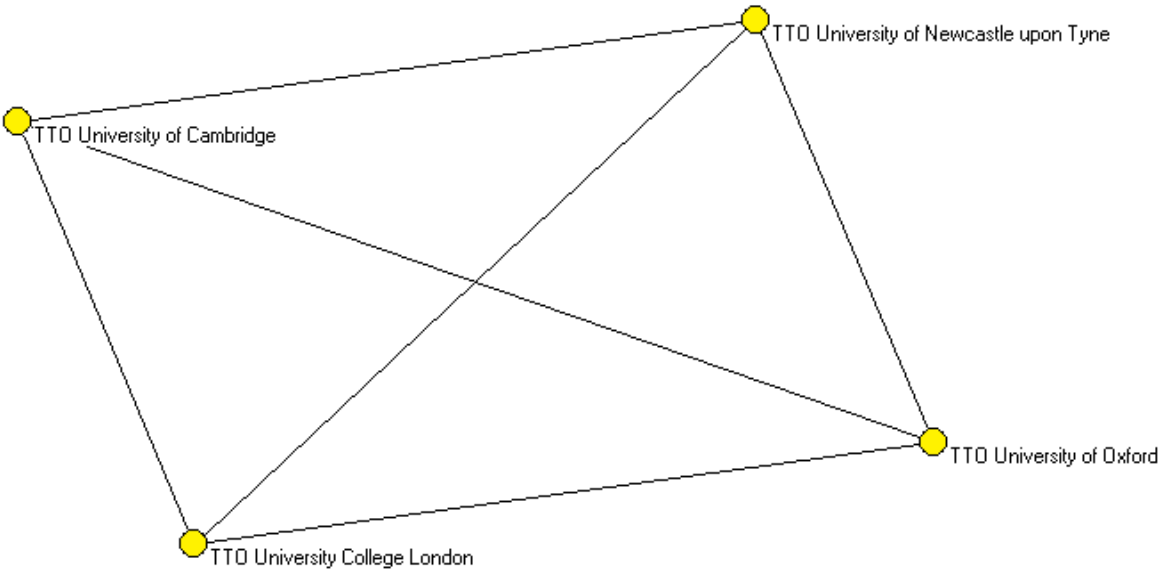

Table 5 Key Technology Transfer Hubs (Betweenness Centrality)

Rank	Value	TTO*
1	0.0058	TTO University College London
2	0.0030	TTO Imperial College London
3	0.0029	TTO University of Cambridge
4	0.0026	TTO King's College London
5	0.0015	TTO University of Oxford
6	0.0015	TTO University of Nottingham
7	0.0015	TTO University of Newcastle upon Tyne
8	0.0012	TTO Queen Mary, University of London
9	0.0012	TTO University of Birmingham
10	0.0012	TTO Institute of Cancer Research

* All TTOs listed have at least one link with another TTO formed from creating a spinoff company.

Table 6 HEIs with Greatest Commercial Opportunities (Structural Holes)

Rank	Value*	TTO**
1	0.087	TTO University College London
2	0.105	TTO University of Cambridge
3	0.113	TTO Imperial College London
4	0.125	TTO University of Edinburgh
5	0.126	TTO University of Newcastle upon Tyne
5	0.126	TTO University of Oxford
7	0.130	TTO King's College London
8	0.133	TTO University of Nottingham
9	0.143	TTO Napier University
9	0.143	TTO University of Glasgow
9	0.143	TTO University of Aberdeen
9	0.143	TTO Keele University
13	0.157	TTO Institute of Cancer Research

* The values represent aggregate constraint; structural hole is an inverse of aggregate constraint.

** All TTOs listed here have at least one link with another TTO formed from creating a spinoff company.