Inherited Competence and Spin-off Performance in Knowledge Intensive Industries

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Abstract

In this paper we apply the hereditary theory of spin-off formation developed by Klepper to study the evolution of a science-based industry – the biotech industry. In the process we extend Klepper's framework by relating the concept of inherited competence to two different types of spin-offs - university and private sector spin-offs - and two different types of inherited competence - R&D competence and innovation competence. Using the Irish biotech industry as a case-study, we find that differences in pre-entry experience manifest themselves most markedly in terms of the firm's capacity to attract venture capital, with private sector spin-offs considerably outperforming university spin-offs. We argue that the superior performance of the private sector spin-offs is explained by the nature of their inherited competence in that they are characterised by higher levels of innovation competence.

Key words: industrial evolution; inherited competence; spin-off; biotech

1. Introduction

Evolutionary approaches to understanding industrial development are increasingly focussing on the role of spin-off processes. This is partly driven by the work of Klepper (1997, 2001, 2008), who highlighted the important role of spin-off firms in industrial development. He developed a theory positing that firm-specific factors such as inherited competences generate a process through which spin-off firms drive the development of industries. Firms differ innately in terms of their levels of competence, and the competence of firms is based on their pre-entry experience. Spin-offs inherit a large part of their capabilities from their parent, which explains why successful firms tend to give birth to successful firms (Boschma and Frenken, 2011).

Klepper makes no distinction between different types of spin-offs, focussing mainly on private sector spin-offs. His ideas have therefore no direct application in relation to a set of science-based industries where university spin-offs play an important role. Extant research on university spin-offs suggests that they are different in terms of their competences (Clarysse and Moray, 2005; Mangematin et al., 2003). In this paper we build on Klepper's ideas by relating the concept of inherited competence to the two types of spin-offs - university spin-offs and private sector spin-offs. This involves a re-specification of the concept of inherited competences and new ideas in relation to how these competences are linked to spin-off performance. Specifically, we assess whether differences in the pre-entry experience of firms originating in university and private sector settings influences their subsequent performance.

For the purposes of this analysis we utilise the Irish biotech industry as a case-study. The science-driven nature of the biotech industry is well established. The industry has its origins in university-based research at Stanford University and the University of California in the 1970s where university spin-offs, such as Genentech and Biogen, and private sector spin-offs played an important role in its development (Prevezer, 2001). Internationally, the biotech industry is characterized by a large number of university spin-offs (Shane, 2004). The industry has come to be characterised by collaborative research projects involving both university "Centres of Excellence" and dedicated biotech research firms (DBFs), the linkages between leading scientists across advisory boards, and the commercialisation role of the larger biotech and pharmaceutical firms (Audretsch, 2001; Cooke, 2003). Zucker et al. (1998) argue that this dominant role of science expertise has meant that in the biotech industry academics have wielded greater technological influence over firms than has been the case in other industries. Promoting university spin-offs and university-industry links has become a core pillar of biotech development policies across the world. The industry has been a beneficiary of government initiatives ranging from public and public-private financing of start-up firms to risk-sharing and incubation schemes (Wright et al., 2006)

Similarly, the Irish biotech industry's development over the last two decades has been greatly influenced by large scale government-funded investment in research in universities as part of Ireland's National Development Plan (NDP) and the Strategy for Science, Technology and Innovation (SSTI), as well as specific policies and supports aimed at commercialising such research through spin-offs. This has led to a significant increase in university and private sector spin-offs.

We provide a quantitative analysis of the influence of competence inherited via firm origins on the performance of Irish biotech firms. As noted by Shane and Stuart (2002) and Clarysse et al. (2011), traditional accounting-based indicators of performance may be inappropriate for early stage high-tech companies as these companies may initially be loss-making. To overcome this problem, we employ two measures of firm performance which focus on non-accounting aspects of performance, firm 'survivability' and the ability of a given firm to attract venture capital. We find that the spin-offs do not differ in terms of survivability. Spin-offs do differ in terms of incidence of attracting venture capital and in terms of amounts of venture capital received, with private sector spin-offs far outperforming the university spin-offs in terms of amounts of venture capital.

We argue that the superior performance of the private sector spin-offs is partly related to the specific type of inherited competence they are endowed with. We characterise inherited competence as comprising of both the capacity to do R&D, which we refer to as 'R&D competence', and the capacity to manage the innovation process, which we refer to as 'innovation competence'. The relation between these two types of inherited competence and firm performance is analysed by means of qualitative research using data compiled from interviews with ten biotech spin-off firms and industry experts. We find that private sector spin-offs are characterised by higher levels of inherited "innovation competence". We argue that this explains their superior performance, in terms of their capacity to attract venture capital.

This paper is structured as follows: Section 2 provides an overview of the theoretical ideas related to the role of spin-offs in industry evolution and the link with inherited competences. This is followed, in section 3 with by an outline of the methodology and data sources used in this paper. Section 4 details the evolution of the Irish biotech industry. The paper continues, in section 5, with the quantitative analysis of the relation between spin-off type and firm performance in the Irish biotech sector and, in section 6, the qualitative analysis of the role played by different types of inherited competence. The final section draws out some conclusions and the main implications for policy.

2. Linking spin-off performance and inherited competence

Approaches to understanding the development of industries are increasingly informed by evolutionary thinking (Asheim, Cooke and Martin, 2006). Part of the evolutionary scholarship on industry evolution calls for a focus on the role of spin-off processes (Boschma and Wenting, 2007; Ter Wal and Boschma, 2009). Drawing on Nelson and Winter (1982), the characterization of industry evolution emphasizes the role of firm-specific routines within an industry, with 'fitter' routines becoming dominant in an industry and eventually being transferred from the parent to its spin-offs.

An important contribution in this regard has been made by Stephen Klepper, who over the course of a series of influential papers (Klepper, 1997; 2001; 2008) developed a formal model of the evolution of industrial concentrations driven by spin-off processes. The model has been applied to the US tyre industry (Buenstorf and Klepper, 2009) and to Detroit's automobile industry and Silicon Valley's integrated circuits industry (Klepper, 2007; 2010). The theory characterises industry evolution in terms of organisational reproduction and inherited company traits to explain how spin-off firms drive evolution.

Klepper (1997, 2001, 2008) argues that firms differ innately in terms of their levels of competence, and the competence of firms is based on their pre-entry experience. He identifies three types of entrants into a new industry based on their pre-entry experience. These are 'spin-offs', which are founded by employees from incumbent firms; 'start-ups', which are founded by employees of firms in related industries or other capitalists with no experience in the new industry; and 'diversifiers', which are entrants that diversify from related industries. Klepper argues that, of these firm types, spin-offs will have the highest degree of competence, based on inherited organizational and industry experience. Spin-offs can exploit knowledge about the new industry that their founders gained while working in the industry at their 'parent' firms. Start-ups on the other hand are characterised by low competence, reflecting a lack of organisational and industry experience. Thus a firm's pre-entry experience critically shapes its competence, which in turn influences its competitiveness, its chance of survival and growth, and the rate at which it generates further spin-offs. Such spin-off processes are then an important factor in the explanation of industrial development because spin-offs tend to locate in relative proximity to their parent firm.

We propose that Klepper's framework could be refined by distinguishing different types of inherited competence, namely what we term as 'R&D competence' and as 'innovation competence'. This nuanced approach to inherited competence is in the spirit of the Agarwal et al. (2004) distinction between technological know-how and market pioneering know-how. Klepper loosely defines the concept of organisational knowledge and competence as a firm's "competence at doing R&D", its ability to "manage the R&D process" (Klepper, 2008), or its ability to "manage technological change" (Klepper, 2010). We advocate a more nuanced distinction between the competence at managing the narrow R&D process and the competence at managing the broader innovation process.

The two competences are based on different combinations of knowledge, present in different intensities. In relation to the types of knowledge, a distinction has been made between know-why, know-how and know-who knowledge (Asheim et al., 2011). Know-why knowledge relates to natural systems and the applications of scientific laws; know-how knowledge relates to knowledge of technical skills and is often tacit in nature; and know-who knowledge involves knowledge about, for example, relevant business partners or sources of finance. Van Egeraat et al. (2013) and Van Egeraat and Curran (2013), based on their work on innovation processes and knowledge flows in the biotech and animation industries, suggest adding a fourth, crucial, type of knowledge to the categorisation – industry/business knowledge. This includes knowledge of (unmet) market needs, the ability to connect particular inventions to market needs, knowledge about bringing products through clinical trials, knowledge of regulatory procedures, knowledge of raising finance, and so forth.

R&D competence involves a high level of know-why and know-how type knowledge, while know-who and industry/business knowledge play a less important role. The broader innovation process requires a different combination of knowledge. While know-why and know-how type knowledge remain important, bringing a new invention to market requires know-who and industry/business type knowledge. In the biotech industry this know-who/industry knowledge is crucial for success (Van Egeraat and Curran, 2010; 2013). We link this latter knowledge to innovation competence.

Agarwal et al. (2004) in their study of the disk drive industry emphasize the importance of both technical and market pioneering know-how being passed from parent to spin-off. Chatterji (2009) in his study of the medical devices industry argues that it is predominantly non-technical knowledge related to regulatory issues, financing, and market opportunities that generates a performance advantage for spin-offs.

Klepper treats spin-off firms as a homogenous group, focussing mainly on private sector spin-offs. However, there are clearly different types of spin-offs, potentially with different characteristics in terms of inherited competence. An important distinction is that between private sector spin-offs and university spin-offs that tend to play an important role in science-based industries.

Extant research on university spin-offs suggests that they are different in terms of their (level of) competences, at least in the early stages of their development (Clarysse and Moray, 2005; Mangematin et al., 2003). Rasmussen et al. (2011) highlight the literature addressing issues such as which competences are necessary for university spin-off formation, who provides them, and how they are developed. They note that the context of university spin-offs is distinct from that of corporate spin-offs, as university spin-offs usually involve the development of a business opportunity based on novel and potentially disruptive technologies or tacit knowledge emerging from academic research. In addition to this, university spin-offs face a number of obstacles to their development: they may lack business and commercial skills (Vohora et al., 2004; O'Gorman et al., 2008); they may lack technical, financial and human resources (Lockett et al., 2005); and may not be investor ready (Wright et al., 2006). Rasmussen et al. (2011), in their study of four university spin-offs in UK and Norway, find that while the scientific knowledge of university spin-offs was acquired through the academic founders, the specific competencies for venture creation had to be developed or acquired.

This paper explores the relation between firm-origin, inherited competence and spin-off performance, distinguishing between the two different types of spin-offs - university and private sector - and different types of inherited competence - R&D competence and innovation competence. This will be done through the empirical lens of the Irish biotech industry, a science-based industry where university spin-offs are relatively prevalent, alongside private sector spin-offs and other start-ups.

It is possible to further unpack the link between firm origin and performance by taking account of the substantial diversity of business models that biotech firms adopt (Mangematin et al., 2003).[1] In this paper we utilize the typology of biotech business models developed by Biliardi et al. (2005) and Nosella et al. (2005). In a series of studies of the Italian biotech industry, the authors identify five biotech business models: (i) *Dedicated biotech firms* that carry out R&D activities (e.g. discovery and pre-clinical development stages) and then licence their outputs to other firms; (ii) *Integrated firms* that have strong product pipelines and operate across the value chain (from R&D to manufacture and commercialisation); (iii) *Manufacturing firms*, whose activities are based on research of other companies. These firms focus on the later stages of the innovative process by carrying out engineering, production and commercialisation activities; (iv) *Biotech suppliers*, who carry out the industrial development and customized production of biotech products for other firms, i.e. they supply biotechnologies that are used in the production process; (v) *Services firms* providing research services, such as diagnostic tests, chemical synthesis, studies of cloning, and sequencing for other drug-orientated companies.

3. Data sources

[1] The concept of "business model" is defined by Schafer et al. (2005) as "*a representation of a firm's underlying core logic and strategic choices for creating and capturing value within a value network*", where *core logic* refers to how a firm articulates and makes explicit key assumption and cause-and-effect relationships and the internal consistency of strategic choice, while *creating and capturing value* refers to a firm's ability to do things in way that differentiate them from their competitors.

The focus of the research is the modern (post-genetic engineering era) biotech industry. For the purposes of this paper, modern biotech is defined as per OECD (2006), which employs a list based definition that includes various techniques and activities: synthesis, manipulation or sequencing of DNA, RNA or protein; cell and tissue culture and engineering; vaccines and immune stimulants; embryo manipulation; fermentation; using plants for cleanup of toxic wastes; gene therapy; bioinformatics, including the construction of databases; and nanobiotechnology.

The population of firms in the modern biotech industry in Ireland has been established using existing survey material available from the *Biotechnology Ireland* website (hosted by Enterprise Ireland, a government industrial development agency). This material was updated based on information available from the *FAME* database[2], interviews with industry experts (see below), and extensive Internet search of official company websites and media sources. The set of firms has been back dated to 1994 based on information contained in the *Irish Biotechnology Sourcebook* (1994, 1997). The resulting dataset contains information on the origins of each firm and, in the case of spin-off firms, identifies whether such firms emerged from existing private firm or universities. In addition, it contains data on firm exit and acquisition. The activities of firms have also been detailed, allowing for firms to be categorised in terms of their business models as per Biliardi et al. (2005) and Nosella et al. (2005).

In relation to the identification of spin-off firms in the dataset, it should be noted that multiple definitions exist for the term spin-off (for a discussion see Myint et al., 2005). We apply a broad definition that covers a wide range of firms, including: (1) firms started as the result of a mother-organisation splitting off existing units or departments and the mother company holding (at least initially) equity stakes in the new firm and (2) firms formed by employees or groups of employees leaving an existing organisation to form an independent start-up firm. The parent entity can be a firm, a university, or other organisation. In the second case the firm is only considered a spin-off if the employees received some form of assistance/support/stimulation from the parent organisation or if they are based on intellectual property/core capability developed during the employees' stay at the parent organisation.

Firm level venture capital data for Irish biotech companies was obtained from the Irish Venture Capital Association (IVCA) (www.ivca.ie) for the period 2007-2012. This venture capital data was extended back

[2] *FAME* is a database of UK and Irish companies which provides accounts data for 2.8 million public and private companies. See http://www.bvdinfo.com/Products/Company-Information/National/FAME.aspx.

to 1994 (expressed in constant 2010 euro)[3] using the *Irish Times* archive (a leading Irish newspaper). Qualitative data on the different types of knowledge and competence possessed by spin-off firms within the Irish biotech industry was collected via semi-structured interviews. Interviews were conducted with actors in ten biotech spin-off firms, two venture capital firms, industrial development agencies and with other industry experts.

4. Evolution of the Irish biotech industry

The biotech industry in Ireland is made up of a foreign and an indigenous segment. The foreign-owned companies have a strong manufacturing focus and the two segments have separate evolutionary paths. This section focuses on the indigenous segment. The development of the industry took off in earnest in the 1990s. Along with the formation of start-up firms, spin-off processes play an important role from an early stage. Figure 1 illustrates the chronology of spin-offs entry and exit over the period 1994-2008. Private sector spin-offs begin to enter from the early 1990s while university spin-offs enter from the mid-1990s. The remainder of this section discusses the dynamics of the two types of spin-offs in more detail.

[Figure 1 here]

Elan Corporation, one of the first private sector start-ups established in 1969, was initially a specialist in drug delivery systems, providing drug absorption control technology for antibiotics produced by other global pharmaceutical companies. By the 1990s Elan's interests extended into the area of neuroscience and the company subsequently undertook the development of its own products for the treatment of Alzheimer's disease, Parkinson's disease, and multiple sclerosis. To facilitate this product development, Elan embarked on an aggressive acquisitions strategy. At the same time, Elan began building a web of strategic partnerships, acquiring minority stakes in a number of companies that in turn paid the company licensing fees for its technology. However, Elan's stock market value collapsed in 2002 after the US Securities and Exchange Commission launched an investigation into the company's accounting practices. Elan responded by implementing a recovery plan which involved the divesting of a number of subsidiaries and licenses in an effort to drive down debt (*Irish Times*, 29 October 2010).

[3] In 1992 the chief financial officer of Trinity Biotech noted that funding for start-up ventures such as Trinity Biotech was simply not available in Ireland at that time, either from the banks or from venture capital companies (McGrath, 1992).

This divesture of biotech assets, accompanied by the departure of a substantial number of executives and scientists from Elan's Irish operations, has led to the emergence of a wave of Irish biotech firms that were either spun off from Elan or formed by former Elan staff. During the two-year period between 2002 and 2004 alone, eight firms were spun off and another three firms followed between 2005 and 2008. Elan's divestiture of biotech assets and product rights, as well as the dispersion of former Elan executives and researchers throughout the Irish biotech industry, fundamentally changed the trajectory of the Irish biotech industry. Prior to its restructuring, Elan was characterized by industry analysts as being *"hermetically sealed from the rest of Ireland's indigenous life sciences industry"* and as operating *"on a different plane compared to the small-scale, undercapitalized ventures that otherwise constituted the sector"* (Sheridan, 2008).

In parallel with the wave of Elan spin-offs, since the mid-1990s Ireland has witnessed a strong increase in university spin-offs. This development should be seen in the context of substantial public sector investment over the last 10 years which has significantly enhanced the biotech research performance of Irish universities. This funding injection has been timely, given the changing organisation of the global biotech industry in the post-genome era and the enhanced opportunities for small scale university spin-offs and dedicated biotech firms to explore new avenues of research, into which larger integrated firms are unable or unwilling to allocate resources. In 1998 the Irish government launched the Programme for Research in the Third-Level Institutions (PRTLI) and Science Foundation Ireland (SFI), which since its inception has invested €865 million (including exchequer and private matching funds) into strengthening national research capabilities via investment in human and physical infrastructure.[4] A biotech-related example of this public sector funding is the SFI's recent investment of €10 million in the Regenerative Medicine Institute (REMEDI) based in NUI Galway (Ahlstrom, 2010).

A further effort, aimed at cultivating university–industry linkages, has been the establishment of seven Centres for Science, Engineering and Technology (CSET). The process of technology transfer within Irish universities has also evolved over the last decade. According to Geoghegan and Pontikakis (2008), a significant empowerment of Technology Transfer Offices of the Irish universities has occurred over the last decade, in tandem with a rapid realignment of university research activities. Many of these programs were accompanied by specific policy measures aimed at commercialising the research output, with a big role for Enterprise Ireland, the national agency with responsibility for promoting indigenous enterprise.

[4] See www.hea.ie for further details.

Over a 20-year period, these developments have led to a substantial indigenous biotech industry. Our inventorisation of the development of the modern biotech industry has identified the presence of 106 indigenous Irish biotech firms over the last two decades. Of these firms, 64 are currently in operation, a further 23 have been acquired, and 19 have ceased operations. On basis of firm-level data available from the FAME database and reports from industry experts we estimate that the indigenous firms and those initially indigenous firms that have since been acquired employed just under 3,000 persons in 2009.

University spin-offs account for 34 per cent of total number of indigenous firms while private sector spin-offs account for 28 per cent. Private sector start-ups, as defined by Klepper (2008), account for the remaining 38 per cent of firms.[5] The majority of university spin-offs are micro-enterprises, employing less than 10 staff. Private sector spin-offs tend to be larger employing 42 staff on average. As a consequence, the university spin-offs account for only 10% of biotech employment while private sector spin-offs account for 46%. The remaining 44% is employed in private sector start-ups.

[Table 1 here]

[5] The focus of this paper is on the inherited competence of spin-off firms. While we differentiate between two types of spin-offs (those originating from universities and private sector), we do not distinguish between *de novo* start-ups and diversifiers and refer to them collectively as ‘private sector start-ups’.

5. Findings: the relation between spin-off origin and firm performance

In the quantitative analysis of Irish biotech industry that follows, we employ two measures of firm performance: firm 'survivability' and a firm's ability to attract venture capital.

5.1 Survivability of Irish biotech firms

Survival analysis, an established quantitative tool for analyzing industry evolution and firm performance, is predicated on the idea that firms with greater competence will increase the competitive pressure within an industry leading to the failure of firms with lower levels of competence. Firm survival rates can be modeled using an event history analysis. Survival analysis has become an established quantitative tool for analyzing industry evolution, survival analysis. Survival analysis has been employed in studies of the British, US, and German automobile industries (Klepper, 2002; Boschma and Wenting, 2007; Cantner et al., 2006), the German laser industry (Buernstorf, 2007), the Dutch banking industry (Boschma and Ledder, 2010), and the Danish wind turbine industry (Menzel and Kammer, 2012) amongst others. The duration of the survival analyses varies greatly, spanning 143 years in the study of Boschma and Ledder (2010), 40 years in Buernstorf (2009), 34 years in Menzel and Kammer's (2012) study, and just 4 years in Carree's (2003) hazard analysis of Russian commercial banks over the 1994-1997 period. The duration in the present study spans 18 years, from 1994 to 2012. The start date of 1994 is justified on the grounds that at this time the modern biotech industry in Ireland was still in its infancy in this year.

We estimate a Cox proportional hazard model (Cox 1972). The basic specification can be written as:

$$h_t = h_0(t)e^{X\beta}$$

The partial likelihood method is used to estimate the slope parameters in the β vector. Partial likelihood focuses on the ordering of events - in this case the failure (exit) of a firm – and calculates the conditional probability of failure for the observation that is actually observed to fail. The Cox proportional hazard model is known to not necessitate any assumptions about the distribution of survival rates (the functional form of the baseline hazard). As per Wennberg et al. (2011), we use Stata's *exactp* option to adjust for multiple firms exiting in the same year.

The dependent variable is the survival time of the firm, i.e. the number of years for which the firm exists, with 1994 taken as the starting point. Firms that still exist in 2012 and those that were acquired are right censored, which means that these firms are removed from the population at that date (2012, or the date of acquisition) but are included in the analysis prior this date. So, for the purposes of our analysis, acquisition is not deemed to be an exit. The analysis includes variables on type of spin-off (university spin-off and private sector spin-off), with private sector start-ups being the reference category or benchmark in the analysis. The inclusion of dummy variables distinguishing between academic and private sector origins of firms finds precedence in Buenstorf (2007). As noted above, the time period for this analysis is 1994 to 2012, and a dummy variable (*D_post-2000*) is included to control for spin-off entry over the period 2000-2012, as this period yielded substantially more spin-offs than 1994-1999.

Table 2 presents the results of the Cox proportional hazard analysis for the Irish biotech industry. Results are presented as hazard ratios, which can be interpreted as survival probability relative to the reference variable. From Table 2 it is clear that university spin-offs are over 3 times more likely to fail (exit) than the reference group, private sector start-ups (hazard ratio: 3.410). Similarly, private sector spin-offs are also over 3 times more likely to fail than private sector start-ups, (hazard ratio: 3.562). As indicated by the negative co-efficient, firms entering the industry from the year 2000 onwards are less likely to fail than firms that entered prior to 2000 (hazard ratio: 0.297). Estimated hazard ratios and corresponding coefficients for university spin-offs and private sector start-ups are significant at the 10% level.

[Table 2 here]

Our survival analysis of Irish Biotech firms points to university spin-offs and private sector spin-offs displaying similar survival rates. However, there are limitations inherent in survival studies, due to the assumption that survival and good economic performance are equivalent (Agarwal et al, 2004, p.518). Firm survival may not be solely determined by performance. Underperforming firms may persist for significant periods of time, due to entrepreneurs adhering to varying firm-specific performance thresholds influenced by the potential switching costs they would face, the value of capital in alternative uses, and non-income benefits derived from retaining an underperforming business as a going concern (Gimeno et al., 1997; Cefis and Marsili, 2011). In light of these questions over the suitability of survival rates as a measure of firm performance, the next section presents one further performance measure: the ability of a given firm to attract financial resources in the form of venture capital.

5.2. Venture capital attracted by Irish biotech firms

We now consider the ability of biotech firms to attract venture capital. The Irish biotech industry's development in recent years has been greatly shaped by the availability of venture capital funding. Total venture capital investment in Ireland has more than doubled since 2002, while the Irish proportion of venture capital secured by the Irish biotech industry has also experienced a marked increase since 2002. Despite a more restrictive funding environment in recent years, venture capital funding for Irish companies appears to have remained resilient, increasing by 19 per cent between 2007 and 2012. In 2002 the biotech industry received slightly less than 2 per cent of total Irish venture capital investment, rising to 31 per cent in 2009, but falling back to 2002 levels by 2012 as software services and cloud computing firms began to attract increasing shares of venture capital (PWC 2005 and IVCA 2007-2012).

For the purposes of our analysis, we consider first the probability of firms of different origin attracting venture capital. A cross-sectional Probit regression is utilized for this purpose, in which the dependent variable (venture capital inflow) is a binary variable taking a value of 1 if a company has attracted venture capital to 2012, and 0 otherwise. The variables university spin-off and private spin-off are binary variables indicating the origin of the firm, with private sector start-ups (as defined in section 2) serving as the reference variable. The intensity of venture capital inflows is then considered in specifications (3) and (4) by means of a cross-sectional OLS regression, with the dependent variable consisting of log transformed venture capital inflows. However, in specifications (3) and (4) only the subset of firms that received venture capital are considered (40 of the 106 firms in the dataset).

From the results presented in Table 3 it can be seen that university spin-offs have a higher probability of incidence of venture capital funding (regression specifications 1 and 2). However, of those firms which attract venture capital funding, it is private sector spin-off firms that receive greater quantities of venture capital, with the statistically significant *PSO* estimated coefficient almost three times greater than the insignificant *USO* estimated coefficient (regression specification 3). Our findings appear to be at variance with the findings of Munari and Toschi (2011), who in the context of the micro- and nanotechnology sector in the UK, find no evidence of a venture capital bias against investment in academic spin-offs. Apart from the different sectoral context, the contrasting results may also stem from the indicators applied. In Munari and Toschi (2011), the ability of spin-offs to attract venture capital is measured by the incidence of venture capital investment, irrespective of the size of the investment. However, in our study, ability to attract venture capital is measured both by the incidence and by the size of the actual investment.

[Table 3 here]

It is possible to further unpack the link between firm origin and performance by taking account of the substantial diversity of business models that biotech firms adopt (Mangematin et al., 2003). For this we utilize the typology of biotech business models developed by Biliardi et al. (2005) and Nosella et al. (2005), as outlined in Section 2. Table 4 and the corresponding Pearson statistic indicate that private sector and university spin-offs differ in terms of the activities they undertake in the biotech industry. University spin-offs tend to function primarily as either dedicated biotech research firms or biotech service providers, while private sector spin-off firms are more distributed over the Services, Manufacturing and Integrated categories.

[Table 4 here]

In Table 3, the business model categories are introduced as interaction variables. The binary dummy variables *USO_DBF, PSO_Integ*, *PSO_Manu*,and *PSO_Manu* denote university spin-offs which operate as dedicated biotech research firms and private sector spin-offs which operate as integrated firms, manufacturers, and biotech service providers, respectively.

The data show that it is university spin-offs that operate as dedicated biotech research firms that have a higher probability securing venture capital funding (specification 2). However, if we consider the amount of venture capital secured (specification 4), we find that private sector spin-offs which acquire or license biotech intellectual property for products which they then manufacture (*PSO_Manu*) are particularly successful in acquiring venture capital. The *PSO_Manu* estimated coefficient is almost twice that of private sector firms who adopt integrated business models (*PSO_Integ*). A more detailed disaggregation of the underlying venture capital data by firm origin (see Table A1 in the Appendix) indicates that these results are driven by those private sector spin-offs which originated from Elan. Over the period 1994-2012 Elan spin-offs attracted 60% of biotech venture capital inflows – twice as much as that of university spin-offs.

6. Findings: Inherited competence in the Irish biotech industry

The quantitative analysis of biotech firm performance of the preceding section has indicated that the relation between spin-off origin and firm performance manifests itself most markedly in terms of the firm's capacity to attract external investment. In this respect, a sub-group of private sector spin-offs far outperform the university spin-offs and private sector start-up firms. We now link spin-off performance and firm-origin in the biotech sector more directly to the different types of inherited competence. As outlined in Section 2, we posit that inherited competence relates both to the capacity to undertake R&D, which we refer to as 'R&D competence', and the capacity to manage the innovation process, which we refer to as 'innovation competence'. We explore the role played by these distinct competences in the Irish biotech industry by means of data compiled from interviews with actors involved in university and private sector spin-offs and other industry experts.

We contend that the difference in ability to attract venture capital reflects differences in inherited organisational competence. From our interview data we find that university spin-offs are typically founded, managed and directed by the university professor(s) responsible for the invention/patent that lies at the basis of the new firm formation. Generally these academics have a large amount of know-why and know-how knowledge, supporting narrowly defined R&D competence. However, in general, innovation competence, based on know-who and industry/business knowledge, is less developed. This knowledge is crucial for success in the biotech industry and a lack of it tends to impede performance in the university spin-offs. "The barrier to entry in our industry is not the technology, it is the regulatory environment. And the universities have no […] familiarity or finesse with the Food and Drug Association. […] The academics are there to create innovation, not to exploit innovation" (Interview, venture capital firm). In spite of the often promising patents, many of these university spin-offs are slow to develop and are unable to attract the required finance. According to the industry participants we have interviewed, many university spin-offs do not develop beyond the initial start-up stage and end up being wound-up or continue in a dormant form.

> The classic case is for a scientist or a post-grad to set up a campus company and then the problem for [the industrial development agency] is to get those companies off the campus and into some sort of a situation where they are taking rational decisions. Because very often these become life-style companies which are a kind of a hobby for a university professor. So, most funding agencies and certainly VCs would not fund these technical people [Interview, former director industrial promotion agency].

Firm A, although certainly not a failed university spin-off, neatly illustrates a number of these issues. The company was established in the mid-1990s by two university professors and three of their Ph.D students to exploit the research output of the Department of Genetics. These five academics formed the core management team. One of the Ph.D students discontinued his studies to act as CEO, with responsibility for international marketing and business development. The two university professors retained their university position, and their day-to-day involvement in the company was quite limited after the initial establishment of the company. The management team inherited absolutely no commercial competence. This proved to be a handicap.

> The principal barrier to our success has not been the technology, it has been the market. It has been the deployment of the technology within the market. […] The key to doing that is trying to understand the market better, how the market operates. […] I guess we had to learn a lot about the market. So this was a steep learning curve, in terms of trying to understand how this technology could add value in a market place, and that required what were essentially scientists to key into a more fundamental understanding of the environment of trade. […] No one really knew how to handle this market. […] The market understanding has come retrospectively. [...] In the earlier days we didn't have that [business knowledge] and arguably, had we had that, we could have gone faster. [Interview, Firm A]

At the time of the interviews the company was over ten years in business, still in the development phase, and "not hugely profitable". The company had recognized the lack of innovation competence as an issue and had begun to bring people with a business background into the company. The company also established a business advisory board that included industry experts in various sectors and from different geographies to provide market innovation related advice. And "even in the last three or four months we have had to get new frame shifts. We are looking at […] what I call market innovation, as opposed to technological innovation" (Interview, Firm A).

Firm B, although arguable the most successful university spin-off company in the Irish biotech industry, is of interest because it illustrates how university spin-offs can overcome the lack of inherited industry/business knowledge and inherited competence. This drug development company was founded in 2004 as a university spin-off. However, the actual entrepreneurial drive and business acumen came from the private sector. In 2003, an Australian biotech serial entrepreneur contacted an Irish industrial promotion agency with the idea of commercialising unexploited innovative projects or intellectual property in Ireland. He was introduced to three professors at an Irish university which possessed complementary intellectual property. It was decided to establish a company focusing on developing new drug candidates exploiting the existing intellectual property, with the Australian entrepreneur acting as CEO. It was this entrepreneur that pulled all the business and clinical plans together and secured the initial funding in 2004. Other than being on the board of directors and providing advice, the three founding professors had no line-management role in the company.

The interview data compiled for this study identifies private sector spin-offs, notably the Elan spin-offs, as having inherited strong technical R&D competence, as well as a rich know-who and industry/business knowledge, which has formed the basis of their innovation competence. In fact, in some cases the technical R&D competence appears of secondary importance to innovation competence. This is because a substantial number of these spin-offs operate as "hollow companies" from an R&D perspective. They have a limited internal R&D infrastructure and focus on commercializing R&D, rather than on performing R&D.

> Can I tell you about Ireland's dirty little secret? We have some very successful companies. While they are Irish companies, the vast majority of their employees are in the US - sales forces. They buy-in innovation and they resell it. […] Many companies are virtual. […] They use the different biotechnology companies and service providers and their job is 'Legoland', putting pieces of Lego together … creating value (Interview, venture capital firm).

A good example of both the importance of inherited innovation competence for private sector spin-offs and the workings of a hollow business model is *Firm C*, founded in 2003 by a group of former Elan executives. The CEO held a number of senior management positions with Elan, including VP of R&D, where he successfully directed the development and regulatory approval of a number of projects. *Firm C*, employing four staff in 2010, operates a hundred per cent outsourcing model. The company adapts molecular entities for the treatment of gastrointestinal conditions. It acquires promising patents from external sources and brings these through clinical trials. In this the company benefits strongly from the innovation competence inherited from Elan and embodied in the CEO. The narrower R&D competence is less relevant to the company since all R&D, analytical services and clinical trial activity is outsourced. "They are not fermenting, cloning, purifying, developing cell cultures. They take entities from the clinic and put them through clinical trials and bring them to the market. [They] are not involved in research. They are much cleverer than that" (Interview, Irish Bio-industries Association)

Another example of inherited innovation competence combined with a hollow business model which emerges from our interviews is *Firm D*, a specialty bio-pharmaceutical firm. The company was established in 2005 by three former Elan executives. The company inherited a large amount of innovation competence. The CEO had a 20-year tenure at Elan and had most recently been responsible for managing Elan's group-wide business and corporate development activities. The other two founders had acted as Vice President of Finance and Vice President of Strategic Planning at Elan. The management team was specifically assembled to support the commercial strategy of the company which is to identify, evaluate, selectively acquire and enhance the value of late stage development and FDA approved pharmaceutical products. The company only buys in products that are already approved by the regulatory authorities and conducts no R&D. Apart from the core management team, most of the employees are involved in sales functions.

Private sector spin-off, *Firm E,* portrays a similar importance of innovation competence, while R&D competence is less relevant. This firm was established in 2004 in the wake of Elan's divestment of its Biotechnology Research unit at Trinity College. A small group of biotech entrepreneurs acquired oral drug delivery patents developed at Elan Biotechnology Research. The chief executive had a background in toxicology but was working as vice president at an Irish venture capital company. The Chief Operations Officer had a 20-year commercial background in business development and marketing at multinational pharmaceutical companies. Elan's Head of Product, Technology and Business Development joined the board of Directors. Apart from acquiring the IP, the company inherited no R&D competence from Elan and internal R&D competence appears less central to the firm's performance. The management team swiftly built up a team of 25 employees to further develop and exploit the acquired IP. The company operates a semi-outsourcing model, retaining some in-house R&D capability but outsourcing important elements of the development activities. For example in the context of the *in-vivo* pre-clinical studies, the actual administration of the drugs into the animals was conducted by a contractor in the US. In addition, the company contracted out a range of routine analytical services. Although the company is no longer involved in early stage research, it is important for the company to have access to knowledge and new developments in methodologies and techniques. However, for this, the company uses consultancy services of a professor at one of the local universities.

7. Discussion and conclusions

In this paper we applied Klepper's (1997, 2001, 2008) ideas in relation to firm-origin, inherited competence and spin-off performance to a science based industry, the biotech industry in Ireland. In the process we extended his theoretical framework by relating the concept of inherited competence to two different types of spin-offs - university and private sector spin-offs - and two different types of inherited competence – R&D competence and innovation competence. The extended framework proved fruitful in explaining the evolution of the Irish biotech industry and the diverging levels of performance of different types of spin-off firms.

We assessed spin-off performance using two measures: survival rates and ability to attract venture capital. While university and private sector spin-offs display similar levels of performance in terms survivability, their performance in terms of the attraction of venture capital funding differs markedly. University spin-offs have a higher probability of incidence of venture capital funding. However, of those firms which attract venture capital funding, it is private sector spin-off firms that receive greater quantities of venture capital. In this respect, private sector spin-offs considerably outperform university spin-offs. In further support of Klepper, we see that in the Irish biotech industry a high competence parent (Elan) has borne high competence spin-offs, as indicated by the flow of venture capital in the industry.

We further explored the link between firm origin and performance by including business model into the analysis. This showed that, although university spin-offs operating as dedicated research firms enjoy a significantly higher probability of the incidence of venture capital, when the actual size of venture capital inflows are taken into account the private sector spin-offs adopting a manufacturing or integrated business model are performing significantly better.

With the qualitative analysis of interview data we linked spin-off performance and firm-origin in the biotech industry more directly to the different types of inherited competence – R&D competence and innovation competence. This analysis suggests that private sector spin-offs and university sector spin-offs in the Irish biotech industry have inherited different levels of innovation competence. The high level of innovation competence of the private sector spin-offs plays an important role in their relative performance levels.

These finding have a number of implication for industrial policy in the context of science-based industry. Recent policy in Ireland and elsewhere has been characterised by a strong focus on stimulating university spin-offs. The formative role of private sector spin-offs in industry evolution suggests that policymakers should at least pay as much attention to stimulating private sector spin-offs as to university spin-offs, and should be mindful of the proportion of industrial promotion agencies' resources that are directed to each of these cohorts. Government agencies should leverage the role of private sector spin-off processes and specifically, within that, the role of high competence parents such as Elan.

Of course, that is not to say that investment in the science base and the promotion of university spin-offs is counterproductive. The literature provides examples where university spin-offs are playing an important role in industrial development and cluster formation. Rather, we are arguing for a greater focus on the commercial aspects of innovation in the science and industrial development promotion efforts of the state and its development agencies. For example, it seems prudent to include people with strong business and industry knowledge and innovation competence in the management team of university spin-offs at the earliest possible stage. This may need to be at a more hands-on level within the university spin-off than the current practice of including a person with business expertise on the board of directors. We concur with Rasmussen et al. (2011) that a greater focus should be placed on identifying which actors can provide university spin-offs with specific competencies, such as articulation of business concepts, development and acquisition of resources to build the new venture, and the leadership role to sustain the venture, as well as understanding how these competencies can be developed over time.

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Appendix

[Table A1 here]

Table 1: Irish biotech sector firm and employment distribution

	Biotech firm breakdown (%)	Biotech employment (%)	Avg. firm size (no. of employees)
Spin-offs:			
University spin-offs	*34%*	*10%*	*9*
Private spin-offs	*28%*	*46%*	*42*
Private Sector start-ups	38%	44%	43

Source: Authors' calculations based on *FAME* database and information from industry experts.

Table 2: Survival Analysis of Irish Biotech Firms, 1994-2012

Dependent variable: timing of exit	*Hazard Ratio*
University spin-off	3.410*
	(2.381)
Private spin-off	3.562*
	(2.468)
D_post-2000	0.297**
	(0.152)
No. of subjects	106
No. of failures	19
Log-likelihood	-66.06

Note: Standard errors are given in parentheses; *, **, *** denote significance at 0.10, 0.05, and 0.01 levels, respectively. The reference variable is other private start-up firms.

Table 3: Regression analysis of Irish biotech industry venture capital inflows

	Dependent variable: venture capital inflow (probit)		Dependent variable: venture capital inflow, logged (OLS)	
	(1)	(2)	(3)	(4)
Constant	-1.147***	-0.912***	6.235***	6.714***
	(0.276)	(0.228)	(0.593)	(0.464)
cohort_2000	0.744**	0.817***	1.135**	0.812
	(0.269)	(0.277)	(0.483)	(0.505)
University Spin-off	0.949***		0.657	
	(0.326)		(0.605)	
Private Spin-off	0.210		1.716**	
	(0.347)		(0.688)	
USO_DBF		0.789**		0.565
		(0.338)		(0.500)
PSO_Integ		0.498		1.287*
		(0.438)		(0.702)
PSO_Manu		0.504		2.533**
		(0.588)		(0.883)
PSO_Services		-1.043**		
		(0.527)		
Pseudo R^2	0.15	0.18		
Log-likelihood	-59.88	-57.34		
LR chi^2	20.74***	25.83***		
Adjusted R^2			0.21	0.24
F statistic			4.40**	3.48**
Observations	106	106	40	40

Note: Standard errors are given in parentheses; *, **, *** denote significance at 0.10, 0.05, and 0.01 levels, respectively.

Table 4: Firm type, broken down by business model

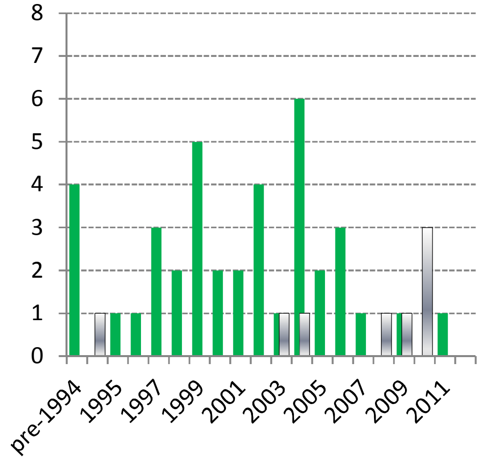
	DBF	**Integrated**	**Manufacturing**	**Services**	*Total*
University spin-off	24 (62%)	0 (0%)	1 (3%)	14 (36%)	*39 (100%)*
Private spin-off	2 (6%)	11 (34%)	6 (19%)	13 (41%)	*32 (100%)*
Private start-up	5 (14%)	9 (26%)	8 (23%)	13 (37%)	*35 (100%)*
Total	*31*	*20*	*15*	*40*	*106*

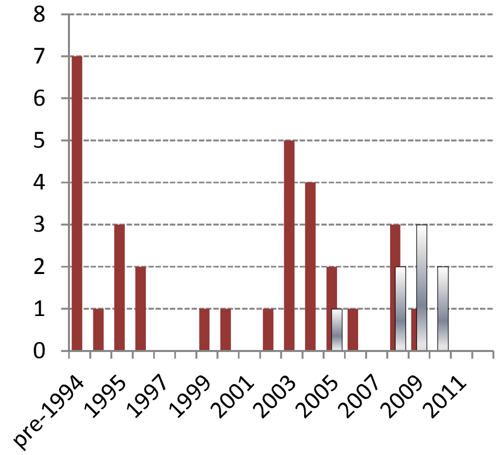
Pearson chi^2 = 38.3421 P-value (probability of independence) = 0.000

Table A1: Venture capital inflow by business model

	Firms	Venture Capital (€ mill)	%
University spin-offs	**39**	**111.64**	**31.93%**
DBF	*24*	*88.23*	*25.23%*
Integrated	*0*	*0*	*0.00%*
Manufacturer	*1*	*0.80*	*0.23%*
Services	*14*	*22.61*	*6.47%*
Private spin-offs (excluding Elan spinoffs)	**21**	**19.87**	**5.68%**
DBF	*1*	*0.00*	*0.00%*
Integrated	*9*	*14.25*	*4.08%*
Manufacturer	*4*	*5.29*	*1.51%*
Services	*7*	*0.32*	*0.09%*
Private spin-offs (Elan spinoffs)	**11**	**209.74**	**59.99%**
DBF	*1*	*8.58*	*2.45%*
Integrated	*2*	*95.09*	*27.20%*
Manufacturer	*2*	*106.07*	*30.34%*
Services	*6*	*0.00*	*0.00%*
Private start-ups	**35**	**8.38**	**2.40%**
DBF	*5*	*4.17*	*1.19%*
Integrated	*9*	*0.75*	*0.21%*
Manufacturer	*8*	*3.46*	*0.99%*
Services	*13*	*0.00*	*0.00%*
Total	**106**	**349.63**	**100.00%**

Figure 1: Entry and exit of university spin-offs (left) and private sector spin-offs (right) 1994-2012





Note: Exits denoted by light shaded bars; entrants denoted by dark shaded bars.