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The Survival of Academic Spinoff Companies: An Empirical Study of Key Determinants

Daniel Prokop, Robert Huggins, Gillian Bristow

School of Geography and Planning, Cardiff University

Abstract

The formation of university spinoff companies has been studied extensively, yet limited attention has been devoted to their survival. Consequently, little is known about spinoffs' later stage developments. Spinoff companies exist in university networks where they access resources through multiple type actors, however it remains unclear which actors specifically these firms should focus their networking efforts on, especially in relation to their success. It is also poorly understood how the regional economic environment affects spinoff's survival. This paper examines the core determinants of survival of academic spinoff companies. The paper analyses a unique sample of 870 UK spinoff companies from 81 universities formed between 2002 and 2013. It is found that spinoff company survival is dependent on three core university network actors: investors, external entrepreneurs, and technology transfer offices (TTOs). Additionally, it is observed that spinoff companies born into less industrially diversified regions enjoy greater probability of survival.

Keywords: university spinoffs; networks; firm survival; entrepreneurship

Introduction

There is growing evidence that university spinoff companies are important to economic development (Vincett, 2010), as they constitute one of the modes of translating academic research into societal and economic impacts. Consequently, over the past two decades scholars have devoted significant efforts to improve the understanding of how to increase the efficiency of this commercialisation process, to form more spinoff companies (Javier Miranda et al., 2018; Fini et al., 2017; Lockett and Wright, 2005; Mustar, 1997).

With such solid fundamentals recent studies have concentrated on understanding the later stages of spinoff companies, especially post-start-up performance (Iacobucci and Micozzi, 2015; Visintin and Pittino, 2014) and their success (Hayter, 2016b; BVCA/Library House, 2005). Performance of spinoffs is typically measured as growth/change in turnover and/or employment (Visinting and Pittino, 2014; Scholten et al. 2015). Whilst the success has been mostly treated as reaching Vohora et al.'s (2004) sustainability stage – where a firm achieves stable returns, other studies define success as progression through Vohora et al.'s critical junctures (Hayter, 2016b), where it refers to any form of firm's achievement in terms of operational persistence.

Another approach used in industrial organisation is to observe the survival of firms – operational existence or persistence over time, which offers an insight into the factors that lead to firm's sustainability or broadly defined success. Firm survival is regarded as a comprehensive indicator of its performance related to profitability (Alchian, 1950), efficiency (Jovanovic, 1982), or simply higher productivity levels (Klepper and Simons, 2000), based on an optimal arrangement of firm's resources and capabilities (Kogut and Zander, 1992). Until now, only a small number of studies have covered survival of spinoff companies, with a very narrow scope for any generalisations given their focus on: single university and industrial concentration (Nerkar and Shane, 2003), or single region and human capital (Criaco et al., 2014).

It is acknowledged that spinoffs exist in networks of actors that contribute resources to their successful development (Hayter, 2016a; Rasmussen et al., 2015). The literature on spinoffs typically identifies four types that play critical roles in their lifetimes: investors, technology transfer offices (TTOs), business incubators, and experienced entrepreneurs. Whilst much of the engagement of these actors is typically ascribed to the early stages of spinoff development, it remains unknown whether they influence the survival of these firms.

Furthermore, the spatiality of spinoff companies has attracted limited interest (e.g. Iacobucci and Micozzi, 2015), particularly how diverse regional economic structures relate to their survival, resulting from predominantly small sample studies. This is especially important as it makes it difficult to establish what policy instruments, at national or regional levels, would best serve and support spinoffs, given their significant return on public investment in underlying research (Vincett, 2010).

This study aims to answer the following research questions: (1) which network actors determine the survival of spinoff companies?, and (2) how are the regional economic development conditions related to spinoff survival? To answer these questions a sample of 870 UK spinoff companies from 81 universities formed between 2002 and 2013 is examined in terms of their survival. The academic spinoff company is defined here as a firm founded by academic staff to exploit university-generated intellectual property.

The paper finds that the university network plays a critical role in spinoff company survival, particularly, when it is composed of investors, external entrepreneurs and TTOs. Furthermore, the survival of the spinoff is also related to its network structure and regional industrial character. The major implication of these findings stems from the importance of the networks and their specific architectures, pointing to greater survival prospects of spinoffs with less constrained network positions.

This paper is structured as follows: section 2 introduces the literature on survival, networks, and spinoffs; section 3 outlines the methodology and data employed; section 4 presents the results and discussion of findings; whilst section 5 concludes the paper.

Firm survival and networks

Firm survival

In the lifecycle theory of the firm and its industry there are four key struggles that define firm success, liabilities: a) of newness, b) adolescence, c) senescence, and d) obsolescence (Coad, 2017). The liability of newness posits that younger firms are more likely to fail, as they have not had enough time to develop their unique resources and capabilities, resulting in decreased external credibility and legitimacy (Bower, 2003). Some evidence for this could be observed from studies on diversification strategies typically employed by older firms (Borghesi et al., 2007). In contrast to this, the liability of adolescence acknowledges that firms experience 'honeymoon effect' (Hudson, 1987) in their first years of operations, due to sunk costs (Murray, 1988), which leads to higher survival rates in the early years, and an increase in failure in the subsequent years.

The remaining two liabilities could be best described as issues of inertia (Hannan and Freeman, 1984). Over time firms develop their human capital, procedures, routines, technologies and become reluctant to change when the conditions in the industry present competition type challenges. This leads to a loss of market or productivity disadvantage, and over time results in increased risk of failure. For example, these processes of inertia have been linked to the evolution of oligopolies (Klepper and Simons, 2000), where only the adaptable firms remained in the market. However, firms that enjoy a dominant position in their industry may avoid such existential threats, even despite organisational rigidity (Van Witteloostuijn, 1998).

These liabilities present a set of non-linear characteristics of firm’s age, where at some point age changes the direction of its relationship with firm’s survival (Coad, 2017). For example, Jelfs (2016) and Lawton Smith et al. (2014) observed that UK spinoffs experienced limited failure rates in their first three years (‘honeymoon’), only increasing afterwards, suggesting spinoffs’ liability of adolescence.

As such, the survival of a firm is dependent on its human capital, the characteristics of the firm, and the broader macro-environment. There is an established body of literature that finds a generally positive relationship between human capital and firm survival (e.g. Gimmon and Levie, 2010). Spinoffs benefit from the commercial (Wennberg et al., 2011) and management skills of their external entrepreneurs (Grandi and Grimaldi, 2003). For example, Criaco et al. (2014) found that spinoffs whose management teams had entrepreneurial education or included an academic founder had improved survival rates. Conversely, Nerkar and Shane (2003) observed previous start-up experience to be positively associated with spinoff's failure, suggesting a very complex interplay of human capital factors explaining spinoff survival.

Firm characteristics, such as demographics and innovativeness, are also critical to its survival. Particularly, firm's age (Coad, 2017), size (Holmes et al., 2010), or the number of company founders (Cressy, 1996) are positively associated with firm survival. The importance of human capital to firm success extends into its innovative activities, given the need for greater absorptive capacity (Cohen and Levinthal, 1990) in the form of a more educated workforce (Mata and Portugal, 2002). In the case of spinoffs, Nerkar and Shane (2003) found that their technological radicalness and broader patent scope are positively related to survival, pointing to a strong role of firm's innovativeness.

Being embedded in their regional environment makes firms dependent on unique socio-economic and spatial conditions (Bristow, 2010). A number of studies found a relationship between firm survival and its location (Howell, 2017; Huggins et al., 2017). For example, firm survival is related to the economic conditions of its territory, whether measured by output growth (Huggins et al., 2017; Jensen et al., 2008), industrial structure (Tavassoli and Jlienwatcharamongkhol, 2016), or industry concentration (Nerkar and Shane, 2003).

Consequently, it is impossible to disentangle the firm from its broader environment without taking a more network-based perspective (Huggins and Prokop, 2016).

Firm survival and networks

Firm success is dependent on its ability to configure its resources and capabilities in a way that makes them valuable and difficult to reproduce by other firms (Barney, 1991; Teece et al., 1997; Wernerfelt, 1984). This is particularly important as the creation of such unique firm characteristics involves the use of networks (Kogut, 2000) to appropriate and process knowledge into firm's operational and strategic decision-making (Jovanovic, 1982; Sidney and Winter, 1964), and products or services. Such knowledge encompasses business management, finance, markets, and product or service innovation. Although networks are found to play a critical role in firm survival (Zhao and Burt, 2018; Wilson et al., 2013; Bosma et al., 2004; Littunen, 2000; Singh and Mitchell, 1996), they are not commonly studied in industrial organisation, as information on firm networks is generally difficult to capture.

Networks exert a dual influence on firm activities (Borgatti and Foster, 2003), one side stemming from network structure (Burt, 1992), the other derived from what is transmitted in the networks (Coleman, 1990). The structural aspects relate to the composition of a network, which can be strongly interconnected (approaching closure) or sparsely, where actors may exist on a spectrum between strong homogenous structures or weaker diverse configurations. These characteristics have a particular set of effects on firm performance. Firms that are part of strong homogenous groups exhibit problems of inertia, path dependence and homophily (Hite and Hesterly, 2001) limiting their performance due to a lack of risky ties with newer diverse actors. Conversely, firms that exist in poorly connected networks remain less constrained in developing ties to heterogeneous actors, allowing them to exploit network opportunities (Burt, 1992) by increased proactivity in searching for new ties (Hite and Hesterly, 2001). This is observed in a study of spinoff formation, where UK universities with more open networks generate more spinoffs (Franklin et al., 2001). Furthermore, Capaldo (2007) finds that actors located in between the two extremes enjoy greater innovation performance.

The resources exchanged in networks allow understanding of the nature of particular networks. Specifically, the type of resource transmitted defines whether the networks have a more social character: e.g. friendship, or economic (Huggins, 2010; Hite and Hesterly, 2001), e.g. innovation. This resource access is important to firm performance, where firms unable to form ties struggle to satisfy their growth needs (e.g. financial capital, specialist skills), whilst those that increase their connectivity improve their success prospects (Borgatti and Foster, 2003). Hite and Hesterly (2001) indicate that such strong resource access is particularly critical at the emergence stage, when firms resort to their established identity-based ties that form socially cohesive sets (Borgatti et al., 1990). At later growth stages firms tend to form ties with a select group of actors that bring in specific resources as and when they are required (Huggins, 2010; Hite and Hesterly, 2001). Such heterogeneous resource access requires structural network adjustments beyond the comforts of a homophilous set (Lin, 2001), essentially combining the structural network aspects with the resource ones. Grandi and Grimaldi (2003) point out that the first networks that spinoffs build are inherited from their parent organisations, indicating the cohesiveness and embeddedness of their initial networks. As spinoffs develop, their parent-centred networks shift towards commercially-oriented contacts (Hayter, 2016a), suggesting the transition from ascribed social to purposively acquired network capital (Huggins, 2010; Hite and Hesterly, 2001).

Since firms in their infancy suffer from resource-starvation and legitimacy problems, they would naturally refer to their networks to overcome such issues. For example, networking allows spinoffs to build credibility, legitimacy (Bruneel et al., 2012; Bower, 2003), secure necessary funding and further opportunities for growth (Grandi and Grimaldi, 2003) and survival (Mustar, 1997). In other words, academic spinoffs develop networks primarily to access resources otherwise not available to them (Hayter, 2016a, 2013a). Furthermore, the close homophilous links are found importantly related to firm survival (Littunen, 2000), indicating that firms need to maintain their early developed network in order to build new connections, especially to heterophilous actors (Hite and Hesterly, 2001; Lin, 2001). As such, early stage firms rely more on social capital for survival (Bosma et al., 2004), particularly that of their founders (Huggins, 2010; Hite and Hesterly, 2001). Therefore new firms with larger boards of directors exhibit lower risk of failure (Singh et al., 1986). However, the effect of social capital on firm survival is also visible among more established firms (Pennings et al., 1998). Furthermore, a firm founded within a region that its founder is familiar with enjoys a greater probability of success, thanks to the regional embeddedness explained by greater accumulation of social capital (Dahl and Sorenson, 2012).

As firms grow, they switch from their reliance on social capital towards more instrumental and calculative network capital (Huggins, 2010), that provides specific and unique resources unavailable from homophilous relations. In essence, such firms start decreasing their network constraint (Burt, 1992), by connecting with new and heterophilous actors, resulting in improved entrepreneurial and survival opportunities. However, firms remaining in embedded sets that are not proactive in such network building processes may suffer from poorer survival prospects as their connections reconfigure their own positions by adding new ties (Singh and Mitchell, 1996). Such overreliance on the cohesion of own network leads to decreased structural holes, resulting in inferior performance (Zaheer and Soda, 2009).

University spinoff survival and network actors

The academic entrepreneurship literature has devoted much of the attention to the conditions underlying the birth of spinoff companies (Javier Miranda et al., 2018). Although this is a salient issue, it neglects the stylised facts of the industrial organisation, for example the strong and positive correlation between firm formation and failure (Geroski, 1995). Some limited voice was given to this matter when Lambert Review (2003) concluded that universities should focus on the quality of the spinoffs, rather than their numbers. Whilst universities may have acted in line with such suggestions, little scholarly effort has been expended on understanding the factors that contribute to spinoff survival, with a notable exception of Nerkar and Shane (2003) and Criaco et al. (2014). This is critical, given that spinoffs originate from non-commercially-oriented individuals and organisations of charitable status, endowing them with a distinctive set of features in comparison to the remaining populations of firms, as evidenced in studies of Swedish university spinoffs compared to corporate spinoffs (Wennberg et al., 2011), US venture-capital-backed university spinoffs compared to other venture-capital-backed firms (Zhang, 2009), or Italian spinoffs compared to other high technology firms (Civera et al., 2018). Furthermore, UK studies reported that university spinoffs do not reflect characteristics of high-growth firms, but rather struggle financially (Jelfs, 2016) and could be classified as lifestyle companies (Harrison and Leitch, 2010), making their survival particularly important to understand. Additionally, spinoff's survival may also be linked to the character of the parent university (although not ownership level as observed by Ferretti et al. (2018)), especially its eminence (Lawton Smith et al., 2008), traditional science focus (Shane, 2004), or patenting activity (De Nicola et al., 2018), but also with the seniority and gender of the academic founders, given studies suggesting that academic entrepreneurship is more prevalent among older academics (Hewitt-Dundas, 2015) with a strong male bias (Lawton Smith et al., 2017).

Networks are critical to understanding spinoffs in a university-centred environment (Hayter, 2013a). Of particular importance here are the networks with TTOs, investors, external entrepreneurs, and business incubators, which constitute a heterogeneous set of key actors with linkages to spinoff companies. Specifically, investors and external entrepreneurs have a heterophilous character, with the TTOs and especially on-campus-based business incubators being homophilous in nature, suggesting that the former would be positively related to spinoff's survival, whilst the latter could have detrimental or no effect on its survival.

Overall, networks encompassing a range of actors can be recognised as critical to a spinoff's success (Hayter, 2016b) as they are expected to provide them with greater access to a wider set of actors and resources. Specifically, an academic spinoff'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 spinoff's development (Hayter, 2016a). In fact, spinoffs 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 a spinoff's strong network position is related to its performance (Scholten et al., 2015) and survival (Mustar, 1997).

A specific set of key actors forming university network is important to spinoff's success. As such it is essential to offer clarity between what constitutes a *network* and a *university network*. The term *network* is used here as a generic expression meaning groups of actors or ties between actors and could represent both social and network capital (Huggins, 2010). Conversely, *university network* has a specific meaning in terms of its relational composition. When using this term the paper considers university, TTO, business incubator, external entrepreneurs and investors. As *university network* includes actors that have a more deterministic function, this embeds them in a network capital conceptualisation (Huggins, 2010).

Investors

Much of the literature on academic spinoffs focused on the role played by investors, primarily in the form of business angels (Mosey and Wright, 2007), public funds (Huggins, 2008), university venture funding (Munari et al., 2018), or private venture capital industry (Bonardo et al., 2011). These actors contribute vital resources that add to the development of a spinoff company and ensure its growth (Clarysse et al., 2011b). In exchange for equity, investors offer finance to otherwise cash-starved businesses (Van Geenhuizen and Soetanto, 2009), allowing them to process university knowledge into technologies and finally develop revenue-generating products or services. The receipt of investment not only influences spinoff's growth (Rodríguez-Gulías et al., 2017), but also signals the credibility (Vohora et al., 2004), quality (Fini et al., 2017), and entrepreneurial orientation (Diánez-González and Camelo-Ordaz, 2016) of the spinoff. This is because investors are often highly risk-averse (Mason and Stark, 2004) and engage in high-selectivity of spinoff ventures (Clarysse et al., 2005). Such signalling is often used as a prerequisite for other investors engaging with the venture, especially as spinoff companies require multiple rounds of funding to fuel their growth (Wright et al., 2006) in order to reach the stage of sustainability (Vohora et al., 2004) or scalability (Bigdeli et al., 2015). Furthermore, there is a tendency for investors, especially venture capitalists, to co-invest in order to reduce information asymmetries related to higher-risk companies (Brander et al., 2002), and improve own investment performance associated with greater survival prospects of firms funded by such syndicates (Hochberg et al., 2007). Consequently, spinoffs that can attract a greater number of investors undergo more frequent selectivity evaluations, signalling their better survival prospects.

Hypothesis 1. *There is a positive relationship between the number of investors holding equity stakes in a spinoff company and its survival.*

External entrepreneur

Although academics are found to be entrepreneurial (Fini et al., 2010), only a proportion of them have the right mindset, skills or networks to develop their own company (Goethner et al., 2012). The successful creation of an academic spinoff (Hayter, 2013b) and further growth (Lundqvist, 2014) are positively influenced by engaging an experienced entrepreneur. These effects are especially visible in the strategies employed at the universities most successful at creating spinoff companies (Lockett et al., 2003) recognised as more flexible and open to such actors. The core benefits experienced entrepreneurs bring to the venture include business experience, networks (Franklin et al., 2001), and commercial (Wennberg et al., 2011) and management skills (Grandi and Grimaldi, 2003). In fact, the presence of external entrepreneurs is positively related to entrepreneurial orientation of academic spinoffs (Diánez-González and Camelo-Ordaz, 2016). These entrepreneurs are crucial in securing investment (Vohora et al., 2004) and adding credibility to their management teams (Wright et al., 2006). Additionally, Visintin and Pittino (2014) observe that it is the diversity of the founding team (inclusion of academic and non-academic entrepreneurs) that is critical to spinoff's performance. This was also noted in Criaco et al. (2014) who found that the university experience of a member of the founding team (or presence of an academic founder) is positively related to spinoff survival. Therefore, a spinoff company's survival is expected to be associated with the presence of such experienced entrepreneurs.

Hypothesis 2. *There is a positive relationship between the presence of experienced external entrepreneur(s) and spinoff company survival.*

Technology transfer offices

Whilst the main purpose of the TTOs is to commercialise university-generated intellectual property (Fitzgerald and Cunningham, 2016), there is a growing body of literature which suggests that TTOs are necessary for other knowledge commercialisation activities (Bourelos et al., 2012), beyond forming spinoff companies (Aldridge and Audretsch, 2011). This is particularly important as TTOs are traditionally associated with creating spinoff companies (Shane, 2004). Clarysse et al. (2011a) indicate that faculty entrepreneurial intentions are independent of the presence of TTOs, therefore it is unlikely that TTOs have any major impact on academic entrepreneurship. This concurs with Vohora et al., (2004), who found that it is frequently the inventor who recognises the commercial opportunity of a piece of research.

A further complication of the TTO's role arises from Fini et al.’s (2017) study, suggesting that the quality of the spinoff companies in attracting first round of VC funding is negatively affected by the presence of a TTO. However, TTO's initial seed investment in the spinoff is positively associated with the receipt of venture capital (Gubitta et al., 2016).

Since TTOs are subject to resource constraints and organisational rigidities present at universities, it is expected that the TTOs that have been operating for longer are able to accumulate the knowledge of supporting spinoffs along with the evidence to justify to the university administrators the need for greater endowments. As such, they can translate these resources into improved support for the spinoffs, increasing their survival prospects.

Hypothesis 3. *There is a positive relationship between the experience of the TTO and spinoff company survival.*

Business incubator

Business incubators are critical to spinoff formation and widely discussed (Degroof and Roberts, 2004), considered as one of the key modes of organisational or governmental intervention in nurturing entrepreneurship (M'Chirgui et al., 2016). These facilities offer a list of support services: office space, administration, training, investment, consultancy and professional business management support (Bruneel et al., 2012; Grimaldi and Grandi, 2005; Wynarczyk and Raine, 2005). Their key role is to accelerate business development and reduce the chance of a firm failing by isolating it from immediate market risks (Carayannis and von Zedtwitz, 2005). However, in studies of university spinoff rates (Gonzalez-Pernia et al., 2013), they were not found to be significantly influenced by the university access to business incubators. This may result from the fact that the majority of the spinoff companies are not based in any business incubators (Hewitt-Dundas, 2015). Consequently, it remains difficult to expect business incubators to shield spinoffs from failure.

Hypothesis 4. *There is no relationship between access to business incubators and spinoff company survival.*

Spinoff's network position

Although much of the academic spinoff literature stresses the role of networks (e.g. Bourelos et al., 2012), little comprehensive empirical evidence exists. Specifically, whilst access to particular university network actors conveys important information on spinoff company's ability to ensure its successful development (Hayter, 2016a), the structure of the concomitant network and the position of a spinoff within it is important to understanding its survival. For example, Scholten et al. (2015) found that bridging ties of Dutch spinoff companies played a role in explaining their early growth. Spinoffs occupying more central positions (Freeman, 1978) may enjoy greater network benefits compared to those with poor centrality. This may result in greater access to knowledge and resources (Hayter, 2016b).

Furthermore, spinoffs may gain opportunities from exercising their favourable network positions by being the main linking actor between its most immediate connections, if these connections are poorly or not interlinked (Burt, 1992). This is especially important when firms reconfigure their network positions by closing non-redundant connections (Gulati, 1999) to allow them to bypass structural limitations of their networks. Some evidence of this has been observed in the evolution of the spinoff company networks (Rasmussen et al., 2015). Therefore, spinoffs that have a lower degree centrality constraint (DCC) (i.e. high level of non-redundant connections based on degree centrality rather than Burt's (1992) strength of ties) are expected to have greater prospects of survival.

Hypothesis 5. *There is a negative relationship between spinoff's degree centrality constraint and its survival.*

Regional industrial structure

Much of the research on spinoff companies has been aspatial in nature, largely due to poor availability of data and focus on the entrepreneurial processes without considering the macro-environment within which these processes take place. Studies that control for the regional aspects considered macro-activity of R&D intensity in the region (Fini et al., 2017; Lockett and Wright, 2005), the formation context (Fini et al., 2011), or how spinoffs are important to the regional economy (Berggren and Dahlstrand, 2009; Benneworth and Charles, 2005), yet the determinants of spinoff survival may differ from those of spinoff formation. In particular, the regional context is clearly important to spinoffs (Rodríguez-Gulías et al., 2018; Lawton Smith et al., 2014; Gonzales-Pernia et al., 2013; Garnsey and Heffernan, 2005) and to firm survival (Tavassoli and Jlienwatcharamongkhol, 2016), given each region's unique organisation of actors and resources. For example, Iacobucci and Micozzi (2015) found that spinoffs with greater turnover were based in more developed and industrially diversified Northern Italian regions (Mameli et al., 2012). In the UK stocks of existing entrepreneurship are positively related to industrial diversity and specialisation, yet new venture registrations are greater in less industrially diverse regions (Huggins and Thompson, 2016), indicating that firms born into less industrially diverse regions like London (O'Donoghue, 2016) would enjoy higher survival rates, with this effect reversing once the firms become more established. It is therefore anticipated that spinoffs born in industrially diverse and specialised regions will be characterised by lower survival outcomes.

Hypothesis 6a. *The industrial diversity of the region in which a spinoff is born is negatively related to its survival.*

Hypothesis 6b. *The industrial specialisation of the region in which a spinoff is born is negatively related to its survival.*

Methods

Data collection

The university spinoff data was collected from an internet service dedicated to UK spinoffs (www.spinoutsuk.co.uk) on 12th January 2014, which covered the company name and its parent university(/ies) for 1,303 companies founded from the year 2000 onwards. Additionally, the names of spinoff companies were obtained from all UK university websites. This helped ensure that the robustness of the dataset was maximised. A similar approach was employed in Hewitt-Dundas (2015). As virtually all UK spinoffs take the legal form of a limited company at the start-up stage, the list of company names was further enriched with information on the spinoffs from a Bureau van Dijk's FAME (Financial Analysis Made Easy) database, which holds detailed demographic and financial data on registered UK companies obtained from Companies House, as used in similar research (e.g. Lawton Smith et al., 2008). This step provided information on the spinoff's demographics: 1) status - live/deregistered; with exact dates of incorporation and dissolution; 2) size, based on employment information or the type of filed accounts; 3) sector classification according to Standard Industrial Classification 2007 coding (ONS, 2009); 4) address; 5) a list of directors and their details; and 6) shareholders. The list of shareholders was used to construct a network of UK spinoffs and their connections.

The final sample frame for which data was found consists of 1,331 companies. The sample frame is the closest reflection of the population of such firms studied in the UK, details of which are largely unknown and unreported in the literature. The consequent and unfortunate limitation of this is the restricted comparability of the sample's characteristics to those of the census of academic spinoff companies to assess its representativeness. To partially overcome such restriction a comparison is made across 87 universities present in the sample frame and their active spinoff company numbers with data reported in HEFCE's (Higher Education Funding Council for England) HE-BCIS (Higher Education-Business and Community Interaction Survey) (Appendix 1). A Wilcoxon Signed-Rank test was performed, indicating no statistically significant difference between the two samples (Z=-1.156, p=0.248, r=-0.124).

The data was complemented with university-specific information obtained from HE-BCIS, which provided data on universities related to their Third Mission activity and measures for the university network actors. Furthermore, based on the firms' addresses, respective regional data from Office for National Statistics (ONS) was added to the database to describe the industrial structure of regions in which those firms were based. The geographical unit utilised is based on the European Union's NUTS (Nomenclature of Territorial Units for Statistics) 1 level, which covers 12 UK regions. Additionally, university data was collected from HESA (Higher Education Statistics Agency) to capture university size.

As the data on spinoff companies needs to be matched across a number of datasets, there is a natural limitation on the availability of such data across time. Whilst the sample frame captured companies formed between 1959 and 2013, with survival event recorded on 1st May 2014, the official HESA statistics were only available for 2002-2014 at university level. ONS data is less restricted in time with regional employment by sector data available from 1998-2008 from Annual Business Inquiry and 2009-2016 from Business Register and Employment Survey. Consequently, the analysis presented here focuses on spinoff companies formed between 2002 and 2013, whilst the data itself covers the period 2002-2014. This limitation reduces the number of original spinoff companies studied from 1,331 to 870, whilst the number of universities is reduced from 87 to 81. These changes, although reflected in the descriptive statistics presented in Table 1 – especially seen through reduced mean (M=17.01, N=1331; M=11.89, N=870) and standard deviation values (SD=22.68, N=1331; SD=14.01, N=870) of spinoffs formed, do not impose any further major changes to the characteristics of the final sample, with both skewness and kurtosis values only slightly reduced. The sample is representative of the sample frame across both firms' regions (χ^2(11, N=2201)=4.08, p=0.97, V=0.04) and sectors (χ^2(6, N=2201)=2.74, p=0.82, V=0.04), but not age or size, for obvious reasons.

Table 1 About here

Variables

The survival of spinoff companies is represented by a binary variable that records the status of each firm (Criaco et al., 2014). The status represents whether the company is registered with Companies House (i.e. live firm) or not (i.e. deregistered firm) (Wennberg et al., 2011). Whilst this is a frequently applied approach in industrial organization literature that focuses on the typical liquidation (Huggins et al., 2017), it does not capture the full variability related to different motivations for exit or deregistration (e.g. withdrawal of university support). However, the analysis controls for two key alternative forms of exit: a) related to personal circumstances of the company directors (*age of directors*), b) related to acquisitions (*successful exit*). Given that spinoffs are typically dependent on external investments in order to develop the underlying IP (Clarysse et al., 2011b; Huggins, 2008), the exits would be anticipated to take the form of liquidation, especially when the company is formed through careful selection of disclosures (Clarysse et al., 2005), there is an expectation of long-term commitment from the university to maintain the firm alive (due to sunk costs, Murray, 1988). Consequently, dormant firms are also treated here as live firms, as they are typically younger spinoffs (M=5.31, SD=3.53) than non-dormant (M=6.69, SD=3.18) firms (U=9961.5, Z=-2.47, $p<0.05$), and their exclusion from the sample does not affect the results (Appendix 2). Within the sample 82.87% of spinoff companies were still registered as live firms on 1st May 2014, confirming a high survival rate of university-born firms (Vincett, 2010), in line with results typically reported for other European countries (Jelfs, 2016; Bolzani et al., 2014). Given the conceptual model tested in this paper, the data on the university network actors is sourced from FAME and HE-BCIS.

In order to measure whether spinoffs received investment, considered a firm quality indicator (Fini et al., 2017), a measure is used that captures the number of equity-type investors at each spinoff company. The data comes from the shareholders' information, where firms and organisations providing entrepreneurial finance (e.g. venture capitalists, business angel networks, public seed funds) were identified through online searches.

To measure the presence of experienced external entrepreneurs (Visintin and Pittino, 2014), a proxy variable is composed from the directors' information. The variable uses an average of the number of directorships held by spinoff company’s directors, with an expectation that the higher values of the measure would be indicative of the presence of experienced external entrepreneurs.

Given that all universities in the sample have a TTO, the commercialisation experience is measured by establishing the difference in years between spinoff's birth and the formation of the TTO unit (Fini et al., 2017). Whilst information on spinoff company's use of business incubators is very difficult to capture, especially since these are not widely used by spinoffs (Hewitt-Dundas, 2015), university’s provision of access to on-campus and off-campus business incubators, and science parks is used instead. Dummy variables are used to describe whether the spinoff had access to each type of incubator at its birth.

The network position of a spinoff is explored with degree centrality constraint constructed from spinoffs’ shareholders data, typically used in social network studies of listed firms (e.g. Li et al., 2016). The meaning of DCC is closely aligned with Burt’s (1992) structural holes. Structural holes measure the power of an actor that depends on the extent to which her/his network is unconnected (non-redundant) (Burt, 1992), with that actor enjoying greater benefits when the network is more unconnected, leaving the actor the main connecting node. The DCC departs from the structural holes at the measurement of the strength of ties, where instead it relies on the actors' centrality.

The premise behind structural holes is that actor i benefits most if i can negotiate between j and k, when j and k cannot negotiate directly. Once j and k develop a relation/link, i's relations become redundant and structural hole advantage is diminished. Structural holes depend on the strength of ties; hence if i is connected strongly to j and k, whilst j has a weak relation with k, i still maintains advantage in the network. Structural holes are measured as a constraint C of j on i, where i is more constrained in a network with more redundant ties, as it has few or no structural holes to benefit from (Burt 1992). Therefore, the aggregate constraint AG of actor i is defined as:

$$AG_i = \sum_j C_{ij}$$

where:

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

and:

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

with p_{ij} being the proportion of relation values a from actors i to j, and j to i, out of the sum of all relation values $\sum_k (a_{ik} + a_{ki})$ of actor i (Burt 1992). AG_i takes a value of 1 for unconnected actors (with degree centrality of 0) in Pajek. For actors with 1 connection (i.e. degree centrality of 1) the aggregate constraint also takes value of 1, as the term $\sum_{k, i \neq k \neq j} p_{ik}\, p_{kj}$ would be equal to 0 reducing C_{ij} to $(p_{ij})^2$.

Due to resource limitations, the university network studied here has undefined values for relationships, which by default take value of 1 (i.e. $a = 1$), consequently excluding the theoretical considerations of the strengths of ties. As a result the C_{ij} depends on degree centrality DC of network actors:

$$C_{ij} = \left(\frac{1}{DC_i} + \frac{1}{DC_j}\right)^2$$

as:

$$p_{ij} = \frac{a_{ij}+a_{ji}}{\sum_k (a_{ik} + a_{ki})} = \frac{1+1}{DC_i(1+1)} = \frac{1}{DC_i}$$

therefore:

$$C_{ij} = \left(p_{ij} + \sum_{k,i \neq k \neq j} p_{ik}\, p_{kj}\right)^2 = \left(\frac{1}{DC_i} + DC_i \frac{1}{DC_i DC_j}\right)^2 = \left(\frac{1}{DC_i} + \frac{1}{DC_j}\right)^2 = \left(p_{ij} + p_{kj}\right)^2$$

where the aggregate constraint is a product of degree centrality of i and j. Therefore, the variable is assumed to measure the DCC, rather than Burt's (1992) original aggregate constraint. The variable is calculated for all network actors (i.e. universities, spinoffs, and their shareholders); however, the values used here are only those that describe the network position of spinoff companies. The approach employed here focuses on ego-centred formalised networks with clear engagement expressed through equity ownership.

The regional industrial structure is depicted with two variables that originate from Theil's (1972) work on employment entropy to measure industrial diversity and an adopted dissimilarity index to measure industrial specialisation. These measures are widely established in economic geography literature (e.g. Huggins and Thompson, 2016; Fotopoulos, 2014). Here they are used from employment at NUTS1 regions at 2-digit SIC sectors. The industrial diversity DIV_r of region r is defined as follows:

$$DIV_r = \frac{\sum_i \frac{p_{ri}}{p_r} ln \frac{p_r}{p_{ri}}}{\ln(I)}$$

where:

$$p_{ri} = \frac{E_{ri}}{\sum_r \sum_i E_{ri}}$$

and

$$p_r = \sum_i p_{ri}$$

With E_{ri} representing employment in region r and industry i, p_{ri} defining a proportion of employment in industry i to a sum of such employments across all I industries for each region r, p_r being sum of proportions p_{ri} across all I industries for each region r, whilst I representing the total number of industries considered, in this case 15, as in Fotopoulos (2014) (Appendix 3). The variable is bound within [0, 1] interval, where higher values represent more industrially diverse regions.

The industrial specialisation $SPEC_r$ of region r is measured as follows:

$$SPEC_r = 1/2 \sum_i \left| \frac{E_{ri}}{E_r} - \frac{E_{ni}}{E_n} \right|$$

Where E_r is the total employment in region r, E_{ni} is employment in industry i at the national level, whilst E_n is the total employment at the national level. The variable takes values within a [0, 1] interval, where higher values signify more industrially specialised regions. Both variables describe regional industrial structure at spinoff company's birth in its parent university's region.

A number of variables are also used to control for the effects of the characteristics of the spinoff and the university. The firm controls capture age and its quadratic form (Coad, 2017), size expressed as a dummy if the firm is small (Harrison and Leitch, 2010), sector (Criaco et al., 2014) represented by four dummies (detailed composition of variables available in Appendix 4), successful exit dummy capturing whether the spinoff underwent exit in any form: IPO (Mustar et al., 2008) or acquisition (Nerkar and Shane, 2003), number of directors measuring an attempt at executive team building to incorporate experienced individuals (Vohora et al., 2004), age of directors controlling for personally motivated exits (Becker, 1965), nationality of directors representing more entrepreneurially-minded non-native academics (Krabel and Mueller, 2009) or external entrepreneurs (Fairlie and Lofstrom, 2015), and the region's size measuring employment in a region spinoff company is born into (Tavassoli and Jlienwatcharamongkhol, 2016). The number of parent universities is controlled for, as spinoff companies may have more than one parent institution (Lockett et al., 2003). Finally, the university characteristics represent university size (Fini et al., 2017) expressed as total university income, counts of patents (Gonzales-Pernia et al., 2013), and science bias (SB) (Shane, 2004).

Based on the Research Assessment Exercise (RAE) 2008 and the Research Excellence Framework (REF) 2014, SB reflects university's focus on high-quality scientific research. The traditional science fields typically generate more spinoffs due to more tangible IP protection method of patenting (Shane, 2004), and therefore the focus is on REF's (and respective fields in RAE 2008) Panels A and B (www.ref.ac.uk). The approach taken here is to focus on the overall quality profile and outputs deemed world-leading (rated 4*). High-end research (HER) transforms proportion-expressed RAE and REF scores into total submission numbers for every i^{th} university (separately for RAE and REF):

$$HER_i = \sum_j RO_{ij} \times NOS_{ij}$$

where:

HER – high-end research (submission numbers of 4* quality)

RO – percentage of research outputs with overall quality score of 4*

NOS – number of submissions

i – university

j – research field.

Science bias (SB) is a proportion of HER in Panels A and B over HER in all Panels (A-D):

$$SB = \frac{HER_{AB}}{HER_{ABCD}}$$

The variable composed here uses an average of SB measure for RAE 2008 and REF 2014 covering a timeline of 2001-2013.

Table 2 offers a brief description of variables. The descriptive statistics for the variables are presented in Tables 3 for continuous variables and 4 for categorical variables.

Table 2 About here

Table 3 About here

Table 4 About here

Table 5 presents correlations of all variables, with a number of interesting relationships with dependent variable uncovered. Six of the eight independent variables have significant correlations with the dependent variable, notably *Investment*, *External entrepreneur*, *Commercialisation experience*, *On-campus incubator*, *Degree centrality constraint*, and *Industrial diversity* all of expected coefficient signs. Despite the sample size (N=870) there are two pairs of variables that could indicate presence of multicollinearity: *Industrial diversity* and *Industrial specialisation* (r=0.71), and *University size* and *Patents* (r=0.76). Only the first pair presents abnormal behaviour when entered together, with inflated coefficients and significance of *Industrial specialisation* compared to a separate entry. To further test for multicollinearity VIFs were obtained by fitting an OLS regression. When the two industrial structure variables are entered together their VIFs are 8.0 for Industrial diversity and 4.3 for Industrial specialisation, confirming moderate multicollinearity issues. To limit any imprecision in the estimation of the coefficients, the variables are entered in separate models.

Table 5 About here

The dependent variable has a binomial distribution, taking a value of 0 for spinoff companies that were dissolved, and a value of 1 for firms that were still live on 01/05/2014, with a mean clearly falling between these two values (Hosmer et al., 2013), suggesting a logit regression model, with a similar approach found in Criaco et al. (2014) in their study of Catalan spinoffs.

The model fitted to explain university spinoff company survival S_i takes the following form:

$$S_i = \beta_0 + \beta_1 I_i + \beta_2 EE_i + \beta_3 CE_i + \beta_4 BI_i + \beta_5 DCC_i + \beta_6 RIS_i + \beta_7 FC_i + \beta_8 UC_i + \beta_9 RC_i + \varepsilon_i$$

where I_i is equity investment, EE_i represents external entrepreneur, CE_i is commercialisation experience, BI_i capture the business incubator types, DCC_i measures the degree centrality constraint, RIS_i reflect regional industrial structure, FC_i are firm controls, UC_i university controls, whilst RC_i region controls. Out of 870 observations, the analysis in the full model focuses on 869 spinoff companies, given the presence of an outlier in a predictor.

Results and discussion

Table 6 presents a general overview of survival of the UK spinoff companies by formation cohort. Whilst the formation of the spinoff companies has decreased since 2002, there is a clear pattern signifying higher survival rate of spinoffs in their first three years with typically at least approximately 95% of firms in each cohort surviving. In the subsequent two years reported here (i.e. five-year survival), the survival falls at an accelerated rate, suggesting the liability of adolescence (Coad, 2017) or presence of the “honeymoon” effect (Hudson, 1987), observed in smaller samples by Jelfs (2016) and Lawton Smith et al. (2014).

Table 6 About here

The regressed models explaining university spinoff company survival are presented in Table 7, with complementary VIF values in Table 8. The five models presented are an improvement over an intercept-only model (as given by Omnibus test) significant at 1% level, with model 4 offering the best fit as observed from information criteria or pseudo R^2 measures. Classification plots indicate that full models estimate predicted probabilities correctly for circa 88% of fitted values, in particular, the sensitivity tests present that more than 96% of surviving spinoff companies were correctly predicted by the models. Models 1, 4 and 5 pass the goodness of fit test, however, caution is suggested in interpreting the results of models 2 and 3.

Table 7 About here

Table 8 About here

The regression fitted in model 1 introduces variables that define university networks. Models 2 and 3 describe the regional industrial structure of a spinoff. Models 4 and 5 present the full specification, including a set of controls for the firm, university, and regional characteristics. The number of investors has a positive association with spinoff survival, confirming Hypothesis 1. Hypothesis 2 is confirmed by the positive and significant coefficient of external entrepreneur. The TTO's experience of commercialisation is positively associated with spinoff survival, in line with Hypothesis 3, but only in specification with industrial diversity. As expected, no form of business incubation explains spinoff survival (Hypothesis 4). Spinoff's lower DCC is associated with its greater survival prospects, lending support to Hypothesis 5. Finally, it is found that spinoffs born in industrially diversified regions (Hypothesis 6a) have decreased probability of survival. No support is found for Hypothesis 6b, although the coefficient of the industrial specialisation is of the expected sign.

From the firm-level controls it is found that spinoff's survival is related to age with the non-linear term entering the equation significantly, however it is independent of its size. All sector dummies are positively and significantly related to spinoff’s survival, except for manufacturing in model 4. As could be anticipated there is a positive relationship of spinoff's survival to its successful exit. Interestingly, the number of company directors has a negative and significant coefficient, suggesting diseconomies of management. At the same time, exits are more prevalent among younger directors. Nationality of the directors is unrelated to spinoff survival. Furthermore, the number of parent universities has no association with spinoff survival. Only one university control is significant - the size of the university, with a positive coefficient. No evidence was found for science bias or the importance of patents. Region’s size is only significant in industrial diversity specification.

The fact that the number of investors is positively related to spinoff survival (Hypothesis 1) confirms a wide array of literature praising the role of VC (Fini et al., 2017), but also seed capital, public funds (Huggins, 2008), and business angels (Mosey and Wright, 2007). Clearly, university spinoffs struggle to survive without external capital to maintain and accelerate their development. Such non-organic forms of growth promote quicker transition from a small company to a more established one, improving spinoff's credibility, and distinguishing them from lifestyle-type firms (Harrison and Leitch, 2010). The findings may indicate the viability of universities holding their own VC funds (beyond current seed capital or challenge funds) to reduce risks to potential private investors through matched/joint funding.

Although the engagement of the external entrepreneur in a spinoff has been widely discussed (Hayter, 2013a), limited empirical evidence exists that links the role of external entrepreneur to spinoff performance (Visintin and Pittino, 2014). It is clear that these actors are also critical to its survival (Hypothesis 2). The important role of such entrepreneurs stems from experience, commercial (Wennberg et al., 2011) and management skills (Grandi and Grimaldi, 2003) and developed networks (Franklin et al., 2001). More generally, entrepreneurs’ experience is a vital asset to a firm’s survival (Bosma et al., 2004; Taylor, 1999). Additionally, external entrepreneurs could also act as facilitators of investment-driven growth as suggested by Vohora et al. (2004), as their introduction at spinoffs could relieve the academic founders' time from searching for capital to technology development.

The partial results confirming Hypothesis 3 contribute a fresh insight into the role of TTOs, questioned in formation studies (Bourelos et al., 2012). Some scholars argue that TTOs could improve if better resourced and able to employ experienced professionals (Gonzales-Pernia et al., 2013), whilst Degroof and Roberts (2004) suggest that TTOs could collaborate for resource access, or as pointed out by Leitch and Harrison (2005), concentrate efforts on research of commercial potential only. Although such implications are critical at the foundation stage, the experienced TTOs also engage in activities that support the survival of spinoff companies.

Business incubators have a very prominent place in the literature on academic spinoffs (Bourelos et al., 2012), yet no evidence has been found of any significant contribution to their survival (Hypothesis 4). The findings may appear somewhat contradictory, given business incubators' purpose of shielding firms from failure (Grimaldi and Grandi, 2005). However, on the account of recent evidence on the UK spinoffs indicating that they are typically not based in business incubators (Hewitt-Dundas, 2015), the results appear rather unsurprising.

The significance of spinoffs' DCC (Hypothesis 5) lends evidence to the well advanced debate in the literature on the importance of networks (Rasmussen et al., 2015). The network position a spinoff occupies, defined by dynamic and evolutionary network processes (Hayter, 2016a; Rasmussen et al., 2015), is crucial to its activities as a network actor (Burt, 1992). It is important for spinoffs to learn to recognise their network positions, and transform this knowledge into a practical approach, where they can be more calculative and strategic (Huggins, 2010) in using their contacts to pursue competitive advantage. This clearly produces observable results of reduced probability of failure for spinoff companies.

Regional industrial structure at spinoff's birth suggests that firms born into less industrially diverse regions have an increased chance of survival (Hypothesis 6a). However, evidence of the industrial specialisation could not be observed (Hypothesis 6b), confirming similar findings reported in Huggins and Thompson (2016) or Tavassoli and Jlienwatcharamongkhol (2016). Regions that have lower variety of knowledge are fertile grounds for highly innovative new firms, which may benefit from Marshallian externalities in terms of better access to labour or non-traded inputs (e.g. local supply chains for healthcare spinoffs in London (Lawton Smith et al., 2014)).

Conclusions

This paper examines university networks and regional industrial structure in relation to spinoff survival. It studies the spinoff as a firm embedded in a multi-actor network, where connections have deterministic functions (Huggins, 2010). There are five core findings reported here. First, the number of investors is positively associated with spinoff survival, suggesting the importance of credibility signalling (Vohora et al., 2004) and risk-reduction strategies exercised by investors (Clarysse et al., 2005). Second, the presence of experienced external entrepreneur in the management team is critical to spinoff's survival, indicating the acquisition of a set of entrepreneurial capabilities (Wennberg et al., 2011) and company rather than technology building orientation. Third, TTOs are involved in later stages of spinoffs revitalising the debate about the competencies of the TTOs from merely early stage administration (Shane, 2004). Fourth, the network position of spinoffs is critical to their survival, suggesting the need for dynamism and strategy in firm's network development (Rasmussen et al., 2015; Huggins, 2010). Fifth, the regional industrial structure is essential to understanding spinoff survival (Tavassoli and Jlienwatcharamongkhol, 2016), indicating a spatial asymmetry of successful development opportunities for spinoffs.

From a broader perspective, the results indicate that not only university networks are important to spinoff survival, but a particular composition of such networks is critical. Spinoff companies rely on network connections for access to particular resources (Hayter, 2016b), yet key roles in such networks are played by only three actors: investors, external entrepreneurs, and TTOs. It is noteworthy that the university network configuration critical to spinoff company's survival might be different than one calibrated for spinoff formation.

It is clear that the network paradigm is important to understanding firm survival in the industrial organisation literature. Specifically, works on network evolution (Hite and Hesterly, 2001) and network capital (Huggins, 2010) address the issues related to the role of networks in firm survival, where successful firms are more instrumental and calculative in how they configure their ties to access particular resources. Furthermore, it transpires that the survival of the firm is not just a function of the accumulation of generic social capital (Pennings et al., 1998), but rather specific types of resources based on identified growth needs, whether finance, managerial skills or other forms of capital.

Spinoff survival cannot be separated from the considerations of its regional economic environment. Given that the greater survival prospects are in less industrially diversified regions, potentially pertaining to positive externalities of specialisation, the policymakers need to reconsider overcoming spatial asymmetries of outcomes. Particularly, national policymakers should contemplate designing a redistributive fund for universities or spinoff companies based in more industrially diversified regions like West Midlands or Scotland to assist in alleviating issues related to industrial structure. At a regional level there appears a scope for greater collaboration between universities to pool resources. Finally, locally, a concerted effort of universities, investors, and entrepreneurs is required to develop strong networks to support spinoffs, as improved network structure could overcome the complex economic context.

The analysis presented here is not free from imperfections. Firstly, the modelling has a cross-sectional character, as there was no possibility of collecting annual records of the data underlying the external entrepreneurs and the DCC constructs. This leads to another issue, where evolutionary development of spinoff company's network position could not be captured. Secondly, using the number of investors may be quite problematic as it does not portray the value of the investments received. However, such data is difficult to obtain, limiting the depth of the analysis. Finally, shareholder networks are imperfect as not every actor in spinoff networks may hold an equity stake in the firm. It is acknowledged here that this limits the types of actors captured in the analysis, given a breadth of actor types engaged in spinoff success (Hayter, 2016b).

Future studies should focus on longer time frames, given that the growth of spinoff companies decelerates after around three decades (Vincett, 2010), indicating that this paper only captures short to mid-term development. It is important to recognise the heterogeneity of spinoff types. Whilst this paper attempted to control for different types of firms, future research could specifically highlight diverse reasons, motivations and development paths of dormant, lifestyle and growth-oriented spinoffs. Whilst a differential regional industrial structure was investigated here, the spatial configurations of university networks are unknown. These configurations require further elucidation in terms of university network setups at spinoff company formation and survival.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The research supporting this paper was funded by the Economic and Social Research Council, ref: 1231191.

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Appendix 1

Sample representativeness: spinoff companies with or without university ownership

University	Number of active firms (2012/13) HESA	Number of active firms (2014) Own Data	Number of all firms (2014) Own Data
Aberystwyth University	13	1	1
Aston University	6	7	13
Bangor University	5	1	3
Birkbeck College, University of London	1	1	1
Birmingham City University	1	1	1
Bournemouth University	5	1	1
Brunel University	0	2	5
Cardiff University	35	26	29
City University London	9	4	4
Coventry University	13	3	6
Cranfield University	6	4	4
De Montfort University	6	4	7
Durham University	34	14	23
Edinburgh Napier University	6	7	11
Glasgow Caledonian University	2	15	16
Glyndŵr University	8	1	1
Goldsmiths, University of London	1	1	1
Heriot-Watt University	19	25	32
Imperial College London	72	88	106
Keele University	4	3	4
King's College London	14	12	20
Lancaster University	16	13	16
Liverpool John Moores University	9	0	1
London South Bank University	2	1	1
Loughborough University	16	17	19
Manchester Metropolitan University	6	2	2
Newcastle University	28	32	41
Northumbria University	2	1	1
Nottingham Trent University	7	5	5
Oxford Brookes University	3	2	2
Queen Margaret University	0	1	1
Queen Mary University of London	13	17	18
Queen's University Belfast	44	38	47
Robert Gordon University	4	6	10
Royal Holloway, University of London	4	2	4
Royal Veterinary College	1	1	2
Sheffield Hallam University	3	1	1
Staffordshire University	8	4	4
Swansea University	50	6	7
Teesside University	0	5	6
The University of Southampton	16	21	31
The University of Wolverhampton	4	0	1
University College London	50	47	55
University of Aberdeen	23	27	31
University of Abertay Dundee	0	2	5
University of Bath	10	17	19
University of Birmingham	26	27	28

University of Bolton	0	1	1
University of Bradford	8	3	3
University of Bristol	20	29	38
University of Cambridge	60	85	100
University of Central Lancashire	0	1	1
University of Dundee	21	21	26
University of East Anglia	4	7	7
University of Edinburgh	46	55	76
University of Essex	1	2	5
University of Exeter	13	15	20
University of Glasgow	21	24	31
University of Greenwich	3	2	3
University of Hertfordshire	5	0	1
University of Huddersfield	3	1	1
University of Hull	7	7	7
University of Kent	3	3	3
University of Leeds	29	27	33
University of Leicester	14	10	11
University of Liverpool	15	11	17
University of Manchester	39	48	54
University of Nottingham	28	31	32
University of Oxford	58	86	103
University of Plymouth	11	9	9
University of Portsmouth	2	1	1
University of Reading	2	1	2
University of Salford	12	3	3
University of Sheffield	34	29	36
University of St Andrews	24	12	21
University of Stirling	0	3	3
University of Strathclyde	37	44	56
University of Sunderland	0	0	2
University of Surrey	16	15	20
University of Sussex	3	4	4
University of the Highlands and Islands	0	4	5
University of the West of Scotland	1	1	1
University of Ulster	16	13	16
University of Warwick	31	26	40
University of York	22	17	24
Institute of Cancer Research	4	5	6
University of South Wales	13	10	11
Total	1231	1182	1480[1]

[1] There are 1331 original academic spinoff companies in the sample framework, however, a number of those firms were jointly created by more than one institution, with other UK universities in the sample framework, UK public research organisations, and overseas universities. When the number of spinoff companies is presented at a university level, duplication of counts of some firms is inevitable, hence 1480.

Appendix 2

Alternative model specifications: dormant firms excluded from the sample.

	Model 4a		S. E.	Model 5a		S. E.
Investment	0.304	***	0.092	0.254	***	0.089
External entrepreneur	0.122	**	0.048	0.118	**	0.049
Commercialisation experience	0.028	*	0.014	0.022		0.014
On-campus incubator	0.266		0.344	0.049		0.331
Off-campus incubator	-0.296		0.331	-0.265		0.321
Science park	0.312		0.293	-0.137		0.293
Degree centrality constraint	-2.617	***	0.618	-2.662	***	0.615
Industrial diversity	-33.280	***	7.168			
Industrial specialisation				-3.340		3.718
Age	0.272	***	0.055	0.161	***	0.048
Age^2	0.568	***	0.156	0.492	***	0.154
Small firm	-1.174		1.490	-1.401		1.396
Manufacturing sector	0.591		0.432	0.800	*	0.422
Information & communication sector	0.888	**	0.421	0.872	**	0.411
Professional, scientific & technical sector	0.556		0.352	0.561		0.342
Human health & social work sector	1.302	*	0.754	1.233	*	0.734
Successful exit	3.110	***	1.092	3.225	***	1.102
Number of directors	-0.684	***	0.070	-0.642	***	0.066
Age of directors	0.072	***	0.018	0.074	***	0.018
Nationality of directors	-0.463		0.627	-0.807		0.607
Parent universities	0.065		0.403	0.000		0.392
University size	1.968	***	0.741	1.390	*	0.740
Patents	-0.329		0.403	0.378		0.417
Science orientation	-0.037		0.821	0.738		0.829
Region's size	-0.646	***	0.190	-0.198		0.145
Intercept	25.540	***	5.795	0.953		2.004
DF	25			25		
N	837			837		
McFadden R^2	0.395			0.365		
-2LL	474.553			498.230		
AIC	524.553			548.230		
BIC	642.799			666.476		

Note: *** denotes significance at 1% level; ** 5% level; * 10% level.

Appendix 3

Mapping of 2007 Standard Industrial Classification 2-digit codes into 15 industries used in Fotopoulos (2014)

15 industries	SIC 2007 2-digit codes
Agriculture	01, 02, 03
Mining, quarrying and energy supply	05, 06, 07, 08, 09
Food, beverages and tobacco	10, 11, 12
Textiles and leather	13, 14, 15
Other manufacturing	16, 17, 18, 23, 24, 25, 28, 31, 32, 33
Coke, refined petroleum, nuclear fuel and chemicals	19, 20, 21, 22
Electrical and optical equipment	26, 27
Transport equipment	29, 30
Non-market services	37, 38, 39, 59, 60, 75, 84, 85, 86, 87, 88, 90, 91, 92, 93, 94, 96, 97, 98, 99
Construction	41, 42, 43
Distribution	45, 46, 47
Transport, storage and communications	49, 50, 51, 52, 53, 61, 79
Hotels and restaurants	55, 56
Real estate, renting and business activities	58, 62, 63, 68, 69, 70, 71, 72, 73, 74, 77, 78, 80, 81, 82, 95
Financial intermediation	64, 65, 66

Appendix 4

Classification of firm sectors based on 2007 Standard Industrial Classification

Sector categories	Alphabetical SIC sectors	Numerical SIC sectors
Manufacturing	Manufacturing	10821, 10822, 13910, 13990, 14120, 20140, 20411, 20420, 20590, 20600, 21100, 21200, 23110, 23440, 23690, 23990, 24450, 25110, 25210, 25500, 25730, 25990, 26110, 26200, 26301, 26309, 26511, 26512, 26513, 26600, 26701, 26702, 26800, 27110, 27120, 27310, 27320, 27900, 28110, 28132, 28250, 28910, 28960, 28990, 29201, 32200, 32300, 32500, 32990, 33140, 33200
Information and communication	Information and Communication	58110, 58210, 58290, 59111, 61200, 61900, 62011, 62012, 62020, 62030, 62090, 63110, 63120, 63990
Professional, scientific and technical	Professional, Scientific and Technical	70100, 70229, 71111, 71121, 71122, 71129, 71200, 72110, 72190, 72200, 73120, 73200, 74100, 74209, 74300, 74901, 74909
Human health and social work	Human Health and Social Work	86102, 86210, 86220, 86230, 86900

Administrative and support, and other	Administrative and Support Agriculture, Forestry and Fishing Mining and Quarrying Electricity, Gas, Steam and Air Conditioning Supply Water Supply Sewerage, Waste Management and Remediation Activities Construction Wholesale and Retail Trade Repair of Motor Vehicles and Motorcycles Transportation and Storage Accommodation and Food Service Activities Financial and Insurance Activities Public Administration and Defence Compulsory Social Security Education Arts, Entertainment and Recreation Other Service Activities	77310, 81300, 82990 1110, 1610, 2400, 3210, 9100, 35110, 36000, 37000, 38210, 38320, 39000, 41100, 43210, 43999, 46170, 46180, 46440, 47190, 47749, 47789, 47890, 47910, 49319, 52290, 55900, 26702, 26800, 27110, 27120, 27310, 27320, 27900, 28110, 28132, 28250, 28910, 28960, 28990, 29201, 32200, 32300, 32500, 32990, 33140, 33200, 64999, 66190, 66210, 84110, 84120, 85310, 85320, 85421, 85590, 85600, 90020, 90030, 93199, 95110, 96090

Table 1. Number of spinoffs generated: descriptive statistics of sample frame (1959-2013) and sample (2002-2013).

		Sample frame	Sample
Mean		17.01	11.89
Std. Deviation		22.68	14.01
Skewness		2.28	2.15
Kurtosis		5.71	5.33
Minimum		1	1
Maximum		106	67
Quartiles	Low	2.00	2.00
	Median	7.00	6.00
	Top	24.00	17.50
N		87	81

Table 2. Description of variables.

Dependent variable	
Spinoff survival	A binary variable taking value of 1 if the company was still registered as a live firm on CH on 1st May 2014.
Independent variables	
Investment	The number of institutional investors (seed funds, business angels, VCs) that were recorded as spinoff company's shareholders on 1st May 2014.
External entrepreneur	An average of the number of directorships held by spinoff company directors on 1st May 2014.
Commercialisation experience	The age of a TTO since or until its creation at spinoff's birth. In cases with multiple university parents, the age of the oldest parent is used.
On-campus incubator	A binary variable taking value of 1 if the spinoff company had access to on-campus business incubator at its birth.
Off-campus incubator	A binary variable taking value of 1 if the spinoff company had access to off-campus business incubator at its birth.
Science park	A binary variable taking value of 1 if the spinoff company had access to science park at its birth.
Degree centrality constraint	A modified version of Burt's (1992) structural holes where aggregate constraint is dependent solely on degree centrality and not on the strength of ties. It measures the position of spinoff companies within their networks of shareholders.
Industrial diversity	Industrial diversity of a spinoff's region at company's birth.
Industrial specialization	Industrial specialization of a spinoff's region at company's birth.
Control variables	
Age	Spinoff's age.
Age^2	A quadratic term for spinoff's age.
Small firm	A binary variable taking value of 1 if the spinoff company was a small firm (0-49 employees) on 1st May 2014.
Manufacturing sector	A binary variable taking value of 1 if the spinoff company registered its main activities in the manufacturing sector.
Information & communication	A binary variable taking value of 1 if the spinoff company registered its main activities in the information and communication sector.
Professional, scientific & technical sector	A binary variable taking value of 1 if the spinoff company registered its main activities in the professional, scientific and technical sector.
Human health & social care sector	A binary variable taking value of 1 if the spinoff company registered its main activities in the human health and social care sector.
Successful exit	A binary variable taking value of 1 if the spinoff company was acquired by another firm or underwent an IPO.
Number of directors	The number of company directors on 1st May 2014.
Age of directors	Average age of spinoff's directors on 1st May 2014.
Nationality of directors	The nationality is expressed as a proportion of spinoff's directors that are British out of all directors.

Parent universities	The counts of parent institutions involved in the formation of a spinoff company.
University size	Total university income at spinoff's birth. For spinoff companies with multiple university parents, the sum of total incomes is used. The variable is expressed in billions of pound sterling.
Patents	The number of university granted patents at spinoff company's birth. Where spinoff companies had more than one UK parent institution, the values of the patents were added together. The number of patents is expressed in thousands
Science orientation	Proportion of RAE or REF outputs of 4* quality that are in traditional science fields (REF's Panels A-B) out of 4* outputs in all academic fields (REF's Panels A-D) of a university corresponding to spinoff's birth year. In cases when a spinoff was formed by more than one university, the sum of 4* outputs of all universities involved was first established in order to calculate the percentage.
Region's size	The size of the spinoff's region at company's birth expressed in total employment across all sectors. The variable is expressed in millions.

Table 3. Descriptive statistics of continuous variable (N=870).

Variable	Mean	Std. Deviation	Minimum	Maximum
Investment	1.2	1.96	0	14
External entrepreneur*	3.41	3.87	0	50
Comm. experience	16.19	10.08	-2.77	44.32
Degree centrality constraint	0.21	0.21	0.01	1
Industrial diversity	0.75	0.03	0.66	0.81
Industrial specialisation	0.07	0.04	0.03	0.16
Age	6.64	3.21	0.42	12.28
Number of directors	4.48	2.41	1	18
Age of directors	47.06	6.91	21.86	68.54
Nationality of directors	0.86	0.24	0.00	1.00
Parent universities	1.13	0.39	1	4
University size	£0.42	£0.33	£0.02	£2.26
Patents	0.39	0.62	0	3.69
Science orientation	0.54	0.17	0	1
Region's size	2.53	0.95	0.67	4.45

Note: * N=869.

Table 4. Properties of categorical variables (N=870).

Variable	Yes	No
Spinoff survival	721	149
On-campus incubator	753	117
Off-campus incubator	723	147
Science park	636	234
Small firm	857	13
Manufacturing sector	144	726
Information & communication sector	147	723
Professional, scientific & technical sector	451	419
Human health & social work sector	30	840
Successful exit	81	789

Table 5. Correlations between variables (N=870).

		1	2	3	4	5	6	7	8	9	10	11	12
1	Spinoff survival	1.00											
2	Investment	*0.07*	1.00										
3	External entrepreneur	**0.10**	**0.14**	1.00									
4	Comm. experience	**0.13**	0.03	0.06	1.00								
5	On-campus incubator	*0.07*	0.04	0.05	**0.16**	1.00							
6	Off-campus incubator	0.06	**0.09**	-0.04	0.01	**0.10**	1.00						
7	Science park	0.00	-0.01	**-0.12**	-0.02	-0.02	*0.09*	1.00					
8	Degree centrality constraint	**-0.15**	**-0.42**	-0.04	-0.05	-0.02	**-0.14**	-0.03	1.00				
9	Industrial diversity	*-0.08*	**0.10**	0.01	**-0.15**	-0.04	*-0.07*	**0.30**	0.03	1.00			
10	Industrial specialisation	-0.05	-0.04	-0.01	-0.04	*-0.08*	0.05	**-0.37**	*-0.07*	**-0.71**	1.00		
11	Age	*0.08*	**0.27**	*0.07*	**-0.22**	**-0.15**	0.04	-0.03	**-0.30**	**0.40**	0.02	1.00	
12	Age^2	**0.15**	-0.03	-0.04	0.06	-0.05	0.00	0.03	**0.13**	**0.11**	0.02	0.02	1.00
13	Small firm	-0.01	**-0.17**	-0.02	*-0.07*	0.01	0.00	0.01	**0.09**	-0.03	0.00	**-0.12**	-0.05
14	Manufacturing sector	0.02	0.04	-0.06	-0.04	-0.05	0.03	-0.03	**-0.10**	0.00	*0.07*	**0.10**	0.00
15	Information & communication sector	0.00	-0.05	**-0.10**	-0.06	0.04	0.00	0.02	0.02	0.06	-0.06	0.00	0.00
16	Professional, scientific & technical sector	*0.07*	**0.10**	**0.10**	**0.09**	0.01	0.06	0.00	*-0.08*	-0.03	0.00	-0.03	0.06
17	Human health & social work sector	0.00	-0.06	0.00	-0.04	0.00	-0.05	-0.01	**0.11**	-0.03	0.02	-0.03	-0.06
18	Successful exit	**0.14**	0.01	0.04	*0.08*	0.01	-0.02	-0.01	-0.07	0.00	-0.05	*0.08*	0.02
19	Number of directors	**-0.35**	**0.40**	0.02	0.03	-0.07	0.01	0.01	**-0.26**	-0.02	*0.08*	**0.11**	**-0.15**
20	Age of directors	**0.12**	*0.07*	**0.11**	**0.09**	0.02	0.01	0.00	-0.03	-0.06	-0.03	-0.05	-0.03
21	Nationality of directors	*-0.08*	0.00	**0.09**	*-0.08*	-0.06	-0.04	-0.05	0.07	**0.11**	-0.04	0.05	-0.01
22	Parent universities	0.05	**0.25**	0.04	**0.14**	*0.08*	**0.11**	**0.10**	**-0.19**	0.00	0.03	**0.15**	-0.03
23	University size	**0.16**	**0.12**	0.00	**0.45**	**0.18**	**0.15**	**0.16**	**-0.16**	**-0.33**	0.01	**-0.22**	0.04
24	Patents	**0.11**	0.03	-0.02	**0.33**	**0.17**	**0.16**	-0.06	**-0.12**	**-0.55**	**0.26**	**-0.27**	0.03
25	Science orientation	*0.08*	*0.07*	0.01	**0.21**	**0.11**	**0.14**	-0.05	**-0.13**	**-0.47**	**0.34**	**-0.10**	-0.02
26	Region's size	-0.01	0.05	-0.01	**0.10**	0.01	0.00	**-0.14**	**-0.11**	**-0.59**	**0.26**	-0.03	*-0.08*

Note: Correlations of External entrepreneur are available for 869 observations only. Correlations in italics significant at 5% level (2-tailed); correlations in bold significant at 1% level (2-tailed). Correlations between continuous variables are Pearson's, correlations between continuous and categorical dummy variables are point-biserial, correlations between categorical dummies are phi coefficients.

Table 5. Correlations between variables (N=870).

		13	14	15	16	17	18	19	20	21	22	23	24	25
14	Manufacturing sector	0.00												
15	Information & communication sector	0.00	**-0.20**	1.00										
16	Professional, scientific & technical sector	-0.02	**-0.46**	**-0.47**	1.00									
17	Human health & social work sector	0.02	*-0.08*	*-0.09*	**-0.20**	1.00								
18	Successful exit	**-0.09**	0.00	-0.05	0.02	0.03	1.00							
19	Number of directors	**-0.19**	0.04	**-0.09**	0.02	-0.01	-0.03	1.00						
20	Age of directors	-0.03	0.03	**-0.17**	**0.11**	*0.07*	0.04	**0.11**	1.00					
21	Nationality of directors	0.04	0.02	-0.03	0.01	0.00	**-0.17**	0.05	**0.13**	1.00				
22	Parent universities	**-0.11**	0.01	-0.04	0.03	-0.05	-0.02	**0.17**	*0.09*	-0.02	1.00			
23	University size	*-0.07*	-0.02	-0.06	**0.11**	-0.03	0.06	*0.07*	**0.09**	**-0.16**	**0.40**	1.00		
24	Patents	-0.01	-0.03	*-0.08*	**0.09**	0.02	0.06	*0.08*	0.05	**-0.11**	**0.25**	**0.76**	1.00	
25	Science orientation	-0.03	-0.02	-0.02	0.02	-0.02	0.05	0.06	0.01	**-0.10**	*0.07*	**0.36**	**0.44**	1.00
26	Region's size	-0.03	-0.03	-0.06	0.06	0.01	0.04	**0.12**	*0.08*	-0.04	0.04	**0.33**	**0.46**	**0.43**

Note: Correlations of External entrepreneur are available for 869 observations only. Correlations in italics significant at 5% level (2-tailed); correlations in bold significant at 1% level (2-tailed). Correlations between continuous variables are Pearson's, correlations between continuous and categorical dummy variables are point-biserial, correlations between categorical dummies are phi coefficients.

Table 6. Survival patterns of UK spinoff companies.

Start Year	Births	3-year survival	5-year survival
2002	102	99.02%	97.06%
2003	85	100.00%	92.94%
2004	90	100.00%	93.33%
2005	81	98.77%	87.65%
2006	84	98.81%	86.90%
2007	85	96.47%	89.41%
2008	63	95.24%	90.48%
2009	59	94.92%	86.96%
2010	75	98.67%	-
2011	62	96.67%	-
2012	64	-	-
2013	20	-	-

Note: N=870.

Table 7. Logit of spinoff survival.

	Model 1	S. E.	Model 2	S. E.	Model 3	S. E.	Model 4	S. E.	Model 5	S. E.
Investment	-0.004	0.057					0.309 ***	0.092	0.259 ***	0.089
External entrepreneur	0.111 ***	0.039					0.125 **	0.049	0.120 **	0.049
Commercialisation experience	0.032 ***	0.010					0.028 **	0.014	0.023	0.014
On-campus incubator	0.333	0.245					0.323	0.343	0.105	0.331
Off-campus incubator	0.202	0.236					-0.312	0.327	-0.281	0.318
Science park	0.068	0.210					0.315	0.290	-0.131	0.290
Degree centrality constraint	-1.582 ***	0.424					-2.407 ***	0.592	-2.430 ***	0.586
Industrial diversity			-7.822 **	3.341			-33.451 ***	7.165		
Industrial specialisation					-3.653	2.303			-3.410	3.715
Age							0.267 ***	0.055	0.159 ***	0.048
Age^2							0.585 ***	0.155	0.503 ***	0.153
Small firm							-1.208	1.489	-1.435	1.397
Manufacturing sector							0.628	0.429	0.846 **	0.420
Information & communication sector							0.941 **	0.418	0.918 **	0.408
Professional, scientific & technical sector							0.619 *	0.349	0.627 *	0.340
Human health & social work sector							1.308 *	0.738	1.252 *	0.714
Successful exit							3.204 ***	1.086	3.283 ***	1.099
Number of directors							-0.686 ***	0.070	-0.648 ***	0.066
Age of directors							0.075 ***	0.018	0.076 ***	0.018
Nationality of directors							-0.438	0.616	-0.799	0.595
Parent universities							0.058	0.402	-0.005	0.392
University size							1.904 ***	0.733	1.334 *	0.735
Patents							-0.303	0.402	0.404	0.416
Science orientation							-0.161	0.821	0.664	0.828
Region's size							-0.656 ***	0.190	-0.211	0.144
Intercept	0.642 *	0.39	7.443 ***	2.515	1.855 ***	0.201	25.603 ***	5.791	0.911	2.009
DF	8		2		2		25		25	
N	869		870		870		869		869	
Nagelkerke R^2	0.085		0.011		0.005		0.505		0.473	
McFadden R^2	0.057		0.007		0.003		0.394		0.364	
Percentage correct	82.85%		82.87%		82.87%		88.38%		87.80%	
Sensitivity	99.44%		100.00%		100.00%		96.67%		96.67%	
Specificity	2.68%		0		0		48.32%		44.97%	
-2LL	750.864		790.888		794.277		482.564		506.501	
AIC	766.864		794.888		798.277		532.564		556.501	
BIC	805.003		960.100		963.489		651.748		675.685	

Hosmer & Lemeshow Test	10.111	17.403 **	17.074 **	4.235	5.900

Note: *** denotes significance at 1% level; ** 5% level; * 10% level.

Table 8. Variance Inflation Factors.

	Model 1	Model 2	Model 3	Model 4	Model 5
Investment	1.2			1.5	1.5
External entrepreneur	1.0			1.1	1.1
Commercialisation experience	1.0			1.3	1.4
On-campus incubator	1.0			1.1	1.1
Off-campus incubator	1.0			1.1	1.1
Science park	1.0			1.3	1.3
Degree centrality constraint	1.2			1.4	1.4
Industrial diversity		1.0		2.9	
Industrial specialisation			1.0		1.5
Age				1.8	1.4
Age^2				1.1	1.1
Small firm				1.1	1.1
Manufacturing sector				2.2	2.2
Information & communication sector				2.2	2.2
Professional, scientific & technical sector				2.9	2.9
Human health & social work sector				1.3	1.3
Successful exit				1.1	1.1
Number of directors				1.3	1.3
Age of directors				1.1	1.1
Nationality of directors				1.1	1.1
Parent universities				1.4	1.4
University size				3.5	3.6
Patents				3.4	3.3
Science orientation				1.5	1.5
Region's size				1.9	1.5