Growing fast or slow?

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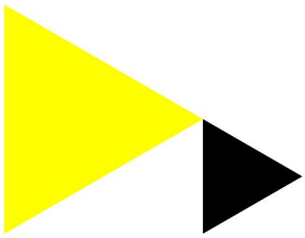

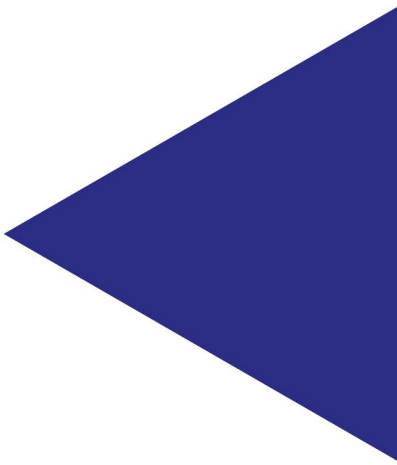

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Growing fast or slow?: Understanding the variety of paths and the speed of early growth of entrepreneurial science-based firms

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ABSTRACT

The paper explores the process of early growth of entrepreneurial science-based firms. Drawing on case studies of British and Dutch biopharmaceutical R&D firms, we conceptualize the speed of early growth of science-based firms as the time it takes for the assembly (or combined development) of three types of critical resources—a functionally-diverse management team, early fundraising and development of technology. The development of these resources is an unfolding and interrelated process, the causal direction of which is highly ambiguous. We show the variety of paths used by science-based firms to access and develop these critical resources. The picture that emerges is that the various combinations of what we call "assisted" and "unassisted" paths combine to influence the speed of firm growth. We show how a wide range of manifestations of technology development act as signaling devices to attract funding and management, affecting the speed of firm development. We also show how the variety of paths and the speed of development are influenced by the national institutional setting.

1. Introduction

The growth of science-based firms is a key factor in discussions on how economies commercialize and benefit from the economic impact of science and innovation (Casper, 2007) and on the technology transfer process (DiGregorio and Shane, 2003). In particular, the speed of growth of such firms is important given the amount and duration of funding required and the technological complexity and uncertainty faced by these firms. Moreover, the window of opportunity for such firms to exploit scientific and technological discoveries is constantly shrinking due to knowledge spillovers to competitors and competition from other scientific discoveries.

This paper explores the speed of early growth of entrepreneurial science-based firms. Recent studies have investigated how high-tech firms grow, adopting a variety of perspectives. For example, studies have explored the sequence of archetypes in venture evolution from an organizational theory perspective (Ambos and Birkinshaw, 2010), the links between the competitive environment and resource management in different modes of growth from a resource-based view (Clarysse et al., 2011), and the simultaneous experimentation and variety in business models from an organizational learning perspective (Andries et al., 2013). While these contributions have provided important insights into how these firms grow, why different growth patterns exist, the importance of resource configurations, and the effect of the (competitive) environment on growth, they do not address directly the speed of growth.

The speed of growth of new science-based firms is an interesting empirical phenomenon in its own right, but particularly because established theories of innovation management offer limited guidance. Thus, its study offers an opportunity for theory development. Both economics and management of innovation literatures have examined speed in connection to innovation. Economics of innovation scholars have explored economic growth as a process of transformation driven by innovation, focusing on innovation patterns, technological spillovers and divergence across firms and countries (Nelson and Winter, 1982; Dosi et al., 1988). The concern with speed in this literature regards the rate at which innovation is diffused throughout firms, sectors, regions and countries (Mansfield, 1961; Perez, 1983; von Tunzelmann, 1995).

For the management of innovation literature, instead, speed refers to the rate at which discoveries are converted into rent-producing assets, as rapid exploitation of such opportunities can give rise to first-mover advantages or other temporary rents. Contributions explore the importance of decision-making speed (Eisenhardt, 1989; Forbes, 2005); the time period between the founder's leaving of academia and the establishment of his/her firm

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(Muller, 2010); the timing of start-up activities for different types of founders (Alsos and Kolvereid, 1998); the commercialization time of patent-protected technologies by university technology transfer offices (Markman et al., 2005); and the time-to-market of innovative products by firms of different characteristics, especially those with venture capital (Hellman and Puri, 2000; Sternitzke, 2010).

While these strands are useful in shaping our work, we still know relatively little about two questions: How does fast growth of science-based firms occur? How is speed of early growth shaped by the institutional setting? Addressing these questions calls for fine-grained insights into the process of development of new science-based firms, through a comparative multiple-case study. We conducted 60 interviews with founders and executive managers in 18 British and 17 Dutch biopharmaceutical R&D firms. These firms provide either R&D-intensive services, for instance, platform technologies such as genetic sequencing, or they conduct R&D with the goal of developing future products such as new therapeutic drugs or diagnostic kits. We also draw on interviews with 14 supporting organizations, press releases and articles in trade journals. From this rich data emerged an understanding of the nature of the paths and speed of early growth of science-based firms.

We derive four key findings. First, we conceptualize the speed of early growth of science-based firms as the time it takes for the assembly (or combined development) of the three types of critical resources—a functionally-diverse management team, early fundraising and development of technology. The development of managerial competence, early finance and technology is an unfolding and interrelated process, the causal direction of which is highly ambiguous. For some firms, having access to managerial competence facilitates external fundraising, and, in contrast, for other firms, raising external financing facilitates the recruitment of managerial competence. Second, we show the variety of paths used by science-based firms to access and develop critical resources. The picture that emerges is that the various combinations of what we call "assisted" and "unassisted" paths lead to different speeds of development. Third, we show that the variety of paths (and speed) of early growth of science-based firms is influenced by the national institutional setting. We find a marked difference in the role of intermediaries, especially the support of venture capital and technology transfer offices in enabling these paths. In environments where these are available and strong, the period of time it takes for founders to develop a functionally-diverse management team and raise funds is shorter. Fourth, we show the importance of a wide range of manifestations of technological development that act as signaling devices and intervene in the early firm growth process, having both positive and/or negative mediating effects in attracting both funding and management.

We provide next the theoretical framework. After that we describe the research design and data analysis. We then present the findings. A discussion and conclusion follow.

2. Theoretical framework: Approaches to exploring the early growth of science-based firms

First, we explore the peculiarities of science-based firms, which make it necessary to single them out for a study of their early growth. Second, we draw on the work of Penrose (1959) and resource-based perspective to position our approach. Third, we explore how the (national) institutional setting affects the access and development of firm resources.

2.1. The phenomenon: Why entrepreneurial science-based firms?

Entrepreneurial science-based firms in general (and biopharmaceutical R&D firms in particular) have peculiarities that may set them apart from (other) high-tech firms in their early growth. First, entrepreneurial science-based firms typically emerge as research spin-offs from academic departments or industrial firms (Mustar et al., 2006; Knockaert et al., 2011; Rasmussen et al., 2011), and they tend to be located near universities, with which they collaborate intensively. In the case of academic spin-offs, the academic/scientific inventors (often the founders) are essential to the continuing success of the firm not only because of their own scientific expertise but also because of access to their networks of academic scientists which facilitate flows of complex technical knowledge, enabling firms to meet their technological milestones (Kenney, 1986; Liebeskind et al., 1996; Murray, 2004; Owen-Smith and Powell, 1998; Zucker et al., 1998).

A second peculiarity is that the R&D process in entrepreneurial science-based firms is different from that of (other) high-tech firms. While high-tech firms use science to develop innovation, science-based firms are engaged in the advancement of science itself (Autio, 1997). They not only face market, but also scientific or technological uncertainty, as their main assets are R&D projects in emergent technologies. For science-based firms, R&D is about successively reducing uncertainty through the acquisition of information (selecting and screening), a highly iterative and inductive process (Pisano, 2006). In (most) high-tech ventures, after conception and development, there is a move to the commercialization stage where the focus is on learning how to make a product work well and how to produce it beyond the first stage prototype (Kazanjian, 1988). Science-based firms, in contrast, do not typically develop a prototype during the early growth stage.

Third, science-based firms have very high capital requirements for long term R&D. They often lack complementary capabilities in clinical testing, regulatory processes, manufacturing and distribution or marketing. They need to raise large amounts of external finance from private investors, institutional investors or public offerings of equity for products that take many years (typically 10–15 years in the biopharmaceutical industry) to reach the market (if at all) and in many cases cannot rely on a progressive revenue stream. They often rely on venture capital for fundraising.

Venture capital is not only a funding source but also a governance structure, which involves knowledgeable investors capable of providing complementary assets to generate value. Venture capital has implications for control and may constrain the activities of science-based firms. It requires developed exit markets (and therefore a suitable institutional setting). Venture capital is a governance arrangement developed (and arguably more suitable) for other high-tech firms, because it has a rather short exit horizon (3–5 years) compared to the long product development time required by science-based firms (Pisano, 2006). An alternative to venture capital financing for new science-based firms is to enter into strategic alliances with, or acquisitions by, established firms. This alternative may offer the funding or capabilities in clinical testing, regulatory processes, manufacturing, distribution or marketing that they lack (Powell et al., 1996). Early growth of science-based firms may therefore be influenced by the extent to which they are positioned not only in the "market for products", but also in the "market for (technology) assets" as an input into the development of products by other, more mature corporations (and including as a possible target for acquisition by these) (Colombo et al., 2010; Miozzo et al., 2016).

There is great diversity among science-based firms themselves. Nevertheless, the above suggests that science-based firms face particular organizational and technological challenges that merit an examination of their early growth.

2.2. Penrosean-inspired approach towards the early growth of science-based firms

Many studies of firm growth adopt a resource-based perspective, following Penrose's (1959) seminal contribution. We build on four analytical insights from Penrose's work and contributions inspired in her work for our analysis of growth of new science-based firms.

The first insight is regarding the organizational limits to firm growth. In Penrose's work, firms consist of human and non-human resources, under administrative coordination and integration. Human, and especially managerial, resources are the most important, but a firm's uniqueness derives from the distinction between its resources and the services that those resources can provide. Even though individuals may hold critical resources, the firm's organizational choices determine whether and how individual resources are translated into organizational competence, which eventually lead to a firm's superior economic position (Best and Garnsey, 1999; Kor and Mahoney, 2004; Lockett, 2005; Nelson and Winter, 1982).

In this framework, different services are required for different activities or stages of firm growth. For example, the type of entrepreneurial/managerial services needed to raise funds are different from the type of services needed to run a firm efficiently. The raising of capital depends on the entrepreneur's (or founding team's) ability to create confidence, and, as firms grow, there is more emphasis on the "administrative integration" of the productive resources under the firm's control (Lazonick, 2002).

Unused productive services provide excess capacity, and this excess capacity creates an internal mechanism for growth of the firm, but there are managerial limits to firm expansion (Penrose, 1959). In new firms, the founders are the main providers of managerial services, which reside in their tacit knowledge and personal investment in the firm's ongoing viability. Bringing outside managers (other than venture capital investors) to supplement the original entrepreneurial team may constitute a distraction if they bring only general business expertise and lack firm-specific tacit knowledge (Kroll et al., 2007). Existing managers must train new managers, the development and integration of whom require the services of incumbent managers (Pettus, 2001). In other words, managerial resources with experience within the firm are necessary for the efficient absorption of managers from outside. Nevertheless, because the small number of incumbent managers has limited availability, there is a constraint in the amount of expansion that can be planned and undertaken in any period of time.

A second insight is the effect of uncertainty on the development of the firm's resources for growth. A number of contributions have explored the resources relevant for the growth of entrepreneurial high-tech firms—technological resources (specific products and processes) (Clarysse et al., 2011; Mustar et al., 2006), human resources (knowledge, skills and entrepreneurial experience of the founder and/or founding team) (Mosakowski, 1998), social resources (industry and financial ties and contacts) (Khaire, 2010) and financial resources (amount and type of finance) (Lee et al., 2001). In the context of science-based firms, where there is strong uncertainty, "observable" resources can act as signals of quality for investors. Patents (granted and applied) and research alliances are argued to attract more prominent venture capital funds or initial public offering (IPO) and higher funding (Audretsch et al., 2012; Conti et al., 2013; Haussler et al., 2014). This "signaling" effect however may diminish in sequential rounds of funding (Hoenen et al., 2014; Hsu and Ziedonis, 2013).

The uncertainty connected to science-based firms does not only arise from the technology, but also from the abilities of the management team. Founders' experience in founding prior ventures and social network also act as signals, increasing the likelihood of attracting venture capital (Burton et al., 2002; Clarysse and Moray, 2004; Hsu, 2007). Functionally-diverse teams with management experience and diverse prior affiliations have positive effects on obtaining venture capital and going public (Beckman et al., 2007; Certo, 2003).

A third insight is that different resources support different production bases. Penrosean-inspired analyses argue that although there can be a range of objective "productive opportunities" open to the firm, their recognition is subjective (Druilhe and Garnsey, 2004) and depends on access to special knowledge. Moreover, risk and uncertainty play a very important role, as they make the managerial task more difficult, requiring more skills or a greater variety of managerial services for expansion (Penrose, 1959).

A key point is that as firms grow, they accumulate different resources, including staff and material resources, and that the heterogeneity of those resources means that they can be used in different ways. These resources can support different "production bases" (each type of productive activity that uses machines, processes, skills and raw materials that are complementary and closely related) (Penrose, 1959, p. 109), associated with different technological characteristics. A move into a new base requires the firm to build competence in a different area of technology (Penrose, 1959). The type of "productive opportunities" chosen influences the resource requirements, including the need for new partnerships or collaborations to enter into new technology fields (Druilhe and Garnsey, 2004; Garnsey and Leong, 2008).

Fourth, growth follows a non-linear, iterative process. The movement from emergence to early growth is characterized by the development of new resource configurations. Garnsey (1998) shows that the early growth phase of new firms is dominated by search activities, the initial problems centering on the perception of opportunities and resourcing prospects. In this phase, the relations between founders and other organizations, such as former associates and funders, are key. Access to finance is crucial at this early stage, and convincing funders of the prospects for their venture is critical to identifying openings beyond the entrepreneurs' immediate means. Garnsey (1998) argues that success in doing so reflects institutional arrangements for investing in new ventures.

Similarly, Hite and Hesterley (2001) explore the movement of firms from emergence to early growth and argue that, as they transition, firms face problems of resource acquisition, including availability, accessibility and uncertainty. They define early growth as "the point in the firm life cycle at which a firm makes clear strategic decisions to intentionally grow beyond mere survival, viability, or sufficiency" (p. 277). They argue that, in the transition to early growth, firms need to access and develop a greater scope of resources. Also, Sirmon et al. (2011) show that resource orchestration differs in each stage of the firm life cycle. In the emergence stage, which is characterized by experimentation in accessing resources, managers make a substantial contribution to the venture. In early growth, overcoming early deficiencies becomes the main concern, requiring the development of relations to distinctive stakeholders such as financers to foster growth.

To sum up, a "Penrosean"-inspired approach to examining the early growth process of firms concludes that: (1) there are organizational limits to firm growth; (2) uncertainty affects early firm growth; (3) different types of resources support different production bases, associated with different technologies; and (4) the transition from emergence to growth requires a different configuration of resources. Nevertheless, theoretical and empirical work on how fast growth of science-based firms occurs is still lacking.

2.3. Influence of the institutional setting

Most of the contributions reviewed above are based on an examination of US firms, many of which are located in California's Silicon Valley. In this region, managerial labor, and the knowledge intrinsic

in that labor, is highly mobile, contributing to increased knowledge diffusion (Saxenian, 1994; Almeida and Kogut, 1999). Venture capital is also particularly abundant compared to other regions, having emerged out of the region's base of high-tech enterprises. Venture capitalists are unusually knowledgeable and involved with new ventures, e.g. giving advise on business plans, finding co-investors, recruiting managers and serving on boards of directors. The institutional setting of these start-ups is unique and highly conducive to the emergence and growth of science-based firms. We expect that other institutional settings will affect differently the strategic choices of founders in the early growth of such firms.

Literature on comparative capitalisms (Hall and Soskice, 2001; Hollingsworth and Boyer, 1999; Whitley, 1999) explores the effects of the institutional setting on the production strategies of firms and the likelihood of success in different product markets (Casper and Whitley, 2004; Soskice, 1999). This literature focuses on the effect of national institutions – the industrial relations system, the education and training system, the financial system, and the relations between organizations – which are viewed as mutually complementary (Amable, 2000; Crouch et al., 2005). These institutions, created by the state and social processes, shape the strategic actions of firms and the national product and technology specializations. This approach is however at risk of presenting an oversimplified analysis. In particular, it downplays the possible varieties of firms' strategies in the same institutional setting (Allen, 2006). Also, it does not explain why some firms may be able to draw on "functional equivalents" and use institutions in new ways to develop different capabilities, and therefore follow different paths from typical firms in the country (Herrmann, 2008; Lange, 2009). Overall, there is a need for a more fine-grained analysis at the firm level.

There is indeed plenty of evidence that a greater range of strategies are open to firms (and science-based firms in particular) within different comparative capitalisms than posited by a strict reading of the comparative capitalisms literature. Studies on biopharmaceutical firms in France, Finland and the UK (Mangematin et al., 2003; Luukkonen, 2005; Hopkins et al., 2013) reveal the wide spectrum of strategies of biopharmaceutical firms within each of these countries. Moreover, Herrmann (2008) and Lange (2009) showed that German biopharmaceutical firms increasingly follow radical innovation strategies by using "functional equivalents" such as open international labor markets or atypical contracts to compensate for the lack of incentives generated by national institutions of finance and industrial relations. It is nevertheless questionable whether these "functional equivalents" can provide a sufficient supply of resources for the majority of German biopharmaceutical firms (Casper, 2009).

While the comparative capitalisms literature stresses the importance of the institutional setting on firms' production strategies, it does not explore how the institutional setting influences the speed of growth of early science-based firms or how and why firms follow different paths. Our study addresses this gap in the literature.

3. Research design and data analysis

We designed an exploratory comparative multiple-case study of biopharmaceutical R&D firms in the UK and the Netherlands. The focus on the biotechnology segment of the pharmaceutical industry is representative of entrepreneurial science-based firms because these firms require extensive financial resources for an extended period of time to develop new products in emergent scientific and technological areas with high levels of uncertainty.

As we aim to understand how the early growth of entrepreneurial science-based firms unfolds and how the institutional setting affects early growth, a case study is an appropriate method for identifying the particular mechanisms of early firm growth and evolution, including expansions and interruptions in dynamic processes (van de Ven and Poole, 2005; Langley, 1999; Chiles et al., 2007). A comparative case study method is appropriate for capturing data that illuminate these processes in different organizational and institutional contexts, when multiple levels of analysis are involved and the boundaries between units of analysis are ambiguous (Pettigrew, 1992; Yin, 1994). We attempt to capture the sequences of events in time and context, paying attention to their temporal ordering, interactions and institutional environment (Langley, 1999; Chiles et al., 2007). Thus, we aim to explore what Tsoukas and Chia (2002) call "organizational becoming", that is, to explore organization as an outcome, a pattern that is constituted, shaped and emerging from change.

Biopharmaceutical R&D firms in the UK and the Netherlands are exemplary cases because the two countries have different institutional settings, yet comparable investment and scientific output in life sciences. In the UK, the financial system is generally characterized as having a high level of stock market capitalization and the labor system as having a low level of employment protection. In contrast, in the Netherlands, the labor system generally has higher employment protection, with longer-term career patterns, and the financial system has relatively lower stock market capitalization (Gospel et al., 2014). Theoretically, in the British context we would expect biopharmaceutical firms to be better able to access and mobilize risk capital to fund the firm and mobile human resources to form the management team than in the Netherlands. Both countries show a relatively high technological advantage in biotechnology as defined by their patent applications. Also, Heimeriks and Boschma (2014) identify Wageningen in the Netherlands and London in the UK as the second and third most important cities in biotechnology knowledge production in terms of total number of publications during the period 1986-2008, respectively, after Cambridge, USA. This suggests firms in both countries should be able to develop the necessary technological resources (OECD, 2009)[1].

We collected data at various points in time between 2006 and 2014. To select firms, we used a minimum firm age of two years and a minimum number of five employees (at the time of first interviews in 2006). These criteria were used in order to ensure that the new firms had achieved a level of operations that required resource mobilization. We also selected firms according to their location, so that one region did not become overrepresented in the study, and aimed for a variety in origin, business models and ownership. To aid the comparison between firms, we sought to balance the sample using the same criteria in the UK and the Netherlands. Unlike the UK, most Dutch biopharmaceutical firms are privately-owned and, as a result, three public Dutch firms were purposefully included in the study, these firms being older and larger than the selected UK firms.

The selection process of firms was iterative and not random. As certain firms were added to the selection, an effort was made to include a comparable firm from the other country. The final selection consisted of 18 British and 17 Dutch firms (see Table 1 for an overview of the selected cases). The selected firms are clearly not representative of the respective biopharmaceutical industries for statistical generalization. The method of selection is based on

[1] The UK is ranked as the second highest country developing biotherapies in Europe per million population (after Switzerland) and the Netherlands is the fourth (after Austria) (OECD, 2009). The UK has 4.23% and the Netherlands 0.94% respectively of total venture capital investments in the life sciences of OECD countries in 2007, with 10.2% of all national venture capital going to life sciences in the UK and 9.6% in the Netherlands respectively (OECD, 2009).

Table 1
Overview of cases.

Code	Origin of firm	Date founded	Model at founding	Summary description of technology	Public or private ownership (in 2006-2007)	Location	Nr. of employees in 2006–2007	Nr. of employees or company status in 2014
UK-GGF	UNIV	1996	Drug development	Anti-fungal drug development	Private	MAN	10–25	10–25
UK-KRA	UNIV	1997	Drug development	Growth factor to protect heart, gene therapy	Public	LON	>100	Dissolved in 2013
UK-NEX	IND	2002	Drug development	Platform for drug interaction in ion channel	Private	CAMB	10–25	50–75
UK-NGP	IND	2001	Equipment	Microarray screening equipment	Private	CAMB	<10	Acquired in 2008
UK-OVE	UNIV	1998	Drug development	Drug development in inflammatory and immune diseases (tick technology)	Public	OXF	<10	Dissolved in 2008
UK-PNI	UNIV	1998	Hybrid	Screening technology and database for protein-based drug development	Private	LON	25–50	Acquired in 2006
UK-RAS	IND	2003	Hybrid	Crystallography and structural-based biology platform for services and drug development	Public	CAMB	25–50	Acquired in 2008
UK-SAV	UNIV	2003	Hybrid	Zebra fish platfrom for toxicity testing and drug development	Public	OXF	50–75	10–25
UK-SPE	UNIV	2001	Hybrid	Platform/assays to measure stem cells	Public	MAN	10–25	50–75
UK-SXD	IND	2000	Diagnostic	Platform to determine the effectiveness of cancer drug therapies	Private	MAN	10–25	>100
UK-TRG	UNIV	1998	Drug development	Drug development for Alzheimers	Public	LOND	<10	<10
UK-XCI	IND	1998	Drug development	Skin and repair generation	Public	MAN	75–100	Acquired in 2008
UK-XHP	IND	2002	Services	Services/methods for drug delivery to the brain	Private	LOND	<10	10–25
UK-XOR	UNIV	2004	Hybrid	Drug development and testing services for Parkinsons	Public	LOND	10–25	Acquired in 2012
UK-XOX	UNIV	1999	Drug development	Platform for developing cancer, hepatisis B and HIV vaccines	Private	OXF	10–25	Acquired in 2007
UK-XSS	UNIV	2001	Drug development	Drug development and testing services fro Alheizmers	Private	MAN	<10	Dissolved in 2014
UK-XTG	UNIV	1997	Services	Genotoxicity assays to detect potential cancer-causing compounds	Private	MAN	>10	10–25
UK-YLP	UNIV	2001	Services	Platform to use polymers in developing new drug products	Private	LOND	<10	75–100
NL-AIK	IND	1997	Hybrid	Drug development for cancer	Private	GRON	10–25	10–25
NL-AREK	IND	1990	Services	Proprietary labelling system for DNA probes	Private	AMS	25–50	10–25
NL-BRN	UNIV	2003	Services	Platform technology on drug delivery to the brain	Private	LEID	<10	10–25
NL-EPP	UNIV	1999	Hybrid	Services and drug development based on protein technology	Private	LELY	10–25	25–50
NL-HTP	IND	2001	Drug development	Development of known molecules for new indications	Private	UTR	<10	<10
NL-KLA	IND	2005	Drug development	Drug development for inflammatory diseases	Private	UTR	<10	<10
NL-KYS	IND	2004	Services	Microarray for gene profiling	Private	AMS	<10	10–25
NL-LAG	IND	1998	Hybrid	Genomics platform for services and drug development	Public	LEID	>100	>100
NL-MPA	IND	2000	Services	Microassay products and services	Private	EIND	25–50	25–50
NL-OIB	IND	2003	Hybrid	Services in biology, cellular biology and pre-clinic	Private	UTR	<10	10–25

Table 1 (*Continued*)

Code	Origin of firm	Date founded	Model at founding	Summary description of technology	Public or private ownership (in 2006-2007)	Location	Nr. of employees in 2006–2007	Nr. of employees or company status in 2014
NL-ORP	IND	2002	Drug development	Drug development for Duchenne muscular dystrophy	Private	LEID	<10	75–100
NL-PMA	UNIV	2002	Drug development	Drug development for infectious and inflammatory diseases	Private	UTR	25–50	10–25
NL-QIP	UNIV	1999	Hybrid	Diagnostic products and drug development using monoclonal antibodies for therapeutic purposes	Private	GRON	25–50	25–50
NL-RIV	UNIV	2002	Drug development	Outlicensing and servicing drug development (prevention, treatment and diagnosis) for a new virus	Private	ROTT	<10	<10
NL-RUC	UNIV	1992	Hybrid	Platform technology to genetically modify the blood system by putting genes into hemopoetic stem cells	Public	LEID	>100	Acquired in 2011
NL-TOC	UNIV	1995	Hybrid	Contract research organization; drug development on proprietary technology	Public	LEID	>100	>100
NL-VAA	UNIV	2000	Services	Technology that provides parallel experimentation at intermediate and high throughput	Private	AMS	75–100	>100

IND = Industry; UNIV = University; MAN = Manchester; CAMB = Cambridge; LOND = London; OXF = Oxford; GRON = Groningen; AMS = Amsterdam; LEID = Leiden; LELY = Lelystad; UTR = Utrecht; EIND = Eindhoven; ROTT = Rotterdam.

the study's theoretical framework and is designed to conduct a comparative analysis of firms within and across national settings.

Data on the selected firms were collected from primary and secondary sources. Prior to the initial semi-structured interviews, information about the firms published in secondary sources (e.g., websites, annual reports, press releases, and trade press) was gathered and analyzed. This was useful in establishing timelines, for instance on financing, or uncovering managerial changes and R&D or product developments that could be verified and further explained during the initial interview. The information from the secondary data was entered into a case study database and used to triangulate the information gathered from interviews.

In 2006 and 2007, we held initial semi-structured interviews with founders and executive managers to understand the early growth of the firms in greater depth. Interviews were conducted in English, at the firms' premises, and the average length of interviews was 90 min. To gather sufficient detail on the founding and financing history, an original founder was interviewed. To reduce retrospection bias, we alternated between open and closed questions, verifying anecdotal accounts with questions that focused on confirming facts and information gathered from secondary sources. In the few cases where it was not possible to interview the founder, we interviewed the longest tenured employee or external parties, such as accountants or investors, who were involved in the founding and had historical knowledge. Through these interviews we captured the details of early firm formation, the events and decisions taken by the entrepreneurs regarding early funding and the changes in management, finance and technology development. From the data gathered, we developed case histories to understand the events and decisions that founders made.

Between 2008 and 2014, we collected additional data and followed the progress of all firms. In 2011, we held additional interviews with the firms that had reached pivotal points in their growth (e.g. merger and acquisition or liquidation) to understand in more depth how changes unfolded after a period of growth. These interviews were held with the same senior managers. When the same managers were unavailable, we posed the same questions asked in the first wave to the respondents in the second wave to check for consistency. During this period, we continued to collect press releases, annual reports and media coverage on fundraising, management recruitment, R&D collaborations, clinical trial progress, mergers and acquisitions, and liquidations. We chronicled events (e.g. fundraising rounds, IPOs, R&D collaborations, managerial recruitment) and augmented the case histories. Overall, we carried out more than 60 interviews with firm representatives, including founders and various executive managers (e.g. CEOs, CSOs, business development directors, and financial directors).

In addition to the firms interviewed for the study, 14 representatives of supporting institutions were interviewed, including trade associations, science parks, university technology transfer offices, venture capital investors and policymakers. These interviews aided in the analysis of the influence of the institutional settings. Interviews with university technology transfer offices and venture capital investors also served to triangulate the data gathered from firms.

To conceptualize the process of early growth of these firms, we required methods for making sense of process data. We considered events and interactions in their local contexts to detect mechanisms leading to (or patterns of) change over time. This is in contrast to predictive variance methods (that explore associations, or how independent variables lead to changes in dependent variables), more apt for simpler phenomena (Chiles et al., 2007; Langley, 1999). Our approach was partly deductive, inspired by theory, and partly inductive, inspired by data. This mixed approach allowed us to develop creative insights from the data, without necessarily rejecting or reinventing previous concepts or categories (Denis et al., 2001). Deductive and inductive approaches were used iteratively

and insights from one case generated constructs that served as a basis for probing the process of change in others (Eisenhardt, 1989; Yin, 1994). In analyzing the collected data, we used narrative and visual mapping strategies (Langley, 1999) to represent the process data in a systematic way, as it allows for the identification of key events and the evolution of parallel dimensions.

Drawing on Penrose (1959) and Garnsey (1998), which point to the search activities in early growth, in particular regarding perception of opportunities and resourcing prospects, we developed two constructs: fundraising development (how firms are able to access and mobilize the amount and type of financial resources they require) and managerial development (how firms build a functionally-diverse management team and the industry and financial contacts they are able to leverage for this). As we iterated between data and emerging logic, we gradually built a clearer characterization of the process by which firms accessed and developed critical resources in the early stages of firm growth. We differentiate between firm emergence (a stage of experimentation in obtaining finance and the initial management team) and early growth (a stage involving the strategic decision to grow beyond survival, seeking to overcome earlier deficiencies through accessing and developing new resources) (Hite and Hesterley, 2001; Sirmon et al., 2011).

From analyzing the field data, we identified the interrelated processes that unfolded during the early growth of science-based firms. Our inductive work went hand-in-hand with our data coding. However, in order to ground the 'intellectual leap' in the data, we considered in turn alternative explanations for differences found in early growth (Rerup and Feldman, 2011). These alternative explanations included the firms' origin from industry or university, their parent affiliation, or their national origin. We constantly compared data and analysis, identifying emergent concepts and comparing them with the relevant literature (Suddaby, 2006). We used cross-case comparative tabular displays to unscramble our empirical findings and to cluster and process our data (Miles and Huberman, 1994). As we iterated further, it became clearer that resource development was strongly affected by the founders' prior ties and relationships in the emergence stage. We analyzed our data further at the firm level to reveal the important effect of the institutional setting on this.

Another observation emerging from the data drew our attention inductively. This was the importance of strong and persistent (scientific) uncertainty surrounding R&D. It was at this point that we started looking at how this influences firm emergence and early growth. We then included a focus on how firms develop their "production bases" (Penrose, 1959), associated with different technological characteristics into the analysis, and how this evolves and interacts with fundraising and managerial development. From this we found that a wide range of manifestations of technological development had a signaling effect on the access to and development of funding and management.

The narrative and visual mapping strategies allowed us to identify key events and to display simultaneous dimensions (fundraising, managerial and technological development) that revealed precedence, parallel processes, interactions and time duration (Langley, 1999). The visual maps present event chronologies for each firm (the horizontal time scale showing the order and duration of events) coded in several ways (see Figs. 1–3 for examples). The location of the box in one of the three horizontal shaded bands shows the resource domain with which the event is associated. The arrows leading from each box indicate the influence that one event or decision has on another. The thickness indicates the impact of that influence, a thin line having low-medium impact, and a thick line having medium-high impact. The shape of the boxes indicates whether the event is a decision (rounded corners), an activity (square corners) or an event involving external actors (oval). Links with the qualitative database are maintained though short descriptions of each element in its corresponding box.

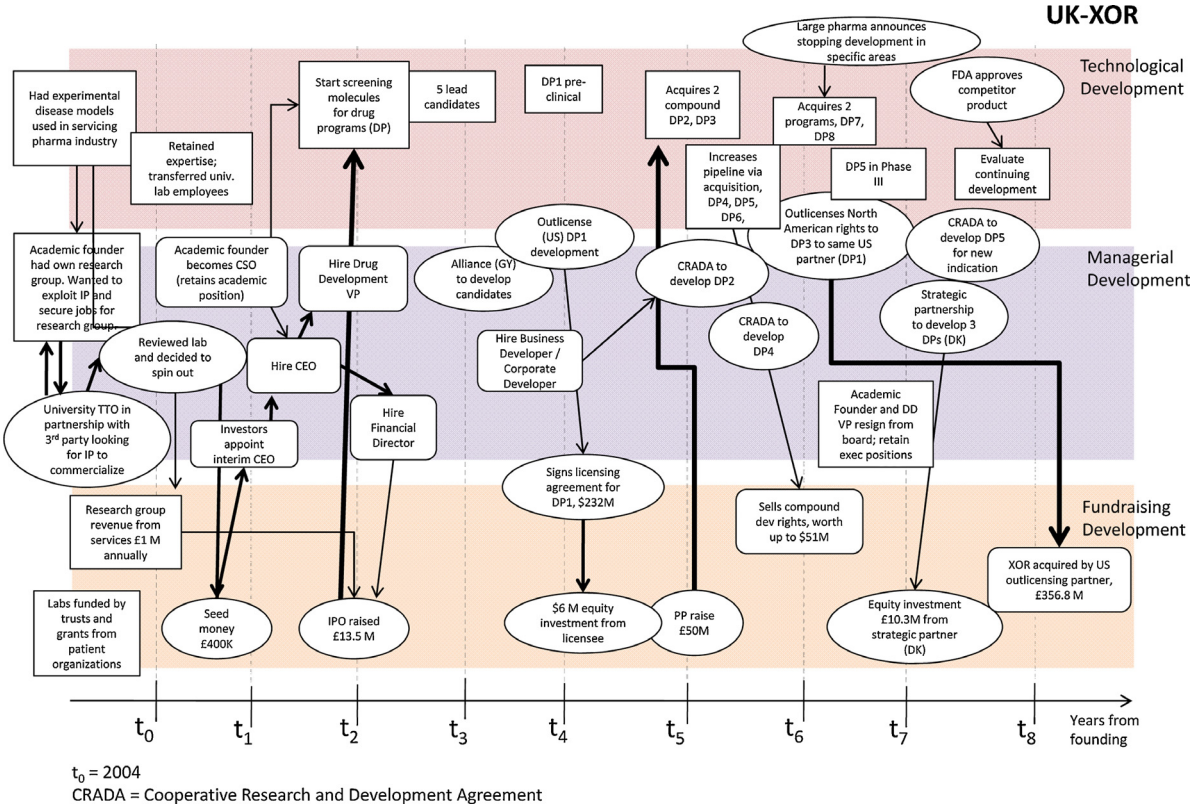

Fig. 1. Visual map of UK-XOR.

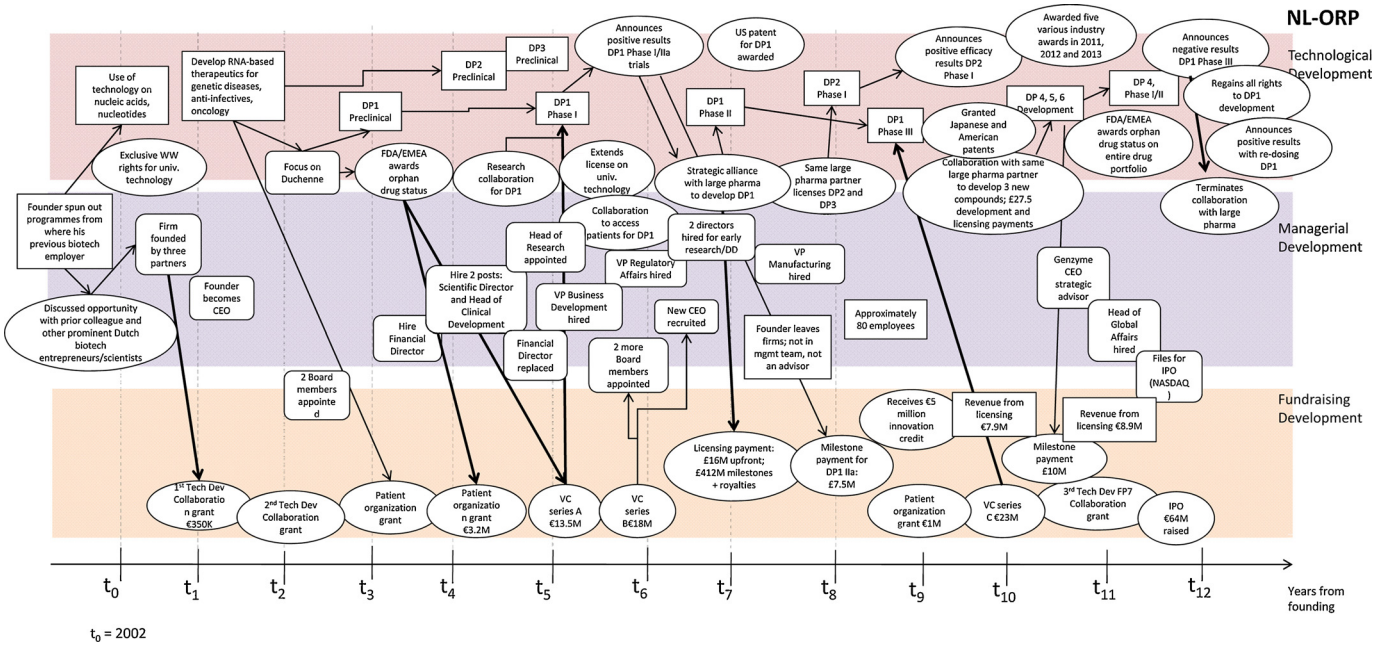

Fig. 2. Visual map of NL-ORP.

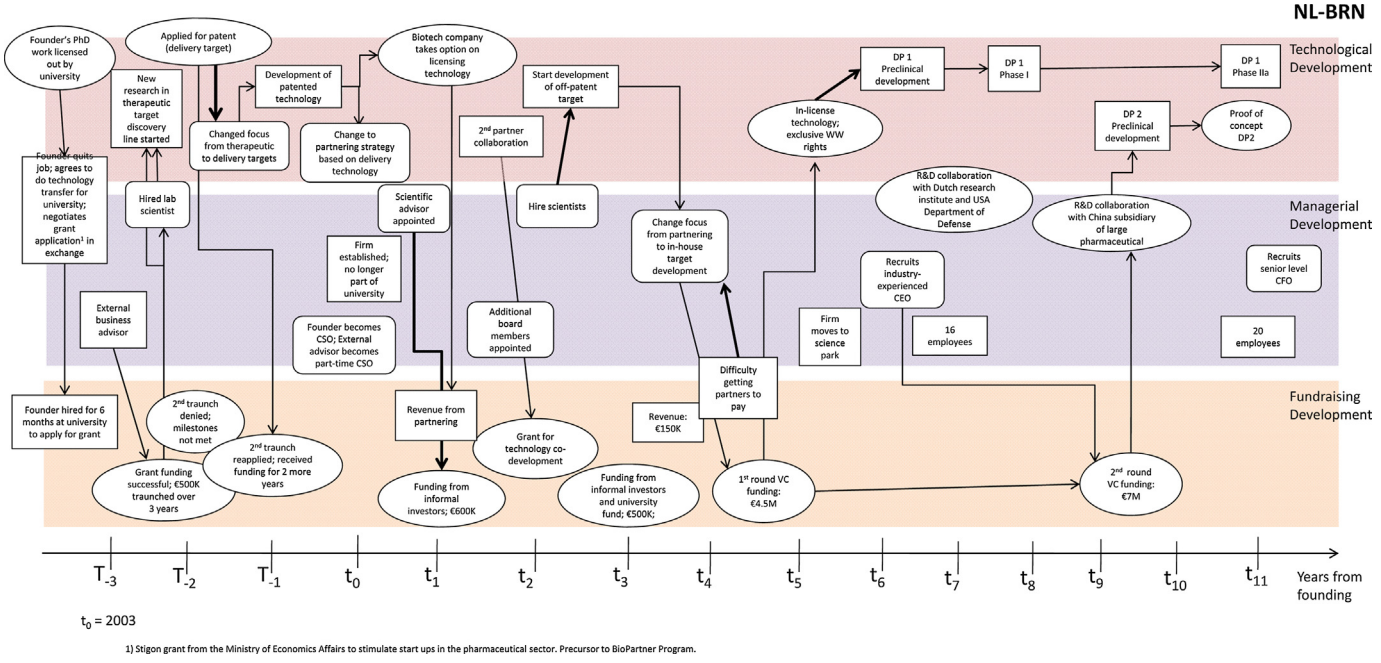

Fig. 3. Visual map of NL-BRN.

4. Findings

To conceptualize the process of early growth of science-based firms, we focused on the interaction between the access and development of fundraising, managerial and technology resources. Based on the evidence from the sample of 35 firms, we uncovered a variety of paths that founders (or the entrepreneurial team) followed to access resources in the emergence phase. We distinguish between what we call "assisted" and "unassisted" paths in firm emergence, which have an important effect on early growth. Assisted paths refer to paths in which founders relied on their own or an intermediary's relations to other organizations to access and mobilize critical resources. Unassisted paths refer to paths in which founders did not have the established relations to access critical resources. Appendix Table A1 provides an overview of the categorization of the paths followed in the emergence stage[2]. Appendix Tables A2 and A3 provide data supporting the categorization of assisted and unassisted paths for fundraising and managerial

[2] We do not assume that the firms followed only one path to access resources. We identified and categorized the dominant path that firms followed to access critical resources, as the dominant path has consequences that impact the further growth of the firm. Since we are interested in how firms progress from emergence to early growth, we emphasize that the categorization in Appendix Table A1 represents the paths followed during the emergence phase of the firm.

development and their associated sub-categories. Our cases also show how a wide range of manifestations of technology development act as signaling devices for the access and development of fundraising and managerial resources in early growth.

4.1. Fundraising development

We identify six distinct paths of how the founding team accessed early stage funding; four of which are assisted and two unassisted. Starting with the assisted paths, the first is a *directly-assisted* path to funding, by which the founding scientists with prior managerial experience in biopharmaceutical firms accessed early stage funding through their direct relations to investors. The second is a *technology transfer office (TTO)-assisted* path, in which founding scientists (from university) accessed early stage financing through the TTOs of their university or partner institutions. This path can be seen in the UK. The third is an *indirectly-assisted* path, in which founders lacked direct access to venture capital investors or established TTOs. Instead, they relied on their own personal or professional relations to facilitate access to investors. The fourth is an *early IPO* path, by which founding scientists avoided venture capital and raised early stage financing by going directly to an IPO to maintain control. This path can be seen in four of our UK firms, as the founding teams had the requisite managerial competence to establish confidence from investors and raise early stage funding successfully from the stock market (the Alternative Investment Market (AIM)).

We also identify two unassisted paths to access early fundraising: a *revenue-generation* and a *grant-generation* path. In more than half of our firms (19 firms), the founding scientists had no prior ties to investors and had to devote considerable time to the search for external financing, building ties to access investors. In order to bridge the period of time between firm emergence and the eventual raising of funds, firms survived by generating revenue and/or grant funding. This path can be seen in many of our Dutch firms (eight Dutch and five UK firms). In the Dutch firms, although founders raised small amounts of seed funding, they did not raise enough, and continued to pursue a revenue-generation path offering services alongside more capital-intensive drug development research. It could be argued that these Dutch firms did not raise external financing because they did not need it, as they followed models to generate revenue quickly after founding, either by selling services or developing low-risk products with short development periods (such as equipment or devices). Nevertheless, we observe that these Dutch firms continued to search for external finance from venture capital investors as they simultaneously developed products, with many (five out of eight Dutch firms) raising external funding after several years of technology development. In contrast, the UK firms following a revenue generation path had no ambitions to develop drug products. Their technology remained at an early stage and therefore could not attract funding for the development of new drug products; these firms discontinued the search for external financing, yet continued generating revenue by offering services.

Founders also relied on peer-reviewed grants or government funding to bridge the gap to raising their first round of external financing. Both Dutch and British firms (four and two respectively) that relied on this path for fundraising had technology in early and unproven stages. Grant funding from government, charitable and other institutions is not sufficient to develop drug products through clinical trials and the firms continued to search for larger rounds of finance.

4.2. Managerial development

We identify five distinct paths of how firms accessed managerial expertise, four assisted and one unassisted. The first assisted path is an *investor-appointed* path, in which firms, after securing external financing, were able to tap into their investors' networks to form a functionally-diverse management team. The venture capital (VC) investors appointed managerial resources and either retained or removed one or more of the founders from the management team. In the second assisted path, a *founder-appointed* path, the founders used their own network or third parties (e.g. executive search, or headhunters) to search for managerial resources. Founders in both the UK and Dutch firms accessed managerial competence following this path. Dutch founders relied primarily on third parties to recruit management. The third assisted path, a *parent-appointed* path, represents firms that accessed managerial resources by appointment from their originating institution. In most cases, but not exclusively, these firms originated from university environments and the appointments were made before raising external early stage finance. The fourth assisted path is a *founders-diversity* path, in which founding teams had functionally-diverse skills from the outset. Founders who had previously worked together at a prior employer were more likely to start the firm with a founding team of complementary managerial competence. This *founders-diversity* path was evident in three UK firms.

For managerial development, there is one unassisted path, a *founders-limited* path. In this path, functional diversity in the founding management team is constrained as managerial resources are not accessed in the emergence phase and founders relied on their own (limited) managerial competence. Founders thus assume all the various managerial roles and responsibilities (in three UK and seven Dutch firms).

4.3. Technology development

Our cases show how a wide range of manifestations of technology development, including but not limited to the intermediate outputs of inventive activity (such as patents), announcements of partnerships or acquisitions, development of services, or success in clinical trials, act as important signaling devices to attract early stage fundraising and managerial resources and advance the early growth of the firm. Establishing proof-of-concept for the technology is a key turning point in accessing both funding and managerial resources.

These signaling devices can have positive as well as negative effects and the use of these signaling devices is complex. For instance, firms can use signals of technology "failure", such as poor or inconclusive results from clinical trials or the discontinuation of drug programs, as clear representations of strategic choices and they can influence early firm growth in positive ways. Using an example from one of our cases, UK-XCI, in anticipating a forthcoming IPO, discontinued a drug program that used controversial technology based on porcine xenografts. In this way, a great deal of technological uncertainty was reduced before its IPO. Another example is UK-OVE. Having inconclusive phase IIa clinical trial results, it had a very difficult time raising follow-on funding from its venture capital investors. Instead, the firm turned to the public equity market, floating on AIM, raising enough funding to continue its drug development programs. A few years later, it reported again poor results from clinical trials and failed to access further funding and was eventually liquidated.

In short, these signaling devices of technology development, albeit positive or negative, interact with the assisted and unassisted paths of fundraising and managerial development. The strong uncertainty of technology development inherent in science-based firms makes it difficult to judge whether one type of path will be more beneficial than another. The resource development paths available to science-based firms affect the subsequent strategic choices of their managers differently and, in turn, their production bases. In the next section, we illustrate with three cases the

interaction of resource development and the effects of technology development signals on early growth.

4.4. Speed of early growth

The combinations of the different paths described above influence the speed of early growth. We show below that firms can develop in a rapid, gradual or arrested way, contingent on the type of access firms have to critical resources. In this section, we highlight and provide narratives of three exemplary cases of firms developing at different speeds.

4.4.1. Rapid development

UK-XOR is an academic spin-off founded by a professor to exploit commercially his academic department's experimental models for Parkinson's disease. The department was entirely reliant on grant funding and the professor wanted to secure employment for the scientists in his department. He had tried for several years to get his university to spin out the department. Once the university entered a partnership with a third party to exploit university technology[3] (more generally), his academic department was targeted for spinning out:

> I had a track record of working with the pharmaceutical industry... I have a number of experimental models in Parkinson's, which I have been using for many, many years in conjunction with industry. ... I had been making noises again about trying to do something in a more commercial environment.

UK-XOR was established in 2004 and a small amount of initial seed funding was supplied by the parent organizations (the university and third party). An interim CEO was appointed shortly after founding. We categorized this access to managerial resources as a *parent-appointed* path. The firm first developed its managerial resources, which had a significant impact on its subsequent access to funding resources. The appointment of an interim CEO helped UK-XOR to overcome bureaucratic hurdles and aided in the recruitment of a CEO within the first year. This access to managerial resources (both the interim and permanent CEO) in the emergence stage allowed UK-XOR to bypass venture capital investment and raise early stage funding from an IPO. We categorized UK-XOR's financial development as following an *early stage IPO* path. To access this funding path, UK-XOR had developed a functionally-diverse management team within the first year of founding to coordinate an IPO and provide confidence to investors in its technological and commercial potential. UK-XOR listed on AIM in March 2005. Following this type of path to access fundraising resources is unusual—not only do young firms need to possess the requisite managerial competence but they also need to be embedded in an institutional setting that facilitates early stage listing on a small-cap stock exchange. The founding scientist described the process:

> We were off very quickly indeed singing our song around the city to the investment managers, and to my surprise, since we had done nothing, [except have] a lot of ideas and a good team, we did very well. We offered 23 million on which we took 13.5 million at the initial placement. And got ourselves listed.

Accessing managerial and financial resources occurred rapidly. Simultaneously with the development of financial and managerial resources, UK-XOR started a number of research programs and recruited another key member of the management team, the head of drug development. The university founder became the CSO but also retained his academic position.

UK-XOR's technology development is fundamental to understanding how fundraising and managerial resources were accessed and developed. The technology platform had strong scientific reputational benefits, as the academic founder had been providing services to pharmaceuticals for many years. This production base gave UK-XOR the opportunity to follow a hybrid business model of offering services and developing drug products. Although both the academic founder/CSO and the CEO believed that the immediate revenue stream was advantageous in pursuing an early stage IPO, both managers emphasized that offering services was not where the value of the company rested.

The utilization of their technology for services to pharmaceutical firms (including regulatory approval) provided externally-focused signals of the quality of its technology development and internally-focused information processing benefits. The CSO and CEO expressed these benefits differently. The CSO emphasized the learning associated with the business model: "we have all this intelligence that is coming in the whole time [and] we have a very close relationship with what [UK-XOR] does and what I do wearing my academic hat and what big pharma wants from a small biotech." The CEO expressed this in terms of reducing the uncertainty inherent in science-based firms' research and product development:

> Developing [products] in Parkinson's has some interesting risk-reward relations. There are many predictive models that exist for Parkinson's which don't exist for almost every other indication ... That is one of the [founding academic scientist's] strengths because he is so intertwined in the industry. He has been running those models for the last 25 years for big pharma and they run those models because they are so predictive. It's an FDA guideline, so what that presented to me was nothing that makes drug discovery any easier, it just makes it less risky to invest more in a program. If it doesn't work you cut it and if it does work, you have the confidence from these predictive models that you're going in the right direction.

The visual map (Fig. 1) shows the progressive and rapid technology and fundraising development that ensued. As discussed above, within two years of founding, UK-XOR had a functionally-diverse management team and listed on AIM. Thereafter, UK-XOR raised subsequent rounds of funding through placements approximately every two years as it moved drug programs through clinical trials, acquired compounds for new drug programs and established a US Cooperative Research and Development Agreements (CRADAs) for drug development with partners such as the National Institutes of Health (NIH), and partnerships with large Swedish and US pharmaceutical firms. A succession of signals from its technology development fuelled firm development, first through outlicensing its founding technology which also provided milestone payments and influenced positively UK-XOR's ability to raise more external financing and then through acquisition of technology which further developed its technology resources and filled the firm's pipeline, again influencing positively outlicensing and collaboration agreements. Eight years after its founding, UK-XOR was acquired by one of its outlicensing partners.

4.4.2. Gradual development

NL-ORP was founded in 2002 by a scientist who had previous work experience in Dutch and US biotechnology firms. With two other Dutch biotech entrepreneurs, NL-ORP began with an "idea to use particular technology on nucleic acids, nucleotides ... and started this with a little bit of money." In the emergence stage, NL-ORP accessed financial resources through a *grant-generation* path, drawing on grants from government schemes to stimulate biotech

[3] The third party partner is a UK company that partners with research-intensive universities to commercialize intellectual property and develop new technologies.

entrepreneurship and later on grants from patient organizations for five years.

The core technology of NL-ORP emerged from the founder's conviction that "to survive we had to develop a therapeutic product out of the technology". He further explained that they came across technology from a nearby university that "was using our type of molecules to develop a therapy for Duchenne disease". It was a technology for gene expression that allowed for correction of a mutation, a "molecular band-aid ... you can mask the mutation and then you can correct it". That technology became the core of NL-ORP's production base and "was patented together with our knowledge of the compounds to do the masking of the mutation". From that point, NL-ORP started to change from a "technology to a product development mindset. We started slowly but surely to develop as a product development company ... That changed the company."

Once NL-ORP had identified their technology focus and production base, they filed for and received orphan drug development status, which acted as a positive signal of technology development as now they could fast track the clinical trials associated with drug development for Duchenne. This occurred three years after founding. The orphan indication also allowed NL-ORP to access more grant-generated funding from patient organizations:

> We didn't have a big pot of money ... so I had to go out and get grant money and then at a certain point we had some good results and I was able to attract some small amounts [of funding] and then I got grants again ... and we built on that. We were able to attract a lot of grant money.

The founder estimated that in the first five years, he received a "total of 6 [government] grants and about 3 to 4 grants from patient organizations. That amounts to ... between six or seven million euros."

A question that arises is why the founder of NL-ORP used grant-generation to raise funding instead of pursuing a path of venture capital investment. An explanation is that NL-ORP had still not established technological proof-of-concept and it was not until after the results of pre-clinical trials that venture capital was raised. In 2007, five years after its founding, NL-ORP raised €13.5 million in its first round of financing from a local venture capital fund. The founder explained that he tried to find VC investment earlier and approached both local and international investors:

> At first I did call up the larger ones and they said 'nice, but you're too small'. I didn't pursue that any further because when two of them already say that you're too small, that's fine. But now [2007] it is a little bit different because we are in the clinic, we are a little bit bigger, new technology, so that they find us interesting ...

Access and development of managerial resources progressed gradually as well. From the very start, the founder assembled an advisory board with two experienced biotechnology scientists and entrepreneurs. The founder referred to how the lack of funding influenced the development of managerial resources: "We didn't have a big pot of money to bring in management." Coinciding with the venture capital investment in 2007, the founder searched for and recruited staff for key posts, including scientific director, head of clinical development, head of research, financial director, business development and regulatory affairs:

> ... because of my experience, knowing that you have to put up a quality system to do this before you can enter into human trials, these guys... came in with their particular expertise in product development, we could cut a lot of the time needed for a young company to set itself up as qualified to do clinical trials.

Thus, managerial development in NL-ORP occurred primarily through a *founder-appointed* path. Shortly after the second round of venture capital financing, approximately seven years after founding in 2009, the founder CEO was replaced.

With advances in technological development (see Fig. 2), managerial and fundraising resource development followed. There were subsequent rounds of financing, along with outlicensing revenue, milestone payments and royalty fees. NL-ORP continued to raise funding through various European grant programs and charities or patient organizations. NL-ORP entered several different alliances, including partnerships with universities (Dutch as well as other European and US universities), hospitals and large pharmaceutical companies, to develop its drug development programs. It successfully progressed its drug programs through several phases of clinical trials. In 2011, NL-ORP received US and Japanese patents, strengthening its technology position. In 2012 and 2013, NL-ORP received five different awards of recognition (e.g. Emerging Star Award). In January 2013, the US Food and Drug Administration (FDA) awarded NL-ORP orphan drug status on its entire portfolio of Duchenne products. In July 2013, eleven years after its founding, NL-ORP listed on the NASDAQ stock exchange, issuing 6.9 million shares and raising €64 million. In September 2013, NL-ORP and its large pharmaceutical partner announced that one of its flagship programs failed to meet Phase III clinical trial endpoints, a signal of technology failure. Indeed, NL-ORP's stock market value dropped dramatically, its share price losing two-thirds of its value in just one day in September 2013, with more than 17 million shares traded. Up until March 2014, NL-ORP made various announcements regarding this program. One significant signal, in January 2014, was the announcement that it would regain the full rights to the program and terminate its collaboration with the large pharmaceutical company. In May 2014, NL-ORP announced they would pursue clinical development with a re-dosing plan, stating that, "treating earlier in the disease and treating for a longer duration confers a treatment benefit"[4].

4.4.3. Arrested development

NL-BRN is an example of arrested development, as it was able to survive but experienced a stagnant development, neither raising early financial resources nor recruiting a functionally-diverse management team. Arrested development combines unassisted paths of both financial and managerial development over an extended period of time, depending on university resources or grant funding for long periods of time.

NL-BRN was founded by a post-doc interested in exploiting the research he did in his PhD. The university was in the process of outlicensing the technology developed over the course of his doctoral work and was involved in technology transfer negotiations. At this point, he began discussing the possibility of starting up a biotech firm, ultimately agreeing that one part of the technology would be licensed and that he would start a company with the other. In 2000, the university hired the founder for six months while he applied for and received a government grant for start-ups. He funded the first three years of NL-BRN's development using government grants and relying on university resources, developing the production base—a platform technology on drug delivery to the brain that could be

[4] The technology development trajectory of NL-ORP can be contrasted with two other firms in our sample, UK-XCI and UK-OVE. These two firms also reported negative clinic trial results and as a result these two firms had great difficulty in securing financial resources subsequent to this signal of technology failure. Both firms were also listed on the AIM stock exchange and eventually liquated their assets by either filing for bankruptcy or selling their technological assets. NL-ORP has withstood this negative technology signal because of the many other positive signals over the long duration of time. With sufficient funds and an experienced and functionally-diverse management team, NL-ORP still continued its technology development.

patented and developed commercially. NL-BRN was legally established three years later in 2003.

The founder was aware that by the end of the grant period they "needed to have investors ... so we validated the technology and got a term sheet from one of the biotech companies that they were willing to have an option agreement with the technology that we were developing." It took NL-BRN eight years from the initial grant funding to raise a first round of venture capital financing (€4 million) in 2008. We categorized NL-BRN as following a *grant-generation* path to access financial resources.

The development of managerial resources in NL-BRN was also limited. Grant funding began before the firm was legally established. At that point, only the founding scientist and a lab technician were working on developing the technology. The founder reflected critically on the way NL-BRN started:

> There was nothing and we really needed that grant money to get a patent out of it. There was really nothing. Normally a company would [start] at the phase were we are now ... that would be more logical. There is a patent and you have some validation. That is where we are about now [2007]. But ... I wanted to start a company without any IP. I did it the hard way. I wouldn't do it again in this way. Too many risks ...

The founder had, at that emergence stage, sought external advice and support during negotiations from a consultant who had pharmaceutical manufacturing experience. This developed into a closer collaboration, and the consultant became an equity partner when the firm was legally established. The founder also had an academic partner, a professor who was a scientific advisor. As a result of generating grants to support technology development, NL-BRN also had four technicians working on the technology through a university arrangement and had a formal agreement that the knowledge would be for commercial use. In its emergence stage, NL-BRN used university facilities, paying bench fees and collaborating closely with university researchers, described by the interviewee as a "continuous flow of knowledge".

In this emergence stage, managerial resource development was *limited*, consisting only of the founding (equity) partners and advisory board members. The founding partners divided managerial responsibilities and roles between the two of them, one assuming scientific responsibility, the other general administration and business development. Recruitment of key managerial positions took place only after venture capital funding was raised eight years later.

In parallel, the technology development of NL-BRN also experienced slow progress. When they started, their ambition was to be a "target-discovery company". The founder explained how they settled on their technology:

> ...we couldn't do much about the scientific plan [looking for targets] because that was what we got the [grant] money for and we needed to do that to get into an IP position. One of the targets was luckily very close to application and we could get a good patent position on that. It was based on drug delivery so ... we were looking for therapeutic targets but the target we found we could just use for drug delivery ... [however] when [the technology was developed] enough to go to investors that market was very dried up.

Leading up to its first round of venture capital in 2008, NL-BRN lacked signals of technology development, which severely impeded the growth of NL-BRN and impacted its strategic choices. Even though NL-BRN had patented technology, which sends a positive signal, it could not generate interest in the technology opportunity, attracting neither venture capital nor collaborative partnerships with biotech and pharmaceutical companies for a long time. The founder realized that progress was slow but acknowledged the learning process: "... the science is mostly paid by research grants. But ... it is too slow. We have learned a lot ... now we know what to do".

Table 2
Paths to fundraising and managerial development and speed of early growth.

		Paths to managerial development	
		Assisted	Unassisted
Paths to fundraising development	Assisted	Rapid development	Gradual development
	Unassisted	Gradual development	Arrested development

NL-BRN experienced a turning point in 2008. After raising its first round of venture capital, it in-licensed technology from a research institute in Taiwan, negotiating exclusive worldwide rights of use. With the help of the VC investor, the firm recruited a CEO in 2009 who had commercial and business development experience in a large US biotechnology firm. Yet, even with these positive signals of technology and managerial development, the development of additional financial resources progressed slowly. It took another three years to raise an additional €7 million. The recruitment of managerial resources also progressed slowly. In 2014, NL-BRN recruited a senior-level CFO from one of the largest Dutch biotech firms. Although the (local) financial and trade media report on NL-BRN's business and technology, NL-BRN still lacks technology signals that encourage a speedier firm development.

5. Discussion

Our study builds on and extends the contributions of Penrose (1959) and Garnsey (1998) on firm growth. It shows the speed of early growth of science-based firms as the time it takes for the assembly (or combined development) of the three types of critical resources—a functionally-diverse management team, early fundraising and development of technology.

A first issue raised by our findings is that the development of early finance, managerial competence and technology is an unfolding and interrelated process, the causal direction of which is highly ambiguous. For some firms, having access to managerial competence facilitates external fundraising, and, in contrast, for other firms, raising external financing facilitates the recruitment of managerial competence. Different studies have used different indicators (e.g., number of employees, funds invested, market capitalization) for exploring organizational growth. Our process analysis has enabled us to take what are usually viewed as outcomes and to consider them explicitly as inputs (management team as input to funding, funding as input to developing a management team). For example, rounds of funding can be regarded not as a measure of performance but as an input that can persuade experienced managers to join the firm.

We show the variety of paths used by science-based firms to access and develop critical resources. The combination of these paths explains how firm growth can unfold in a relative straightforward and rapid way, in a more gradual way (when development is in small steps and represents impeded access to either finance or managerial resources), or can even be arrested (when firms are unable to develop a full functionally-diverse management team and have limited access to early finance). Table 2 shows the paths to fundraising development and managerial development. The basic picture that emerges is that the various combinations of assisted and unassisted paths lead to different speeds of development.

Our study also contributes to the literature on comparative capitalisms (Hall and Soskice, 2001; Hollingsworth and Boyer, 1999; Whitley, 1999), by showing that the variety of paths (and speed) of early growth of science-based firms are clearly influenced by

the (national) institutional setting. We find a marked difference in the role of intermediaries, especially the support of VC and TTOs in enabling these paths. In environments where these are available and strong, the period of time it takes for founders to develop a functionally-diverse management team and raise funds is shorter. For all of the sampled UK firms originating from universities, the TTO from their university or partner university aided in their emergence, providing systematic assistance in accessing seed financing and managerial competence. The TTO facilitated access to venture capital investors, who in turn appointed managerial resources, or the TTO appointed a CEO to run the venture, which in turn raised the necessary finance for firm development. Once the firm recruited investors, they generally removed one (or more) academic founders from the management team; nevertheless, academic founders remained strongly involved in non-executive or advisory roles or as CSOs. In the UK firms, academic founders combined their early management roles with their academic positions and the firms maintained the links to the academics' knowledge and networks. In contrast, in our Dutch firms, assisted paths via intermediaries such as TTOs played a less significant role in early fundraising. In fact, the Dutch firms categorized as having a rapid development did not originate from university environments. Where TTOs were involved in the emergence of Dutch firms, Dutch academic founders had limited or no involvement in the firm founding or further development. Dutch TTOs appointed external managerial resources in the early stage. In cases where academic founders played a key role in the firm founding, they received no TTO assistance and followed "unassisted" paths to access early stage resources.

Also, one of the fundraising paths that UK firms followed was to bypass VC/private equity funding and raise finance by an early stage IPO on the AIM stock exchange. Having a small capital stock market, the UK financial system offered entrepreneurs this avenue to developing financial resources and provided an exit strategy for angel or venture capital from the beginning (although UK biopharmaceutical firms have adapted to recent constraints on the stock market, see Hopkins et al., 2013). Also, in the UK, seed investment is protected through the Enterprise Investment Scheme (EIS). In contrast, the Dutch financial system has less liquidity on the small capital stock market and a labor system with less mobility of managerial and scientific labor, and less support from specialized services. A lack of managerial competence in the early stage may explain why Dutch firms were unlikely to follow the early stage IPO funding path.

The lack of assisted paths in fundraising also has consequences in developing managerial competence. Without the facilitation of mediators, Dutch founders, especially academic founders in our sample, followed primarily unassisted paths in accessing managerial resources, requiring founders to leave their academic positions to commit fully to the firm and increase its credibility. A gradual development represents impeded access to early stage financing; yet firms were able to access managerial resources, which, in turn, allows firms to develop capabilities and technology development signals to raise funding. As shown in Table 2, the combination of one assisted and one unassisted path of early fundraising and development of managerial competence lead to a gradual firm development.

As argued above, having access to managerial resources provides new ventures with funding alternatives that are also rooted in institutional differences. In the UK, the firms that were able to raise funding from early stage IPOs and bypass venture capital investors had the managerial resources to coordinate an IPO. This is a finding that is not exposed enough in the literature on early funding of entrepreneurial firms.

In contrast, Dutch firms are hindered from following this path not only due to the lack of a small capital stock exchange but also the lack of intermediaries to facilitate access to the requisite managerial resources to coordinate an IPO. In the Dutch context, which also lacked domestic venture capital investors, the firms we studied accessed international venture capital and corporate venture capital, investors that do not typically provide the brokering or mediation role needed to access managerial resources. Nevertheless, once firms had secured international investment and gained legitimacy, they were able to recruit managerial resources through other types of local intermediaries (e.g. recruitment agencies).

Thus, in our Dutch cases, while firms can compensate for constraints on financial resources by using "functional equivalents", such as international sources of venture capital, access to managerial resources appears more limited by national or regional boundaries and labor regulations, making functional equivalents more difficult to access and use (Casper and Matraves, 2003; Herrmann, 2008; Lange, 2009). The Netherlands faces shortages of graduates in science and engineering (OECD, 2004) and has a less mobile pool of managerial labor for science-based firms. This contrasts with the UK, where the existence of clusters around respected universities conducting research in the life sciences appears to facilitate managerial development. Here, the availability of knowledgeable and relatively mobile managers with experience in biotech and pharmaceutical firms and also an additional network of private equity and specialized services (e.g. lawyers specializing in intellectual property) provides both a labor pool and support services for the development of new science-based firms. The combination generates a 'recycling mechanism' (or safety net) for scientists and engineers if firms fail given the scientific and commercial uncertainty.

By raising early stage external finance, the Dutch firms studied had not only the financial resources but also legitimacy and credibility to offer executives from international labor markets incentives attractive enough to persuade them to join the firm. Also, Dutch firms more than British firms followed hybrid business models that combined service provision with drug discovery and development to compensate for the lack of early financing institutions and managerial competence (DiVito, 2012). This more obstructed access to and development of critical resources led to firm development that was more gradual. Indeed, this echoes other studies showing the positive impact of government financial support to R&D of existing firms on local biotech firm birth (Kolympiris et al., 2014).

The combination of unassisted paths to access both financial and managerial resources resulted in cases of arrested growth (Table 2). In our Dutch cases, the founders lacked ties (via TTOs or otherwise) to access financial and managerial resources and were often dependent on the facilities of universities. Without the mediation of investors or TTOs, the founders were obliged to assume the various roles of a management team. Again, without these intermediaries, the (limited) managerial teams of these firms remained unchanged for prolonged periods of time, resulting in arrested development.

A second issue raised by our findings is the importance of a wide range of manifestations of technological development that act as signaling devices and intervene in the early firm growth process (Haussler et al., 2014; Hoenig and Henkel, 2015), having both positive and/or negative mediating effects in attracting both funding and management. Our research shows that these signals go beyond the role of patents and alliances acknowledged in earlier literature to include clinical trials, proof of concept, licensing, acquisitions and provision of services. We show that these signals play not only an important role in attracting early funding (as acknowledge by the literature) but also in attracting managers to develop the management team. This is because of the high degree of iteration in R&D in science-based firms; each of these signals contributes to reducing the uncertainty surrounding R&D and improving expectations about future returns, affecting the expansion plans and

time structure. These signals may contribute to alleviating information asymmetries between entrepreneurs and funders and new managers respectively, in the context of long research and product development cycles and uncertain scientific and commercial outcomes, which makes these signals useful (Pisano, 2006).

Our research is in line with Tylecote and Visintin (2007) who suggest that the visibility of (potential) innovation may affect the readiness to invest by financiers. We contribute to this line of research by showing that these signals can be interpreted as a way to make the (highly uncertain) R&D process of science-based firms more visible to outsiders in a context of high technological opportunities (Malerba and Orsenigo, 1996) to attract and develop critical resources. Thus, visibility may not be limited to the highly formalized and regulated process of R&D and protection afforded by patents (which may take many years to materialize), but includes a host of other signals at a more early stage of firm development. Although these signals may not be entirely reliable, as firms may have different standards in advancing drugs from one stage to the next in clinical trials (Pisano, 2006), our research shows that these signals contribute to attracting finance as well as managerial resources (both national and international) to form a functionally-diverse management team.

Our work thus points to the important influences of the institutional setting on the speed of growth. The literature on comparative capitalisms (Hall and Soskice, 2001; Hollingsworth and Boyer, 1999; Whitley, 1999) emphasizes the effect of the incentive structure provided by the network of interactions among national institutions on the production strategies of firms, ultimately influencing and shaping the technological specialization of firms and that of countries (for example, by suggesting that certain countries have institutional settings more favorable to sectors characterized by radical innovation and others by incremental innovation). While it is argued that resources available to firms are influenced by the orientation of the financial system, industrial relations, educational institutions and that these institutions will support or hinder efforts by firms to develop organizational and technological capabilities in different product markets, there is relatively little research on the mechanisms through which these institutional variables influence the development of newly-established firms. Our research builds on this stream of literature and shows how and why these institutions influence the development of science-based firms in early growth, particularly the speed with which firms can assemble their critical resources.

Our findings raise important implications for policy. We show the importance of a range of factors (and interactions) in early firm development, including the ability to use the science knowledge base, institutions of finance, professional careers and mobility of R&D and technical management personnel, role of bridging institutions, and university-industry relations. Policymakers need to be aware of the alternative paths followed by science-based firms in their national economies and develop policies that stimulate their growth, for example, by encouraging the use of international venture capital as a form of early stage financing.

Our work also supports the need for schemes that facilitate the development of networks, connections and mentoring of entrepreneurial science-based firms through relations with both established firms and universities. Moreover, the creation of initiatives that promote 'protected', rather than precarious, forms of employment mobility and the transfer of managerial skills and knowledge and international recruitment of executives in the science-based area would support the early growth of such firms. Policymakers also need to reconsider their policies on academic spin-offs and technology transfer. The challenges that academic founders face need to be addressed by effective policies to engage industry-experienced professionals through various means (e.g. building ties through collaboration with firms) and strengthening the capabilities and efficacy of TTOs in the development and growth of new firms originating from university.

Our findings also suggest implications for science-based entrepreneurs. Entrepreneurs need to be aware that many manifestations of their technology development (beyond the acknowledged role of patents and alliances) can act as signaling devices to attract investors and management. This is particularly important in the context of long development cycles, scientific uncertainty and strict regulatory regimes, which make the development of a track record or the conveying of quality otherwise difficult. This means that firms may not only trade off the postponement of patents (to maximize the years of legal protection) against earlier patenting for signaling effect (Hsu and Ziedonis, 2013) but may also approach other signaling devices in a similar way (e.g. announcement of technology licensing or dropping controversial projects when it is necessary to attract capital and management). The timing of patents is a complex issue, as venture capital investors have a tendency to invest in firms with pending patent applications (Baum and Silverman, 2004) but long development trajectories favor later patent applications for full exploitation of rents. Also, as Haussler et al. (2014) show, information generated in the course of the patenting process affects the financing decision dynamically, long before a patent is granted.

6. Conclusion

Understanding the early growth phase of entrepreneurial science-based firms is an important question for practitioners and policymakers. Many countries invest heavily in sustaining a strong and healthy science base, but face challenges in the ability to commercialize and benefit from the economic impact of science. This paper examines the early growth phase of science-based firms through a study of biopharmaceutical firms in the UK and the Netherlands. Our research brings to light the variety of paths of early fundraising, managerial and technological development. We distinguish between "assisted" and "unassisted" paths for firm emergence and how these paths combine to influence the speed of firm development. A range of manifestations of technology development can act as signaling devices to attract funding and management. We show how the variety of paths and the speed of firm development are influenced by the national institutional setting. This study contributes to conceptual discussions of entrepreneurial science-based firm early growth and has important policy and practitioner implications. It also unveils questions for future research, in particular, how different paths of early growth affect subsequent growth and outcomes in later development stages of science-based firms.

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Appendix A.

Tables A1–A3.

Table A1
Overview of paths followed in firm emergence stage.

	Fundraising Development						Managerial Development					Speed of development
	Assisted				Unassisted		Assisted				Unassisted	
	Direct-assisted (VC)	TTO-assisted (VC)	Indirectly-assisted (VC)	Early stage IPO	Revenue-generation	Grant-generation	Investor-appointed	Founder-appointed	Parent-appointed	Founders-diverse	Founders-Limited	
UK-XOX		✓					✓					Rapid
UK-XOR				✓					✓			Rapid
UK-XCI	✓							✓				Rapid
UK-TRG				✓				✓				Rapid
UK-SAV				✓					✓			Rapid
UK-RAS				✓						✓		Rapid
UK-PNI		✓						✓				Rapid
UK-OVE		✓					✓					Rapid
UK-NEX	✓						✓					Rapid
UK-KRA			✓					✓				Rapid
NL-VAA	✓						✓					Rapid
NL-PMA	✓								✓			Rapid
NL-LAG	✓								✓			Rapid
NL-HTP	✓							✓				Rapid
UK-YLP		✓									✓	Gradual
UK-XTG						✓			✓			Gradual
UK-XSS						✓	✓					Gradual
UK-SXD					✓					✓		Gradual
UK-SPE					✓			✓				Gradual
UK-GGF						✓		✓				Gradual
NL-TOC					✓					✓		Gradual
NL-RUC					✓			✓				Gradual
NL-RIV					✓				✓			Gradual
NL-ORP						✓		✓				Gradual
NL-MPA					✓			✓				Gradual
NL-EPP					✓		✓					Gradual
NL-AREK			✓								✓	Gradual
UK-NGP					✓						✓	Arrested
UK-XHP					✓						✓	Arrested
NL-AIK					✓						✓	Arrested
NL-BRN						✓					✓	Arrested
NL-KLA						✓					✓	Arrested
NL-KYS						✓					✓	Arrested
NL-OIB					✓						✓	Arrested
NL-QIP					✓						✓	Arrested

Table A2
Data supporting categorization of paths to fundraising development.

Type of path	Firm (year founded)	Data supporting path followed to fundraising development during firm emergence	Year of 1st round of fundraising[i]
Assisted			
Directly-assisted (VC)	UK-NEX (2002)	"We didn't need to [search for funding] because all this sort of came together. The [VC] wanted to do ion channels; these guys were around; I was around; so it all just came together." "... a group of people came together at the same time and that is how things got started... They knew the guys we know...it was not like looking for a needle in a haystack. If you want to do something and you got the right people to talk to, then it turns out to be a fairly efficient [process]"	2002
	UK-XCI (1998)	"During a dinner with two old friends, I mentioned that I wanted to return to the UK and my friend [who was a VC] said, start a business and I'll fund it." "I had known the VC now for years and I've known, the other investor [CVC] for over a period of time. It wasn't cold calling. From their actual firm commitment to closing, it was 2 months."	1999
	NL-HTP (2001)	"[The founder] brought these three [investors] together and said I have a good idea to start a company and you three should at least initially come up with some money." "We started with 4 or 5 projects [that the founder had] ...on January 1st, 2001 with these three business angels."	2001
	NL-VAA (2000)	"We are a spin out of ... a mix of petrochemical pharmaceutical companies and three technology universities. [The founder] managed to convince [them] that it had a better chance to flourish outside of [the parent company] and that [they] could still benefit from it by investing. ... He managed to attract quite a few companies [CVC], both initially and in the consecutive financing rounds." "We were founded in Feb 2000 officially ... not too long after that, VCs came on board."	2002
	NL-PMA (originally 2000; re-established in 2002 after a merger)	"It is not the first company I founded ... then they know you personally and they say, well, if you invest, we invest as well ... When it started in 2000... there were other VCs that were willing to invest along with [lead investor] ... then biotech deteriorated and we were not able to close the deals with the other VCs ... So we were stuck with one VC which was not the original plan." "... with that [seed] money you start the contract, you start the subsidy, you have it and then you go to the VC ... then we had the first round, then the merger and then later on [more rounds]."	2001
	NL-LAG (1998)	"... So we spun it out, first as a 50/50 joint venture. [And then we had to make a decision], dilute our 50% stake by allowing VCs in or not. ... we attracted a group of VCs ... to get external funding ..."	2002

Table A2 (*Continued*)

Type of path	Firm (year founded)	Data supporting path followed to fundraising development during firm emergence	Year of 1st round of fundraising[i]
TTO-assisted (VC)	UK-OVE (1998)	"The very early financing was from high net-worth individuals through the university network who put in a matter of a few hundred thousand. . . . the first major round was something like 2 million. . ., and that was put in by [VC] plus a few of these high net worth individuals. "[VC] made their investment in 2001" ". . . in April 2004, we were pretty well out of money, . . . and it had proved very challenging to raise VC money so we floated or died." [Floated in August 2004]	2001
	UK-XOX (1999)	"we were put in touch with the head of department [who] personally knew [the VC]. . .he had been through that process of financing and spinning out companies" "We received 1.1 million pounds as [an initial] investment. That is what we started with on day one." (1999)	1999
	UK-PNI (1998)	". . . there were a bunch of angel investors at [university]. They had a VC arm, a set of high net worth individuals who were looking for spin outs from the university. . . . It was an informal network . . . a bunch of people connected through [university] and [they] had some cash and were doing investments." "Fairly quickly it transitioned to being an independent stand-alone company and the shareholders from the [university] got diluted over time as further investment came into the company."	1999
	UK-YLP (2001)	"[The TTO from another university] had more ability to get the company formed and the infrastructure. They have been very helpful and they were very useful in navigating through the process. "We went to the Wellcome Trust and BioSeed Fund and finally [got] the seed money, which was 2001 or 2002. Basically, 750,000 pounds to start. [The TTO] had also put some money in . . ." "[We formed the company [in 2001] and then we did the seed investment."	–
Indirectly-assisted (VC)	NL-AREK (1990)	"We found a business angel. By our own private network. . . . [The business angel] was the first to start with and then after two years we found another investor which was initially a customer of ours, a distributor . . . He took shares and invested in the company and later on we found a private investor from South Africa." ". . . [the informal investors, high net worth type of individuals] was for the first six years and then in 1999 we get our first institutional investor . . ."	1999
	UK-KRA (1997)	". . . the TTO at my university was not very good. . . . through private contacts I got in touch with a venture capital company . . ."	1998
Early stage IPO	UK-TRG (1998)	"The [inventors] brought the idea to people who had money in [the UK] to get the whole project off the ground and part of those founders did get rewarded with shares when it was initially set up. [UK-TRG] was a company set up to acquire the [inventor] companies and then, when it was floated, shares were issued to the people who had been there at the beginning." "We went on to OFX [Open Financial Exchange] in 1998. . . . Then a bit of money at the end of 1999 just to keep it going until we floated on AIM in March 2000 and raised 5 million pounds."	2000
	UK-XOR (2004)	". . . there is always this worry about dilution going to VC and wanting both arms and both legs and before you look around you don't own the company anymore. I think one of the reasons for doing it the other way [floating] was to sell off a portion of the company but retain control. To float, I think that largely came from [the CEO]." "It was a bit of a surprise to me that we [floated] so fast. . . . it did come around very rapidly considering that we hadn't done anything. We had just ideas and people and that is what we sold them [the investors]."	2005
	UK-SAV (2003)	"I've made some money out of [prior venture]. So now I don't need any business angels. I can be one to myself. There was only two or three people in the company and we were in the university lab but we managed to persuade a set of investors that we were worth 35 million pounds and they put in 15 million on top of that." "Listed on AIM and then we had 10 million in the bank, so off we went. It took us a day and 1/2 to raise the 15 million. I didn't have to go further in London."	2004
	UK-RAS (2003)	"We had four or five ways of funding the company . . . controlling the company was big . . . we didn't want to give away the whole company . . . we didn't want [poor investors] involved with the company . . . we didn't have any confidence in mergers and acquisitions . . . we went down the AIM route . . . our objective was always to float on AIM very quickly" ". . . we founded and then really spent nine months just getting some money together . . ."	2004
Unassisted			
Revenue-generation	NL-QIP (originally 1992; re-established in 1999)	". . . the science park foundation invested . . . then [a bank] put in some money as well in 93. Then [a seed fund] was the first investment . . . We had a little bit more space to develop but it was not a serious financing round. . .We have sold quite some products . . ." "We were ready with a financing round in 2001 or 2002 . . . it was a combination with [a regional investor] and a German company who we had been dealing with for a couple years and we could trust them, but they had a financial problem and from one day to another they said they cannot do it anymore. One and 1/2 years later, [regional investor] decided that they wanted to invest . . . the investment [from the regional investor] was €750,000 million . . ."	–

Table A2 (*Continued*)

Type of path	Firm (year founded)	Data supporting path followed to fundraising development during firm emergence	Year of 1st round of fundraising[i]
	NL-AIK (1997)	". . . [initial company] was financed by two private persons and the university . . . grants from the government. And [we] generated revenue, small, . . . and the initial money of the founders. . . ." "In 2002 VC came in . . . one from the Netherlands and one from the UK. [We moved for regional investment] because we needed more money in 2004. At the end of 2004 we had a second financing round, with the same VCs and [regional investor]."	2002
	NL-RUC (1992)	"I did my own due diligence by finding out who were the best VCs in the industry. I used peers for that . . .That was the seed. Then we established a consortium of VCs and then we did another round with those VCs and then we did the mezzanine. In total four, including the seed. . . . [and] licensing income from licensing this platform technology . . ." ". . . we had maybe a couple of million euros. Most of it, licensing income from licensing this platform technology that we had generated to actually manufacture the gene therapy products. [In 2000 we went public.]"	1996
	NL-MPA (2000)	"Our first funds were my private funds, the second funds came from a very early deal. And the third source of funding was a private investor. . . revenue also includes license money and everything. It is non-equity related income, services . . . so what is happening now a bigger part of the revenue is becoming product sales and services."	2001
	NL-EPP (1999)	". . . the salaries of the group was paid for through 2001 by the university . . . The money for [salaries] was funded by one of the investors and the other 1/2 was earned by ourselves by serving services and products to other companies and laboratories." ". . . gradually we started to pay our own salaries - that could have been in 2002. . . [We found] a major investor who attracted a number of other ones and ended up in a financial round at the beginning of this year which was sufficient to carry us over."	2005
	UK-SXD (2000)	"Raising the cash was hard, pretty hard. We had never done it before, had a lot of conflicting advice. We made it up ourselves as we went along . . ." "We got funding in the June 2001 and our first contract was by Christmas 2001. . . . then the following summer we did our first licensing deal which was a large one. Stuff kicked off fairly quickly; we kind of opened for business in October 2001 and shortly thereafter we got our first [service for fee] contract."	2001
	UK-SPE (2001)	"We didn't need any seed investment. We could cover the cost of our rent from the revenue we were getting and paid the salaries. . . we set up the R&D division and at about that time we had a few small angel investors . . . they invested about 800,000 pounds, largely to sustain the R&D division . . ." "We started in January of 2001 with 4 or 5 staff and we had a revenue stream from the start' . . . in June last year [2005] we had our first fund raising exercise."	2005
	UK-NGP (2001)	"The first round of financing was about 175,000 pounds. . .We tried [to find VC funding]. . . . in 2002 when we got the first round of funding, we spent money on a guy to look for significant venture funding to give the business a leg up. We tried, we failed, we really don't want to go down that route again." "We'd rather grow the company organically . . . We only have to make 3 or 4 sales and we can double our turnover year on year very easily . . . I think VC is less relevant for us now."	–
	NL-TOC (1995)	"In our case [in the beginning], VCs were not interested and the banks were not interested. Nobody was interested in it so in the end it was personal capital that went into it and a loan from the bank. That was because we had two contracts in our hands." "So we first came with contracts and then we got the loan. . .The first VC was in 2002. We had two rounds and now [2006] it's the floating."	2002
	NL-RIV (2002)	"No investors. Something like €50,000 to set it up [from founders personal investment]. We never applied for [government grant funding]. Everybody worked for free. The deal was the moment we can raise the money you get a salary." "I worked for free for 9 months. . . We started with 0 in the bank and we just did it. And nobody invested anything, just time and effort and then direct costs; that is not serious. It's not like you ask for a million VC money."	–
	UK-XHP (2002)	"We were trying to get funding in 2002 . . . and we went down that road and everybody had their hands permanently stuck in their pocket. Nobody wanted to give out any money at all. . . we said well you know, let's try to generate some revenue ourselves. We put money in ourselves." "We did get an investor behind us [in 2004] and that allowed us to get the company up and running. We got the lab set up, bought some equipment, we then got a grant from the DTI which helped get moving and extend the revenue generation so it steadily increased from there."	–
	NL-OIB (2003)	". . . and of course generating revenues after a few months . . . we didn't pay any rent for the facility until [we] generated some revenue . . . The main things we had to pay were salaries and some people said, ok, don't pay my salary for the first months. That makes it more easy to survive than if you have real employees which are not shareholders which you have to pay every month. So in the beginning we didn't have a lot of money or no money and we said ok we will postpone [costs until] we can pay."	2008

Table A2 (*Continued*)

Type of path	Firm (year founded)	Data supporting path followed to fundraising development during firm emergence	Year of 1st round of fundraising[i]
		"Financing . . . was only the money from the university and the [regional government] . . .We applied for subsidies [salary tax deduction] and we also got that. As of today [2006] we always apply for that and we always get it which is very important because it cuts down your salary costs tremendously which helps us and still helps us . . ."	
Grant-generation	UK-GGF (1998)	"The company was set up on 100,000 pounds. That was the original chunk of money. That was raised from the European Union grants and put in by the founders and associates. Following that there was a small round of seed finance, which was really through high net worth individuals who invested in the company at that stage. Contact through friends, . . ."	2002
		"The original money was grant and that lasted for 18 months, 2 years. Subsequent to that there was a small round of money which lasted another 18 months to 2 years. And then we ran into some venture finance."	
	UK-XSS (2001)	"We initially contacted about 100 VCs, went around and talked to a load of them, presentations and all this kind of stuff, eventually, [charity organizations] agreed to fund us. [Charity organizations] were the investors that ended up backing this because it is a slightly longer term opportunity. Therefore maybe the trust invests behind good science. If they make money out of it, fantastic. If they have invested behind good science, that's great and they call it a grant. [The investor] has a long- term strategic interest in this area of science. I suppose you could argue that they are more strategic investors than your traditional VC fund."	2002
		"[Charity organizations] gave us 1.4 million to start with and then about a year ago [2006] they gave us another million."	
	UK-XTG (1997)	"Initially my focus was on public funding, free money because I didn't understand capitalism in the beginning . . ."	2007
		"[We started selling products] in late 2001, early 2002. [Revenue since 2001] grew steadily. The first deals were the early adopters . . . we grew up to about 400 K in 2006."	
	NL-ORP (2002)	"We were able to attract a lot of grant money. That is our main source of income. . . . it was €350.000 [grant money]. With that I got another [government] grant because they matched the money. Some small [investors] came in. . . then we were able to attract larger grants. I got a total of 6 grants from [the government] and about 3 to 4 grants from patient organizations. That amounts up to . . . six or seven million euros."	2007
		". . . they came up with enough money to take us into the next step. . . . and so late last year I started looking for VC for now, for this particular phase and I approached somewhat larger VC firms But now it is a little bit different because we are in the clinic, we are a little bit bigger, new technology so that they find us now interesting and we have now some very good potential investors coming on board."	
	NL-KLA (2005)	"As you can see we have no money. What we did is . . . I came here [university] and I work with this professor for more than 30 years. [the co-founder] . . . I try to get some money together to pay for some graduate students, which then would be employed by [professor's] department and paid by us. If that is possible, I have a desk to sit at and use the facilities . . . I propose projects which go up for grants and if they are granted then I can stay for another few years."	–
		"We have a network mainly in academia and by promoting enthusiasm we are able to do clinical trials at very low budget."	
	NL-KYS (2004)	"we were successful at applying for the . . . grant. I became more and more interested in the project and during the same time that we got the grant it was decided that we would found a company based on this program, which was also one of the aims of the first stage grant."	2007
		"[Lab personnel are still employed at the university] that is part of the IP and licensing deal that we have with the [university]. I don't get paid for my services and in exchange I have shares . . . At some point that will change and then if people are involved they get paid. . . we are at the point [that] it has to be funded by external sources."	
	NL-BRN (2003)	"[The grant money in the beginning lasted] 3 years. The investors that we did find . . . came in through my co-founding partner. . . . not when we started but later on . . .The first round was 600,000 in total. It's not that much. We had to go back for another round. That was August 2004. At the beginning of this year January 2006 we did an additional round with the same investors."	2007
		"We founded the company as a legal entity in 2003. There was no reason to do it earlier. . . . once we got the investors in that was the first time I was on the payroll of the company. Before that I was paid on the grant from the university."	

[i] The first round of fundraising is defined as external financing that is greater than £1 million, or €1.5 million.

Table A3
Data supporting categorization of paths to managerial development.

Type of path	Firm (year founded)	Data supporting the paths followed to managerial development during firm emergence	Year of establishment of functionally-diverse management team
Assisted			
Investor-appointed	UK-NEX (2002)	"... a group of people came together at the same time and that is how things got started." "... at the same time ... we purchased the technology, we actually transferred into the new company some of those employees that had actually worked on that technology ..."	2002
	UK-XOX (1999)	"The CEO was recruited with the help of recruitment agencies, headhunters and the investor had a big role in that." "... the first few months I was given a room at the university until things were sort of up and going. [It took] probably three to four months to hire the CEO... The second CEO was an executive of a listed US based company with a lot of operational experience in biotech in a closely related area. The third CEO diverse background at a mid size well established UK biotech. A few spells in VC areas, financing. He started beginning [of 2006]."	1999
	UK-OVE (1998)	"[The founders] were quite involved but they are both scientists and academics and what the original founding shareholders wanted is someone who could run the business." "[Investors] recruited our medical director who has basically been here since the beginning ... his background is big pharma...We brought [CSO] on because we wanted to kick start the research, And [another manager] as BD for licensing and partnering. ... I [CFO] joined in April 2004. I joined three months before the float ..."	1999
	UK-XSS (2001)	"[The co-founder] started working with me [academic founder] ... and he quit his job so that he could do the fundraising full time. He left about a year ago [2005]. We are a tiny company." "[The second CEO] joined at funding when [the investors] put some money in and part of the conditions of money going in was somebody like myself joining [the company]." Ultimately I [2nd CEO] am responsible operationally as chief executive. We have our CSO who is full time and employed by the company ... We have two people who are full time in the lab and we have an active on going collaboration with [academic founder] ... Our chairman is a physician and he has very hands involvement in any clinical development because that is his area of expertise. In terms of drug discovery, my background is in biology systems and [the CSO] is a chemist. So you have the two key components of how you discover drugs basically."	2006
	NL-EPP (1999)	"One of the first investors brought [the executive management] in. He brought in [business development] and he also brought in the previous CEO but that was a bit of a mistake. We had quite a number of mistakes before we ended up with the management team that we have now."	2003
	NL-VAA (2000)	"The founder/CEO left late 2002. Then we had a CEO-less period and then a CEO and then again a CEO-less period and then [the current CEO] in 2002. [CSO] is with us from the start, 1999. [The business developer] joined in 2003 and [operations manager] in 2000, just after the founding. [The current CEO] was headhunted. He was in [large chemicals firm]. I [business development manager] knew [the current CEO] before hand and the other VP from a previous employer but that does not preclude that we use headhunters."	2003
Founder-appointed	UK-XCI (1998)	"I wanted to hire [him] as CEO when we started but he couldn't leave [CEO's prior employer] at the time. He came on board later. The CEO started in 2004 but he was the chairman of the board since the founding. One of the clinical directors (regulatory) was a good friend of the CEO. The other director (clinical manufacturing) is an old friend [of the founder's] who approached [the founder] for a job. The commercial director was headhunted [2005]."	2000
	UK-GGF (1998)	"We had two founding directors for at least 2 ½ years and they were supported by an industry professional who worked for the company on an ad hoc basis. ... about three years in, we hired a CEO who had commercial and financial experience." "The first two employees were known to the founders, being experienced in the area of the original research ... one was from the University and one was from industry. The next two employees were also from the university, people that were experienced in the particular skills that were required."	2001
	NL-HTP (2001)	"[The CEO is the only founder, the sole founder.] We are a virtual, project management organization. First he hired the secretary. ... Then there was scientist from his department at [prior employer], Then he hired a CFO via a headhunter. I [the chief business officer] heard that he left [our prior employer] ... so I phoned him ..."	2002
	UK-PNI (1998)	"The first CEO had the antibacterial expertise and was found through [university] networks. He was a part time CEO ... in 2000, we had a new CEO, a full time CEO. ... the last CEO was a sort of a jobbing CEO within the biotech sector. He was more of a qualified CEO, from a public company. When we tried to appoint the last [3rd] CEO, the final one, [business development] was a key requirement..." "[CSO] joined the company in 2000, just before I joined, we had a new CEO, a full time CEO, join as well. (The CFO) was recruited in Jan 2001 ... to do the B round because they weren't having any success with it. I think at that point they had got a management team that was complete."	2001
	UK-KRA (1997)	"I [academic founder] was running the company and realized ... I didn't have the commercial focus and understanding of a CEO. At that time I was doing some work as a consultant for a drug company in Europe and their VP was working with me very closely and we got along very well. ... I said: would you be the CEO?"	1999

Table A3 (*Continued*)

Type of path	Firm (year founded)	Data supporting the paths followed to managerial development during firm emergence	Year of establishment of functionally-diverse management team
	UK-TRG (1998)	"In the beginning, there was basically two founders and the chairman came on board at that time. He's still the chairman and CEO now. There was an original chairman in the early days who stepped down or went elsewhere and then [the current one] came on board, ex analyst and broker worked in the pharmaceutical industry, one of his great strengths is that he has lots and lots of contacts in terms of raising finance." "I [CFO] came on board in 1999 which is after we floated on OFX but before AIM, which was 6 or 9 months later. End of 2000, [development director] came on board."	2000
	UK-SPE (2001)	". . . we have 30 people, probably 15 people have worked for me in my previous life. With my senior post doc who had been with me for about 10 years, we thought there was a business to be had providing that scientific know-how." "We have a finance director. We have an executive chairman. And my role until very recently effectively a CEO and CSO. I provide scientific direction for the two divisions. We have two managing directors that manage the two divisions [R&D and CRO services]. We have a research director who manages [R&D] on a day-to-day basis . . . we have a managing director and a commercialization director for that division. The [business development manager] started last September [2005]."	2005
	NL-RUC (1992)	"I've [recruited] very, very strong managers which is proven by the fact that those are the people who are still running this large company. I recruited them when we were still a small company . . . I used headhunters for most of those people . . ." "[First I hired] a business developer because I wanted to reinforce the business end of the company. [Then] the CFO, via a headhunter. Just prior to the acquisition and the IPO, the general counsel whom we found through the network of the CFO."	1996
	NL-MPA (2000)	"The first [hires] were ex-colleagues, people who were on the project. The first person I hired was the CFO. . . . my 2nd CFO was an introduction from [one of the investors]. Before [financing] I think two or three people came on board . . . the VP Scientific Applications, the inventor of the technology. . . . we started with 7 people in January. . . . there was an office manager and a few researchers. . .I had a VP Biz Dev, starting in 2002 . . ."	2002
	NL-ORP (2002)	"Just me [founder, CEO] at the founding. [The advisory board] had a lot of experience in the compounds . . . [and] . . . in starting up younger companies . . .. . .we have a research [head] coming in later this year [2007] . . . Then we have the development group [head] and . . . a clinical director . . . we have project managers and technical project managers . . . There is one major project director . . . we have a lawyer . . . we have a quality control . . . we have a financial CFO type, he is not on the payroll but I am hiring him. He is too expensive for us right now but the new money comes in I have to hire one of those types of guys."	2007
Parent-appointed	NL-PMA (2000)	"I [1st CEO] ran a small venture capital fund. I was approached by the Free University [to head up NL-MPA] because they had invented [technology] and patented their invention." "Then 2nd CEO came along and he stayed there for a year and then the (3rd CEO) came and he stayed for a year. The first one was one of the founders. The second [CEO] stepped down. The third one was German but he was recruited away [poached] after one year. He was interim CEO who then turned into CMO. And then we have [the current German CEO]. We had three Dutch and two German [CEOs]."	2002
	NL-LAG (1998)	"We [CEO of parent firm] recruited the guy to run the division who would become the CEO of that company. [The CEO] worked as [the head of the division in the parent firm] for a year and half working with us to spin it out."	1999
	UK-XTG (1997)	"The [TTO] provided a managing director. They also provided a financial director and a part time project manager. . . . the CEO was a bad appointment and when we were going through the last investment round . . . the leader of the group said we do want to go forward with this but we don't want to have your current CEO. That was fine by me; if they want to invest without him, then we'll get rid of him. During the process of things I met the man who is the current CEO . . ." "There were four when we were doing this work between 1996 and 1999 . . . By 2004 I had seven in the lab . . .We are on our 3rd CEO now."	2000
	UK-XOR (2004)	"[University TTO partner] put one of their people in place to look after us, a guy, who has now gone off to run a [another biotech] company. . . . he sort of came in and pushed us all around. There were some important steps to go through; the college . . . had a very limited history of spin outs . . ." "[The interim CEO] was appointed in 2004 . . . and we started a number of research programs. Then we recruited a CEO . . .We recruited another key member of the team, who had first year drug development experience. I [academic founder] had the research experience and he, who I had known for a long time, had the drug development experience . . . we transferred over most of the long established staff [the university lab employees]."	2004
	UK-SAV (2003)	". . . I wanted to take some people who were working with [university TTO partner] and use them as my management team. . . . they put in the full management team until we went public. . .What we actually did was take the CEO,. . .so we stole him. We set up in March and by August I persuaded this guy to come in and be the CEO."	2003
	NL-RIV (2002)	". . . the university asked me . . . can you structure this? They needed management; they needed structure." "I'm the CEO, responsible for more business decisions, more strategic decisions. Most of the work is done by the deputy CEO. He is supported by a full time legal assistant because we have so much deal flow and documents that we really needed a full time legal person. . . ."	2004

Table A3 (*Continued*)

Type of path	Firm (year founded)	Data supporting the paths followed to managerial development during firm emergence	Year of establishment of functionally-diverse management team
Founders-diverse	UK-RAS (2003)	"We were part of a big company, an American company. They shut down the UK site . . . we all worked in the same department at [prior employer] and we all worked very well together. [The CEO] was our boss at [prior employer]. When we founded the company, there were just the three of us."	2003
	UK-SXD (2000)	"We were working for [large pharmaceutical]. [The founder CEO] was in charge of R&D at [prior employer] and I [CSO] was in charge of, below him, the technology development assessment. We'd become aware of a finance accountant [and] asked her whether she was interested in joining. We three were the three founders and we put our redundancy package into the funding. And then we recruited the business development director later in the year once the business was founded."	2001
	NL-TOC (1995)	"We knew each other for a long time . . . He [CEO] wanted to start his own business . . . he is an entrepreneur . . . [a] pharmacist, a scientist; he has his PhD and worked for an American company in Amsterdam. [But] he also needed academic information, know how and network . . . we sat together and we worked out a plan." "I stayed at the university but I got a number of hours to work at NL-TOC. [As academic founder and CSO for a day a week] I didn't do any management at any time. I tried to help with sales acquisition in the beginning, provide scientific know-how, also at a very operational level in the beginning." "There was no scientific director. Later [one was hired to] lead the new technology department. [That was] 4 or 5 years ago. [Up until that time the CEO was managing the science and] there were project managers. It was a very flat organization."	2001
Unassisted Founders-limited	UK-YLP (2001)	"I [academic founder] put in as much time now as I did before but, before when we were directors and legally liable, we [academic founders] were more involved in managing it. Now [the current CEO] is managing it. He basically came on as CEO [2006] and we left the board. He was hired by the [seed fund] as the entrepreneur in residence. He is a part time CEO for [UK-YLP] and he is also part time CEO for two other companies."	2006
	NL-AREK (1990)	"My co-founder and I were head of experimental pathology department at the Academic Medical Center in Amsterdam. One of the demands of the business angel was we should stop every other job and be 100% dedicated to NL-AREK." "Until 2001, he was CEO and then we had a management change and he was until 2003 scientific officer and then he left the company. He disagreed with the strategy that we developed between 2000 and 2003."	–
	NL-KLA (2005)	"We are with 3 or 4 co-founders in which the content part is by this university professor and myself and the financial part is by the other one. . . [the professor] is writing some of the proposals that we want to submit to get grants. He is guiding the students [the two at the university]. We are, let's say, the scientific heart of the company." "We have [in the university] two people who are involved [in doing clinical trials] and we have a CRO. . . . we attracted a part time CEO . . . he is now involved since Feb [2007] in this company. Because we think it is not yet necessary to have full heads, financial or CEO functions at this moment."	2007
	NL-QIP (original firm 1992; re-established in 1999)	"I [current CEO] started to work for [the seed fund that invested in NL-QIP] and . . . the guy that should have run the company and the company didn't really match . . ." "There were only 2 people working there. . .I [current CEO] started working there part time. . . . in 93 . . . in 1996 started to work there full time . . ."	1996
	NL-AIK (1997)	"The [current] CEO started in 2004 . . . she started as a business developer for the first year . . . and at that time the [2nd] CEO left the company. He was CEO for a few, two or three, years." Preceding the 2nd CEO, the founders formed the management team from 1997 to 2001.	2002
	UK-XHP (2002)	"I [founder, CEO] met a colleague [co-founder] at [prior employer]. My [co-founder] is working as the managing director so there is a role for a CSO but for the moment he is covering that one. . .Three PhDs in the lab . . . analytical, in vitro and in vivo and each of those has one person in them."	–
	UK-NGP (2001)	"There were three of us . . . one [co-founder] disappeared to some extent for the last few years because he was in Maryland . . ." ". . . the day-to-day running of the company and technical development is me [co-founder, CEO]."	–
	NL-KYS (2004)	". . . during the same time that we got the grant it was decided that we would found a company We have somebody who is a technician who is doing the contract research [in the lab at the university]" ". . . basically I [founder, CEO] was involved and am still involved as a CEO and there were 5 additional scientists who became the founders and the university."	2008
	NL-BRN (2003)	"I had someone helping me . . . I needed an external person next to me to negotiate with the university because I was totally dependent on the university that gets the grant money . . . when we got to the point of spinning off the collaboration, we already decided that we would continue to do it together and he would become a shareholder and part of the management." "One of the other founders is the scientific head of the research program. [He is an] academic partner . . . what we do with him is apply for research grants, academic grants. Financing and business development is mostly by my partner."	2010

Table A3 (*Continued*)

Type of path	Firm (year founded)	Data supporting the paths followed to managerial development during firm emergence	Year of establishment of functionally-diverse management team
	NL-OIB (2003)	"At that time we started with 8 people who were employed at another company, myself and [a co-founder] were together the management of [prior employer] and we asked people we already worked with to join us. The management team is me. . . . but to other companies and to VCs it is important to have somebody who can call themselves a CSO. [Another founder] is not really employed here but he is still involved." "In the relocation we lost 2 employees and founders because the travel was too far, they stepped out . . . there are now only 4 founders with us of which I am still the director."	–

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