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ORIGINS AND OUTCOMES: THE ROLES OF SPIN-OFF FOUNDERS AND INTELLECTUAL PROPERTY IN HIGH-TECHNOLOGY VENTURE OUTCOMES

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Spin-off firms originate from several sources including universities, existing firms, and government research centers. Thus far, work on spin-off activity has focused on factors that influence the creation and performance of corporate spin-offs, with recent attention turning to those from universities. Spin-offs from government laboratories and research centers have largely been overlooked. Additionally, little work has compared the outcomes of different spin-off types. Using a database of all nanotechnology firms founded between 1981 and 2002, this study examines academic, corporate, and government spin-offs as well as other start-ups across five outcomes including firm cessation, acquisition, liquidation, bankruptcy, venture capital, and government small business innovation funding. The data show that lineage, both in terms of intellectual property and founder background, does influence outcomes; however, each type of firm origin has provocative distinctions. These findings unpack the categorization of spin-off firms to clarify the role of early knowledge transfer mechanisms and initial resource portfolios. Implications for the study of microfoundations of entrepreneurship are discussed.

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Editor's Comment

The article by Woolley sheds light on the importance of various foundational inputs that can be used in spin-off companies. Based on an excellent blending of well-established ideas for some inputs and intuitive claims for others, the author investigates a complex array of possible effects on several indicators of success in spin-offs. The empirical findings reveal, among other things, that intellectual property and founders from government are quite important. These findings have obvious implications for future theory building and empirical work in the spin-off research stream, where such government origins have played relatively minor roles. As important, the findings have implications for a number of other research streams where the backgrounds of individuals and the sources of entrepreneurial ideas play key roles.

C. Chet Miller, Action Editor

INTRODUCTION

Firms that develop from other organizations, often called spin-offs or spin-outs, are a mainstay in industry creation, market growth, innovation, employment and economic development (Callan, 2001; Dahl & Sorenson, 2014). For example, much of the early semiconductor industry in Silicon Valley was created through spin-offs from Fairchild Semiconductor and Shockley Transistor (Cheyre, Kowalski, & Veloso, 2015; Klepper, 2010; Saxenian, 1994). Indeed, high-technology industries are particularly prone to spin-off activity (Agarwal, Echambadi, Franco, & Sarkar, 2004). As such, spin-offs are important to economic growth, technology development, diffusion, and commercialization. Given the significance of spin-offs, it is not surprising that they have been well researched. What is surprising is that much of our understanding is based on work that treats spin-offs as a relatively uniform group or focuses on either academic or corporate spin-offs, with fairly little attention to spin-offs with other origins.

A few recent studies compare the attributes and performance of different types of spin-offs, with an emphasis on academic vs. corporate spin-offs. This stream of research tends to use the knowledge-based view to specify how the foundational knowledge imprinted on spin-offs by their parent organizations at start-up influences the spin-offs' outcomes (Lockett, Siegel, Wright, & Ensley, 2005). For example, Wennberg, Wiklund, and Wright (2011) argue that the commercial knowledge inherited by corporate spin-offs results in higher growth and survival rates when compared to academic spin-offs lacking such experience. Similarly, Clarysse, Wright, and Van de Velde (2011) argue that corporate spin-offs benefit from their superior industry knowledge to target specific markets, whereas academic spin-offs may benefit from having a broad technology with many applications. Differences in knowledge conversion capabilities of academic and corporate spin-offs lead to variations in productivity, profitability, and revenue growth (Zahra, Van de Velde, & Larraneta, 2007).

> Author's voice:
> What motivated you personally to undertake this research? Why is it important to you?

Although previous work has provided insight into the knowledge-based differences and similarities of academic and corporate spin-offs, many questions remain. First, organizations other than universities and firms spin-out companies, yet there is a dearth of research on spin-offs from other types of organizations (Clarysse & Moray, 2004). For example, government research centers and laboratories generate technology and intellectual property (IP) that is used to establish new firms (Mowery & Ziedonis, 2001). In 2014, the U.S. government funded 25 national R&D centers, 10 system analysis centers, and 6 system engineering centers (National Science Foundation, 2014b), with annual federal funding ranging from about $3 million to $2.3 billion (National Science Foundation, 2014a). These research centers and labs explore a wide range of technologies, but do not seek commercialization, leaving that objective to their spin-offs. Examples of such spin-offs include Amtech from Los Alamos National Laboratory, MEMX from Sandia National Laboratory, and Sion Power from Brookhaven National Laboratory. In fact, between 1997 and 2008, Los Alamos National Laboratory alone enabled over 50 spin-offs (Engardio, 2008). Nevertheless, spin-offs from government facilities are not well represented in the literature compared to other types of spin-offs (Carayannis, Rogers, Kurihara, & Allbritton, 1998; Malo, 2009; Rogers, Takegami, & Yin, 2001). Given their active and unique role in entrepreneurship and technology transfer, government spin-offs warrant additional consideration.

Second, studies tend to focus on a single type of spin-off with little research comparing the varied origins of different spin-off types. No studies to date have compared the outcomes of academic, corporate, and government spin-offs. The dearth of comparative empirical work in this area limits our comprehension of factors that influence a firm's success, particularly aspects related to technology and knowledge transfer.

This brings us to the third set of unresolved research questions regarding the current conceptualizations of spin-offs. Researchers continue to identify spin-offs as firms started using any technology, knowledge, or idea from another organization, measured by one of two conduits: the origins of the IP being transferred *or* the employment of the spin-off's founders by the parent organization (Clarysse & Moray, 2004). However, knowledge transfer *via* changing IP ownership is much different than that which occurs when a former employee starts a new organization since, for instance, these founders bring tacit knowledge that is much more difficult to transmit than codified IP (Knockaert, Ucbasaran, Wright, & Clarysse, 2011). Our current treatment of spin-offs does not distinguish between these two mechanisms and their potential roles in firm outcomes.

This study examines these research questions by focusing on the characteristics and outcomes of start-ups and spin-offs from three different origins: those from universities, firms, and the government. The article begins with a review of work on academic and corporate spin-offs. Next, the insights from these literature streams are integrated with findings from the fairly limited work on government spin-offs to summarize the current state of understanding. Although the existing state of affairs yield some firm expectations for what will be found in an empirical examination, it also highlights some looser speculations in areas of limited past work and inadequate applicable theory. Thus, the article empirically examines the relationship between a firm's origins and its outcomes using a database of nanotechnology firms that were founded between 1981 and 2002. This setting was chosen since nanotechnology is being researched in universities, firms, and government labs, as well as independent start-ups, providing the ability to compare start-up origins in a single domain of activity. The study delineates spin-off origins by source of foundational IP and the composition of the founding teams. The data are analyzed using five types of firm outcomes: closure, liquidation or bankruptcy, acquisition, obtaining venture capital (VC), and receiving government grants. The findings highlight the heterogeneity of spin-offs and the variety of outcomes that they experience. Significantly, the source of a spin-off's IP and the background of its founders, even if they have similar origins (e.g., both from existing firms), may act as distinct and sometimes opposite forces in the outcomes of their firms. For instance, firms based on academic IP are more likely to obtain government Small Business Innovation Research (SBIR) or Small Business Technology Transfer (STTR) grants, whereas those with university founders are less likely. At the same time, firms based on government IP are less likely to obtain such government funding, whereas those with more government founders are more likely. These findings suggest that, indeed, all spin-offs are not created equal and should not be treated as homogeneous. In fact, firm's IP and founders influence its success in distinct and provocative ways that are not well explained by current theory (Helfat & Lieberman, 2002).

Author's voice:
Was there anything that surprised you about the findings? If so, what?

The discovery that variation in spin-offs' origins influences firm outcomes (i.e., corporate vs. university vs. government origins) points to several opportunities for new research. Specifically, comparing the influence of lineage on firm success provides empirically based insight into decision-making by investors with spin-off-related opportunities. I argue that using a stakeholder perspective, such as examining the characteristics of the foundational technology, its adoption, the investors or the motivations and goals of firm founders, will provide more granular insights into how a new venture's resource portfolios and microfoundations influence the development of the firm. I further argue that integrating a stakeholder perspective, such as the motivations of acquiring firms and venture capitalists, can clarify the market for nascent technologies and the perceptions of market participants. Thus, this study explicates the microfoundations of entrepreneurship by deconstructing firm origins and exploring both the supply and demand sides of firm outcomes.

BACKGROUND

Spin-offs are created when IP, technology, or knowledge, codified or tacit, is transferred from one source, such as a firm, university or government research center, to form a new organization (Clarysse & Moray, 2004; Parhankangas & Arenius, 2003; Agarwal et al., 2004).[1] This transfer can occur formally (e.g., licensing agreements or patent transfers) or informally (e.g., inherited knowledge from a founder's previous work experience). As such, the common conceptualization of spin-offs highlights two

[1] Firms with origins in another organization have been called many things including spin-off, spin-out, progeny, and spawn (Dahl and Sorenson, 2014). The literature is confusing since both spin-offs and spin-outs have been associated with employee-based or incumbent firm-backed firms (see MacGregor & Madsen, 2016). Since this study focuses on the transfer of IP and knowledge from one organization and into a new one, I use the term "spin-off."

components: the foundational IP and the founding team that is transferring and acting on knowledge to start the new firm (Clarysse & Moray, 2004). These components are often used as binary conditions such that if a firm has IP *or* founding team members from a university or existing firm, the spin-off is categorized as academic or corporate, frequently without regard to the type of technology or knowledge transfer mechanism involved.[2] This is problematic since it aggregates two very different independent forms of knowledge transfer. IP pertains to work or inventions outside of the mind of the inventor that can be protected by law, whereas a start-up founder is an entrepreneur who starts a business. As such, the IP on which a firm is built does not need to be invented by the founder and a start-up entrepreneur has a background and experiences not captured in codified IP. Thus, IP and founders provide opportunities for heterogeneity in the resulting start-up firms. Indeed, start-ups founded by professors but lacking formal university IP may act differently than firms based on a technology license from a university, but which lack academic founders. To better explicate the potential differences of each knowledge transfer mechanism, I first unpack the current literature. Work on start-ups' IP and founding teams serves as a starting point for this study.[3] The following section disaggregates work on IP and spin-off founders to guide the empirical examination of the relationship between origins and outcomes (Tables 1 and 2).

IP and Knowledge

Spin-offs are often defined by the source of the technology and knowledge on which the firm is based, including patents, trade secrets, processes, and tacit information, which can be thought of more generally as the *foundational IP*. This IP is a resource gained upon creation. Table 1 summarizes work on the influence of IP origins on start-up performance. In most cases, studies compare firms with academic or corporate technology origins with start-ups using internally developed IP (independent from any parent). Rarely do studies compare the different types of origins across IP type or include start-ups using IP from government.

Universities are fountainheads of innovation and technology. Increasingly, universities are using a variety of technology transfer mechanisms to benefit from IP created therein (Friedman & Silberman, 2003). Academic spin-offs have been a key element in such university efforts. Indeed, academic spin-offs have become important contributions to not only university funding and technology development, but also the economic health of nations (Friedman & Silberman, 2003; Vincett, 2010). Academic spin-offs can be based on IP generated from university research, which affords several advantages and disadvantages. For example, the IP on which academic spin-offs are founded is often cutting edge (Wennberg et al., 2011), which can provide a competitive advantage in the market, particularly in emerging domains of technology. Cutting-edge IP may also provide the basis for technology standards on which a nascent market is derived. Spin-off firms can use such IP to achieve market dominance and a first-mover advantage (Lieberman & Montgomery, 1988). Still, academic IP is likely to be far from ready to commercialize (Jensen & Thursby, 2001; Rothaermel & Thursby, 2005; Shane, 2000; Thursby, Jensen, & Thursby, 2001), which hinders a firm's ability to enter the market or survive. Pioneering technology can be too far ahead of its time if a supporting supply chain has not been developed (Woolley, 2010, 2014). Additionally, academic spin-offs are based on ideas created in a noncommercial environment (Bathelt, Kogler, & Munro, 2010) and invented with less regard for market application (Wennberg et al., 2011), particularly when compared to IP generated from corporate R&D that is market driven. As such, university-based inventions are considered high risk (Rothaermel & Thursby, 2005), which can deter investors who view corporate spin-offs more positively (Munari & Toschi, 2011; Schipper & Smith, 1983; Seward & Walsh, 1996). This reduces the likelihood that academic spin-offs obtain funding (Clarysse, Wright, Lockett, Mustar, & Knockaert, 2007). Being perceived as riskier than other ventures can also reduce a firm's ability to survive.

Entrepreneurs also form spin-offs using IP from existing firms. The knowledge-based view of entrepreneurship emphasizes the role of corporate spin-offs in providing incumbent firms with the opportunity to transfer a technology to a new firm where it can be explored outside of the confines of the existing organizational structure (Agarwal et al., 2004). In contrast to academic spin-offs, the IP on which corporate spin-offs are founded tends to be applied R&D (Singh, Tucker, & House, 1986), created with the market in mind, and tends to be closer to commercialization (Chatterji, 2009; Wennberg et al., 2011). As such, IP

[2] Some work identifies spin-outs as firms started by employees of incumbent firms (Agarwal et al., 2004; Franco & Filson, 2006), whereas others calls these spin-offs (Dahl & Sorenson, 2014; Klepper & Sleeper, 2005; Klepper, 2010).

[3] This study focuses on *de novo* start-ups and excludes de alio ventures that are diversifying entrants or subsidiaries from existing firms, joint ventures, and franchises. As spin-offs are new entrants to a market rather than diversifying entrants, they are considered *de novo* firms (Carroll, Bigelow, Seidel, & Tsai, 1996). This study compares the various origins of *de novo* spin-off start-ups with those that are not a spin-off as a referent category.

TABLE 1
Summary of Work on IP Origins of Start-Ups

	Benefits	Examples of Related Work	Disadvantages	Examples of Related Work
Academic	Main type: basic research			
	Cutting-edge technology and IP	Wennberg et al. (2011)	Ahead of market readiness	Woolley (2010, 2014)
			Not invented with market in mind	Wennberg et al. (2011)
			Far from commercialization	Jensen and Thursby (2001), Shane (2000), Rothaermel and Thursby (2005), Thursby et al. (2001), Clarysse et al. (2011), Wennberg et al. (2011)
			Originate in a noncommercial environment	Bathelt et al. (2010)
			Considered high risk	Rothaermel and Thursby (2005)
Corporate	Main type: applied R&D			
	Created with market in mind	Singh et al. (1986)	Lack of outsider perspective	
	Closer to commercialization	Chatterji (2009); Wennberg et al. (2011)	IP from small markets deemed unappropriable	Bruneel et al. (2013)
	Investors perceived as less risky	Schipper and Smith (1983); Seward and Walsh (1996)		
Government	Main type: basic and applied R&D			
	Progressed beyond basic science toward application	Bozeman (2000)	Focused, application specific to government market	Rogers et al. (2001)
	Focused, application specific to government market	Rogers et al. (2001)	Not adaptable to other markets	Rogers et al. (2001)
	Complex and large scale	Hruby et al. (2011)	Unclear market potential	
	Patent quality has improved slightly over time	Jaffe and Lerner (2001)		

originating from existing firms is perceived as being less risky (Rothaermel & Thursby, 2005). However, this IP is not risk free. For example, firm-based IP is often generated with little outsider perspective. A lack of external input can result in products that do not meet the needs of the end user, thus limiting the prospects for adoption. Another risk is that parent firms sometimes divest IP into new ventures when it is believed that the resulting products have small markets or insufficient opportunities for value capture (Franco & Filson, 2006). This IP may be deemed as inferior and, thus, not worth further investment (Bruneel, Van de Velde, & Clarysse, 2013). Spin-offs based on IP that another firm has determined to be inferior may struggle with its commercialization.

Spin-off activity from government research centers and labs has comparatively little representation in the entrepreneurship literature, despite the prevalence of such activity (Carayannis et al., 1998). In fact, Smith and Ho (2006) found more spin-offs from public labs than from universities in the Oxford area of the United Kingdom. Government labs are involved in a range of R&D projects from fundamental sciences to commercially oriented research. Thus, government research centers and labs create technology with elements similar to both university and corporate R&D. Government R&D tends to focus on specific applications of basic science work, usually based on a proof of concept, to get government funding (Rogers et al., 2001). Thus, these projects are closer to commercialization than academic projects based on scientific research. On the other hand, government labs are oriented more toward basic research than corporate labs (Bozeman, 2000) since corporate labs are conducting R&D on commercializable technology, whereas government labs conduct research to solve current problems faced by the government that may not have immediate commercial opportunities. For example, NASA scientists invented a padding material in the 1960s to ensure the safety of astronauts; many years later, this "temper foam" material became widely used in bedding, helmets, and wheelchairs.[4]

Government projects also tend to address complex and large-scale problems that are considered high risk (Hruby, Manley, Stoltz, Webb, & Woodard, 2011). Projects to tackle these grand challenges can generate IP that has both public and private values.

[4] See https://spinoff.nasa.gov/ for more information on their spin-off technologies.

TABLE 2
Summary of Work on Founding Teams and Spin-Offs

	Benefits	Examples of Related Work	Disadvantages	Examples of Related Work
Academic	Scientists and other academic founders			
	Advanced education	Burton et al. (2002), Wennberg et al. (2011), Watson et al. (2003), Sapienza and Grimm (1997)	Often requires continuation of academic founders	
	In-depth technical knowledge	Ding and Choi (2011); Clarysse et al. (2011)	Lack industry knowledge and experience	Clarysse et al. (2011), Wennberg et al. (2011), Zahra et al. (2007), Ensley and Hmieleski (2005), Clarysse and Moray (2004)
	R&D network	Lofsten and Lindelof (2005); Murray (2004)	Lack commercial goals/incentives	Ensley and Hmieleski (2005), Clarysse and Moray (2004), Roure and Keeley (1990)
			Lack entrepreneurship experience, opportunity recognition or exploitation skills	Duchesneau and Gartner (1990), Stuart and Abetti (1990), Franklin et al. (2001)
			Homogeneity leads to reduced decision-making efficacy	Ensley and Hmieleski (2005), Ruef et al. (2003), Beckman et al. (2007), Fesser and Willard (1990), Visintin and Pittino (2014)
			Lack industry network	Zahra et al. (2007), Shane and Stuart (2002), Walter et al. (2006), Mosey and Wright (2007)
			Difficulty developing social capital	Nicolaou and Birley (2003), Corrolleur et al. (2004), Mustar et al. (2006), Mosey and Wright (2007)
Corporate	Former employees of incumbent firm			
	Heterogeneous	Ensley and Hmieleski (2005); Ruef et al. (2003); Beckman et al. (2007)	Lack technical proficiency	
	Industry experience	Fesser and Willard (1990); Klepper and Simons (2000); Colombo and Grilli (2005); Colombo and Piva (2012)	Myopic industry knowledge and experience	
	Industry and market knowledge	Agarwal et al. (2004); Klepper and Sleeper (2005); Wennberg et al. (2011)		
	Network and social capital with industry and former co-workers	Yli-Renko et al. (2001); Shane and Stuart (2002); Higgins and Gulati (2003); Sapienza et al. (2004)		
	Ties with VC	Shane and Stuart (2002)		
Government	Former government employees			
	Team supported by centers with considerable resources	Carayannis et al. (1998)	Lack of business knowledge and commercialization experience	Audretsch et al. (2002), Ensley and Hmieleski (2005), Zahra et al. (2007)
	Concentrated government network		Concentrated government network	
	Relationship with government customers		Limited network scope	

Given that the funding and stimuli for these projects often comes from government agencies, the IP generated frequently focuses on government applications (Rogers et al., 2001). This specialization may limit the market to which the technology can be applied; however, start-ups based on IP with government origins can benefit from targeting the sizeable existing government market. For example, R&D projects at government facilities are created in response to a problem that has already been deemed significant by a government agency. During these projects, agency experts provide feedback to ensure maximum applicability and adoption. As such, the IP generated targets a particular use case that has been vetted by potential customers. This process can focus the technology on government applications that differ from those in the general market (Rogers et al., 2001). Although the quality of patents from government organizations has improved over time (Jaffe & Lerner, 2001), these patents are typically focused on government customers and may not be adaptable to other markets (Rogers et al., 2001).

In summary, each source of IP and knowledge, academic, corporate, government or internal, has its own advantages and disadvantages. The founding team that can act as a transmission mechanism of such IP is heterogeneous as well, with its own set of advantages and disadvantages. In some areas, existing work and ideas suggest clear expectations for empirical outcomes, whereas in other areas, the outcomes remain uncertain. The next section explores the role of founding teams in knowledge transmission and how they affect the firm's outcomes.

Founding Team

Spin-offs are also defined by their founding teams' human capital as social actors and knowledge transfer agents. Most research examining founding teams, particularly spin-off teams, is based in top management team and knowledge-based view perspectives. The top management team literature emphasizes the role of human capital demographics in firm success, whereas the knowledge-based view links a founder's expertise with the ability to lead high-potential ventures (Wennberg et al., 2011). Both perspectives argue that a firm benefits by having a strong fit between the founders' backgrounds and education and the firm's technology and industry. These arguments and related empirical work are discussed here. Table 2 summarizes work on the role of the founding team on spin-off performance.

Start-ups benefit from having professors and researchers on their founding team since academic founders bring advanced education (Burton, Sørensen, & Beckman, 2002; Sapienza & Grimm, 1997; Watson, Stewart, & BarNir, 2003; Wennberg et al., 2011) and in-depth technology knowledge (Clarysse et al., 2011; Ding & Choi, 2011). An academic founder's education and tacit knowledge about the firm's foundational technology can help to establish a competitive advantage in the market and to sustain further product development. Academic founders also bring network ties that are particularly rich in R&D knowledge (Lofsten & Lindelof, 2005; Murray, 2004). Academic entrepreneurs may act as facilitators of precommercialization research that traditionally does not fit either the role of the university nor the commercial firm. This is a scarce skillset that benefits the spin-off and thereby improves its likelihood of success.

However, although academic founders provide skills and knowledge that can create a competitive advantage, they may constrain the start-up activity. For one, by being among the few people who understand the important tacit knowledge on which the firm is founded, they are embedded in the fabric of the firm and their continued involvement is required. If the technology on which a firm is founded is controlled by one academic founder, the firm's growth prospects are limited. Also, academic founders often lack industry experience, which limits market knowledge (Ensley & Hmieleski, 2005; Wennberg et al., 2011; Zahra et al., 2007). Academic inventors, due to commercial inexperience, may overemphasize the technical aspects of the innovation instead of business viability leading to inefficient resource expenditures. Similarly, academic founders may not have the commercial goals and incentives to bring inventions to market, particularly if they remain employed at the university (Clarysse & Moray, 2004; Ensley & Hmieleski, 2005; Roure & Keeley, 1990). Academic founding teams often lack entrepreneurial experience, which can limit their opportunity recognition or exploitation skills and impede the firm's development (Duchesneau & Gartner, 1990; Franklin, Wright, & Lockett, 2001; Stuart & Abetti, 1990). Managers are commonly missing from academic founding teams, which dissuades investors because of the team's lack of industry experience (Clarysse & Moray, 2004). All of these deficiencies can be the source of conflicts between founders and investors and may slow product development, thus impeding a firm's likelihood of success.

The top management team literature has identified that heterogeneous founding teams perform better than those that are homogeneous. Visintin and Pittino (2014) find that heterogeneity in the founding teams of university spin-offs exhibit superior employee and sales growth. However, academic spin-offs tend to have homogeneous founding teams in terms of education and experience, which leads to the lack of diversity in knowledge and skills (Beckman, Burton, & O'Reilly, 2007; Ensley & Hmieleski, 2005; Fesser & Willard, 1990; Ruef, Aldrich, & Carter, 2003). Such founding team homogeneity can reduce the efficacy of their decision-making. Further, academic entrepreneurs often lack an industry network (Mosey & Wright, 2007; Shane & Stuart, 2002; Walter, Auer, & Ritter, 2006; Zahra et al., 2007) and have difficulty developing social capital in the market (Corrolleur, Carrere, & Mangematin, 2004; Mosey & Wright, 2007; Mustar et al., 2006; Nicolaou & Birley, 2003). A founding team with a homogeneous network that lacks industry ties and social capital impedes a firm's ability to obtain resources needed for developing and commercializing products. Thus, academic spin-offs can be hindered by the very people that make them special.

In contrast, the founding teams of corporate spin-offs are more heterogeneous and have more industry savvy than those at academic progeny. This heterogeneity can lead to better decision-making by including a wider range of voices (Beckman et al., 2007; Ensley & Hmieleski, 2005; Ruef et al., 2003). The founding teams of corporate spin-offs also have industry experience (Colombo & Grilli, 2005; Colombo & Piva, 2012; Fesser & Willard, 1990; Klepper & Simons, 2000) that generates market knowledge benefiting their spin-offs (Agarwal et al., 2004; Klepper & Sleeper, 2005; Wennberg et al., 2011).

Corporate spin-offs also benefit from the networks of their founding teams. Founders from firms are more likely to have industry-related networks (Higgins & Gulati, 2003; Yli-Renko, Autio, & Sapienza, 2001), including social ties with former co-workers (Sapienza, Parhankangas, & Autio, 2004) and potentially the VC community (Shane & Stuart, 2002). As mentioned, academic founders are more likely to have R&D-related networks (Lofsten & Lindelof, 2005; Murray, 2004). Although both types of networks can be useful, corporate spin-offs benefit commercially from relationships with customers and market knowledge. Similarly, corporate spin-off founders often have social capital related to industry such as ties with VC investors (Shane & Stuart, 2002). Thus, corporate spin-offs have a higher likelihood of success than those from universities (Lindholm Dahlstrand, 1997). However, founders with business backgrounds are not without disadvantages. For example, the heightened industry experience may come at the expense of technological proficiency. Similarly, heightened industry knowledge and experience can prove overly focused resulting in missed opportunities. Despite these challenges, founding teams with business experience and networks tend to be better suited for venture survival and growth.

The founding teams with government research center and lab origins are unusual in that they tend to be composed of federal employees who leave relatively secure positions at facilities that have considerable resources (Carayannis et al., 1998). These founders worked in supportive environments with a range of resources, including those at other government research centers. Therefore, government founders may have inexperience with harsh start-up conditions, such as limited resources, which can prove particularly detrimental to the firm. Government founders may also have less business experience than founders of corporate spin-offs (Audretsch, Link, & Scott, 2002) and less business knowledge (Ensley & Hmieleski, 2005; Zahra et al., 2007). Government founders tend to have networks concentrated in government relationships with fewer ties in industry, which limits the market and funding opportunities for the firm. However, a well-established network with the government market is useful for firms in industries that target government customers (e.g., defense-related industries). Thus, spin-offs with government founders are both helped and hindered by the founders' focused knowledge and experiences (Table 3).

Synthesis

As discussed, each type of IP and founder has its own set of advantages and disadvantages. Table 3 summarizes the IP and founding team characteristics of different types of start-ups. In general, start-ups with IP foundations based on technology or knowledge spun out of existing firms or those that create their own IP are likely to have a strong market orientation, shorter time to commercialization, more focused application and lower perceived risk (Rothaermel & Thursby, 2005; Schipper & Smith, 1983; Seward & Walsh, 1996). Since venture capitalists look for firms with strong market opportunities and less risk, it follows that start-ups using IP from another firm or internally generated IP are more likely to obtain VC funding (Munari & Toschi, 2011). Similarly, firms based on commercial knowledge inherited from parents may close less often than spin-offs with academic origins (Wennberg et al., 2011).

Although we know a lot about spin-offs and their characteristics (Tables 1 and 2), we do not have a strong understanding about how these similarities and differences might translate into other variations in performance. Take, for instance, a firm's likelihood of being acquired. Firms that have market ready technology are desirable acquisition targets for firms looking to enter the market or complement their own portfolio. Alternatively, because academic and government IP tends to be basic science and early-stage applied R&D, spin-offs based on such IP need more resources and time to reach commercialization. Thus, the earlier stage of technology often pursued by academic and government research may not foster firms that are desirable acquisition targets and may challenge their longevity.

Author's voice:
Table 3 - Origins and Outcomes

TABLE 3
Overview of Start-Up and Spin-Off Characteristics

		Foundation			
		Academic	**Corporate**	**Government**	**Non-Spin-Offs**
IP	Type	Basic sciences and applied	Applied R&D	Basic sciences and applied	Applied R&D
	Market orientation	Low	Strong	Medium	Strong
	Time to commercialization	Long	Short	Short-Medium	Short
	Market application	Technology based, industry agnostic	Industry or application specific	Applied or government related	Industry or application specific
	Relative perceived risk	High	Low	Medium	Medium
Founders	Profile	Professors, scientists	Business	Scientists, government	Mixed
	Education	Extensive	Mixed	Mixed	Mixed
	Industry knowledge	Low	High	Mixed	High
	Network focus	Academia	Industry	Government	Industry
	Technological proficiency	Scientific	Applied	Mixed	Applied

Considering the background of a start-up's founding team, those with founders from established incumbent firms benefit from those individuals' previous market experience and industry network. More broadly, start-ups that are spin-offs from existing firms tend to have a stronger portfolio of knowledge-based resources for success. Logic indicates that firms based on either IP from another firm or that have a founder with business experience have the foundation needed to support their ability to obtain VC funding and be acquired. Thus, these firms should be less likely to go bankrupt or liquidate their assets. Firms with academic founders, on the other hand, benefit from those individuals' extensive education and technological proficiency. Thus, the experience of academic founders may shield such start-ups from negative closures as well. Conversely, government founders may not have the business experience nor technological expertise necessary for firm survival and growth. Given the lower levels of business experience and market readiness, government spin-offs may be the least likely to survive overall.

Firms based on IP from government labs must negotiate the transfer the technology from the government. Venture capitalists focus their efforts on fields in which they have experience and few have experience with government research. Thus, firms based on government IP may be less attractive to venture capitalists. Indeed, the first VC fund dedicated to government start-ups, Govtech, was created in 2014. The process of technology transfer can prove challenging given the bureaucracy inherent in government, which may reinforce the unattractiveness of the IP. Likewise, networks are critical to obtaining VC due to the necessity for relationships and trust between the funders and founders. Start-ups with government founders may lack the connections needed to facilitate VC, but government funding may be easier to obtain.

Thus far, IP and founders have been treated separately. And although each is crucial to the performance of a start-up, their roles differ greatly. For one, the foundational IP can only get a company so far. There are plenty of examples where a superior technology did not win out in the market (e.g., Beta vs. VHS, QWERTY vs. Dvorak keyboard). Indeed, the decisions and actions of the founding team influence everything from the choice of qualified suppliers and employees to marketing and customer relationships. This is why investors look for experienced, knowledgeable teams. A common saying in Silicon Valley is that venture capitalists invest in people before technology. It follows that founding teams may have more influence on the outcomes of firms than the foundational IP.

METHODS

Data and Research Setting

To examine how a firm's origins influence its outcomes, this study analyzes nanotechnology firms started in the United States. Nanotechnology is the R&D of materials and products between 1 and 100 nanometers (National Science and Technology Council, 2000). Nanotechnology has applications in nearly every industry, ranging from semiconductors to optics to biotechnology (National Nanotechnology Coordination Office, 2007). In fact, over 1,800 consumer products were listed by the Project on Emerging Nanotechnologies (nanotechproject.org) at the end of 2014. Additionally, nanotechnology entrepreneurship is particularly useful for distinguishing between different types of start-ups and spin-offs since nanotechnology is being researched in universities, firms, and government labs, as well as independent start-ups.

To study these firms, a comprehensive database was compiled on U.S. nanotechnology firms, which began being founded in 1981. The database is appropriate for this study since all nanotechnology firms were established after the 1980 Bayh–Dole Act, which allowed universities and government laboratories to own the IP created therein that was supported by government funding. Additionally, the year 1981 marks a fundamental milestone in nanotechnology. That year, two IBM researchers invented the scanning tunneling microscope (STM), the first instrument that enabled scientists to see and manipulate material at the nanoscale (Smalley, 1999). The STM is considered the foundation of nanotechnology (Woolley, 2010). Likewise, no nanotechnology-specific firm was founded before 1981, thus providing a starting date for this study. This ensures that the data are not left censored, whereby the origins of an event occur before the opening of the observation window (Blossfeld & Rohwer, 2002; Yamaguchi, 1991).

In 2000, the National Nanotechnology Initiative (NNI) was passed in the United States, which provided researchers in the field with almost a half-billion dollars the first year and contributed five billion cumulatively over the next 5 years into nanotechnology R&D (National Nanotechnology Coordination Office, 2007). Prior to the NNI, the cumulative government funding of nanotechnology R&D (including commercialization) totaled less than what was invested in 2001 alone. To avoid the influence of the environmental change sparked by the NNI, only firms founded through the year 2002 were included in this study. Additionally, using firms founded in this time period allows for over 10 years of post-start-up outcomes to be observed.

A master list of nanotechnology firms was compiled from industry lists, directories, press releases, publications, and websites related to nanotechnology. For example, lists and directories were obtained from (1) Nano Science and Technology Institute (NSTI), (2) NanoInvestorNews (market research), (3) NanoMarkets (market research), (4) NanoTechWire, (5) Small Times Media, and (6) Foresight Institute. These resources obtain data directly from nanotechnology-related organizations. Data from these sources were aggregated and augmented with information about firms discovered in a search for nanotechnology in PR Newswire and PriceWaterhouseCoopers' VC site.

Of the firms that claim participation in the nanotechnology community, many do not operate at the nanoscale. To be truly a nanotechnology firm, the technology used, by definition, must be less than 100 nanometers. For example, in 2006, Lux Research, a nanotechnology research and advisory firm, found that out of 66 firms that claimed to offer sensors using nanotechnology, only 13 harnessed the size-dependent properties at the nanoscale (Hebert, 2005). Unless the firms utilize technology to manipulate components at the nanoscale, they are not considered nanotechnology firms and are excluded from this study. Thus, each firm was analyzed to determine if it fit the criteria for being a nanotechnology firm: single-business ventures founded to develop, produce, and sell nanotechnology products on the merchant market. Thus, captive producers, divisions, and subsidiaries of existing firms, as well as distributors, designers, custom engineering, software, and consulting firms were excluded. Furthermore, included firms must have more than 50 percent of their activities, such as products, IP, R&D, or sales, derived from or related to nanotechnology. As some new firms either had no sales or financial data available, data related to products, patents, and other technology were used as evidence of nanotechnology activity. Several sources of data supplied these details such as the firms' websites, the United States Patent and Trademark Office, press releases, and news articles. The classification process used in this study is similar to previous works that also identified new technology firms (e.g., Schoonhoven, Eisenhardt, & Lyman, 1990).

The final list of nanotechnology firms was compared to that compiled by a colleague who had undertaken a similar process to identify such firms in an independent study at a different institution.[5] The databases had an interrater agreement of 89 percent. Any firms not in agreement were examined using the previously identified criteria for nanotechnology firms. No additional firms met the criteria since they either did not have nanoscale capabilities (e.g., products used micron-level technology, which is 10 times larger than nanoscale) or were software modeling firms. Given the extensive search, it is probable that nearly all new nanotechnology firms have been captured in this database. Nonetheless, if the founders of a nanotechnology company were not involved in the nanotechnology community, elected not to expose their existence, and were not known to others in the community, this firm would not be discernible and not be included. However, as nanotechnology is science based and there are very few people with the substantial knowledge of the

Author's voice:
How did the paper evolve and change as you worked on it?

[5] I gratefully acknowledge the collaboration of Jue Wang on this task. For resulting work, please see Wang and Shapira (2012) and Shapira, Youtie, and Kay (2011).

technology needed for such a commercial endeavor, it is unlikely that a firm would remain undetected by the community.

Dependent variables. Scholars studying survival and death of firms often take a dichotomous view: either the firm succeeds and is alive or fails and is dead (Wennberg, Wiklund, DeTienne, & Cardon, 2010). For the most part, firm exits have been treated in the literature as a failure. Recent work has started to distinguish between firms that end in distress (low performance) and those that are closed while performing well (Bates, 2005; Wennberg et al., 2010). For instance, Rothaermel and Thursby (2005) distinguished between a negative outcome, cessation, and two positive outcomes: survival and graduation from a technology incubator.

To provide a more nuanced analysis of firm outcomes, this study uses five dependent variables of interest: firm closure, acquisition, liquidation/bankruptcy, VC, and SBIR and STTR funding. Firm closure was measured as the cessation of business activity as an individual entity (0 = alive, 1 = the firm had ceased operations). For firms that ceased to exist, the year of cessation was recorded and the number of years from founding to death was calculated. Since firm closure cannot provide insight into the performance of the firm, two additional variables were constructed: closure by acquisition and closure due to liquidation or bankruptcy. Firm acquisitions are a type of firm exit in which all of a firm's assets are purchased by and incorporated into another firm. In contrast to other forms of business cessation such as distress liquidation, bankruptcy, or dissolution, an acquired firm is not necessarily performing poorly. In fact, firms with knowledge and IP valued by the industry and other firms are likely to be the target of an acquisition. Acquisitions also provide investors with a mechanism to exit and potentially profit. Although acquisitions can be hostile or friendly (i.e. with or without cooperation from the firm's stakeholders), the purchase of a firm indicates value. This suggests that we should not hold acquisitions in the same light as other firm exits (Fortune & Mitchell, 2012). In cases such as this study, when financial metrics are not available, information about a firm's acquisition can provide insight into if a firm closed in distress. Here, firm acquisition was measured as a dummy variable (0 = not acquired, 1 = acquired), and the time from founding until acquisition was recorded. Similar variables were constructed to identify firms that closed due to liquidation or bankruptcy, which indicate ceasing operations while in distress.

Just as firm closure does not always indicate positive performance, firm survival does not always indicate success. Thus, two additional variables were constructed to indicate two positive outcomes: VC funding and government funding through SBIR and STTR grants. VC refers to an investment by a company in exchange for partial equity ownership of the focal firm. Venture capitalists not only provide funding, but also often mentor the management of the firm through their own investors who have years of business knowledge. VC funding is a positive signal to the market and helps firms build legitimacy for emerging fields (Aldrich & Ruef, 2006), which is critical for nascent technologies. A binary variable measured if a firm had obtained VC funding and the time to first funding was calculated.

SBIR and STTR are government grant programs funded by 11 of the largest government agencies in the United States and administered through the U.S. Small Business Administration.[6] One of the main goals of the SBIR and STTR programs is to help organizations cross the "valley of death" between invention and commercialization: the point at which an innovation is promising, but too expensive for private investors to pursue (Bonvillian, 2011). Awardees are chosen through a competitive process that focuses on firms believed to be viable and to have the potential to successfully bring their technology to market.[7] These programs provide financing that increases a firm's ability to improve staff skills and conduct long-term research (Cooper, 2003). Obtaining a SBIR or STTR grant also enables recipient firms to better compete with larger firms with more resources. The vetting process also helps to establish legitimacy and credibility for SBIR and STTR recipients. In the present study, a binary variable measured if a firm had obtained an SBIR or STTR grant and the time to first grant was calculated.

[6] The 11 agencies are the U.S. Department of Agriculture (USDA), Department of Commerce - National Institute of Standards and Technology (DOC-NIST), Department of Commerce - National Oceanic and Atmospheric Administration (DOC-NOAA), Department of Defense (DOD), Department of Education (ED), Department of Energy (DOE), Department of Health and Human Services (HHS), Department of Homeland Security (DHS), Department of Transportation (DOT), Environmental Protection Agency (EPA), National Aeronautics and Space Administration (NASA), and National Science Foundation (NSF).

[7] The first phase of SBIR and STTR funding is limited to about $150,000 (originally $50,000 in 1982, which increased to $100,000 in 1992 and to its current level in 2013) over 6 months and focuses on projects that evaluate the feasibility and commercial potential of an R&D effort. STTR grants require the participation of both a small business and a nonprofit research institution. Additional information regarding the SBIR and STTR programs is available at www.sbir.gov.

Independent variables. The independent variables of interest in this study focus on firm origins. In-depth data were collected on each firm including its foundational technology or IP and its founding team. Data were collected from firm, university, and government documents, websites, and patent files, as well as articles from FACTIVA and sources listed above. Data sources also included Dun and Bradstreet, Hoover's, and NAICS listings. Separate dichotomous variables identified whether the firm's foundational IP was from (1) a university research center, (2) an existing firm, (3) a government research center, or (4) internal development. Spin-off firm origins are also distinguished by background of their founding team members. Thus, the employment of each founder was gathered through university records, company documentation, resumes, and profiles. From this set of information, four proportion measures were calculated for each firm: the proportions of founders from universities, businesses, and government labs, and founders without experience in any of these three settings.

Control variables. Since the year a firm was started can influence its mortality (Singh et al., 1986), the models in this study control for the year of the firm's founding. The number of nanotechnology firms alive each year and the square of that number were included to control for density dependence (Carroll & Hannan, 1989; Hannan & Freeman, 1988). The level of resource munificence influences a firm's ability to obtain the resources needed to survive. Thus, the models control for the total amount of federal nanotechnology-related funding each year. To ensure that the closure or acquisition of firms is not simply a reflection of overall firm activity in the economy, the number of all firm closures each year in the United States were included (Hannan & Freeman, 1988). Models with VC as the dependent variable included a control variable for the total amount of VC in the United States. All such environmental control variables were taken at a 2-year lag to provide time for the macro-level condition to have an effect.[8] Closure, negative closure and acquisition models include controls for obtaining VC funding or an SBIR grant by 2012. Finally, all models included controls for the number of firm founders, industries, and obtaining a patent.

Analysis

Event history analyses were conducted on the data using STATA with maximum likelihood estimation and robust standard errors. Data with consistently decreasing survival prospects are best modeled with Weibull, Gompertz, and/or exponential distributions. The data for nanotechnology firms did not have a continuously decreasing hazard function (2 years had the same hazard), which eliminated the possibility of using a Cox regression model that requires that the hazard function have no flat periods. The Weibull distribution was chosen to accommodate the monotomic effect of time since the hazard rates observed in these data were not constant. Models can be compared by considering the difference in the log-likelihood ratios using the chi-square distribution (Blossfeld & Rohwer, 2002). This comparison showed that the best-fitting survival model for the data was the Weibull failure (event) time model. Hazard ratios were estimated such that values over one indicate an increase in the likelihood that the covariate influenced the dependent variable, and values under one indicate lower likelihood of influence. Specifically, the effect size of covariates is calculated as 100 $\times$ (hazard ratio $-$ 1), which equals the percentage change in the hazard for a one-unit increase in the variable (Allison, 1984). As a robustness check, all models were run using Weibull, Gompertz, and exponential estimations as well as discrete time hazard models, and these estimations were highly consistent with the findings presented here.

All firms were included in all models. The time at risk is different for each outcome; since firms reached the various outcomes at different times, the total firm years are different. For example, all firms were included in the models regarding acquisition, but only those acquired were coded as such. Thus, the other firms that ceased to exist were in the models, but did not experience the event of interest.

Robustness Checks

Several additional robustness checks were conducted and details are available from the author upon request. To control for the level of environmental munificence, the annual federal spending on nanotechnology, and the NASDAQ and DJIA values at year end were considered. Since the NASDAQ and DJIA variables were moderately correlated with the number of nanotechnology firms (0.83 and 0.63, respectively) and federal nanotechnology funding (0.66 and 0.54, respectively), each dependent variable was analyzed with the three variables separately. Neither NASDAQ nor DJIA significantly influenced the dependent variables so they were subsequently removed. The models remained consistent with those using federal spending.

Next, all models were tested with a more parsimonious set of control variables. The models shown here use control variables driven by extant literature as discussed earlier and are logically relevant to the

[8] Geographic controls were tested, but did not show significance and were thus not included in the models.

dependent variables. However, some of the traditional control variables for analyzing firm closure, such as market density, environmental munificence, and founder count, are not significant in the models for negative closure and acquisitions, even though these are forms of firm closure. Variables lacking significance add little to modeling the covariates of interest, but are included here for comparison to traditional modeling. Parsimonious models for acquisitions without such controls indicated the same sign and significance for the hazard rates as those with the controls. One difference was that parsimonious models without such controls indicated that academic professors are more likely to suffer negative closures for their firms.

As discussed, the NNI was announced in 2000 and launched in 2001, causing the landscape for nanotechnology ventures to change greatly. Although the models include a control for the year the firm was founded, a sensitivity analysis was conducted to account for the influence of the NNI on the environment. Each dependent variable was modeled using only firms founded before 2001 and, for robustness, with firms founded between 2001 and 2002. The main difference in these models was that the significance of the hazard ratios tended to decrease, but the directions remained the same across all models. For example, in the closure model (1B in Table 7), the p value of the hazard ratio for government founders was .002 for the full sample, but .045 in the model for the subsample of firms founded before 2001. Overall, the models for the smaller samples had hazard ratios in the same direction as the full sample and the results were highly consistent with those presented here. One difference was that in the models using firms founded between 2001 and 2002, start-ups with internal IP were less likely to close than business-based start-ups.

As discussed, Weibull, Gompertz, and exponential distributions for the analysis were compared. As a robustness check of discrete time-hazard techniques, the data were modeled using both logit and the log–log distributions. Both resulted in estimates parallel with those reported here. Additionally, I tested the potential for VC to mediate the dependent variables. VC was only significant in the models analyzing the likelihood of closure (Model 1). Using the Sobel–Goodman Mediation Test (Sobel, 1982; Sobel–Goodman Mediation Test, 2016), I tested each independent variable that significantly influenced firms' closure: government IP, and the proportion of founders with university, business, government, and other experience. The test shows that VC mediates 24 percent of the influence of founders lacking academic, business, or government backgrounds ($p < .01$). The other tests showed no mediation effect (Table 4).

Author's voice:
Table 7 - Origins and Outcomes

TABLE 4
Nanotechnology Firm Origins by IP and Founders[9]

		Founders			
		University	**Business**	**Government**	**Sum**
IP	Academic	34.1%	19.5%	1.8%	42.4%
	Corporate	2.2%	11.1%	0.0%	12.4%
	Government	0.9%	4.4%	5.0%	8.0%
	Internal	9.7%	31.4%	1.3%	38.5%
	Total	46.9%	65.5%	7.1%	

Findings

By the end of 2002, 226 nanotechnology firms had been started, of which 42 percent were based on academic IP, 12 percent based on corporate IP, and 8 percent based on government IP, as shown in Table 4. The remaining generated internal IP. Table 4 also indicates the relationship between the source of IP and the backgrounds of founding team members and shows that these were often not the same. For example, almost 10 percent of the firms had a university founder, but used internal IP instead of academic IP. These descriptive statistics underscore the variety of firm origins and the importance of refining how we define spin-offs.

The firms included several different industries: 33 percent were in the materials industry, 20 percent instrumentation, 12 percent biotechnology, 11 percent pharmaceuticals, 3 percent optics, 3 percent electronics, and 3 percent semiconductors. The remaining firms were active in other industries such as energy and various consumer products. Table 5 shows the means and standard deviations of the variables and Table 6 show the correlation matrix. Figure 1 shows the number of nanotechnology firms each year between 1988 and 2002 by origin. Academic spin-offs with either academic IP or founders, and start-ups with business backgrounds enjoyed the largest growth, especially after 1995. Table 6 reports the correlation matrix. To check for multicollinearity, the variance inflated factors (VIF) for all of the variables were calculated. The mean

[9] Grand sums do not total 100% since a small percentage of founders had more than one type of occupation previous to founding the venture studied here. For example, some founders had previously been both professors and entrepreneurs immediately subsequent to founding the focal venture, and would be classified in each category. Similarly, STTR grants require participation by both small businesses and nonprofit research facilities such as universities and national labs. Thus IP generated from STTR grants were classified in both categories.

TABLE 5
Descriptive Statistics

	Variable	Mean	Standard Deviation	Minimum	Maximum
1	Closed	0.49	0.50	0	1
2	Negative failure	0.14	0.34	0	1
3	Acquired	0.27	0.44	0	1
4	VC	0.46	0.50	0	1
5	SBIR or STTR funding	0.63	0.48	0	1
6	Year founded	1,998.56	3.32	1981	2,002
7	Nanotech firms (density)	547.74	164.66	67	684
8	U.S. funding nano	1,438.46	386.08	40	1,912
9	U.S. firm closures	424.58	22.37	386.55	499.80
10	U.S. VC funding	27.22	6.89	8.02	105.01
11	Instrumentation	0.20	0.40	0	1
12	Materials	0.33	0.47	0	1
13	Bio pharma medical	0.27	0.44	0	1
14	Electronics semi optics	0.12	0.33	0	1
15	Founder count	1.86	1.06	1	9
16	Patent	0.64	0.48	0	1
17	Academic IP	0.42	0.50	0	1
18	Firm IP	0.12	0.33	0	1
19	Government IP	0.08	0.27	0	1
20	Internal IP	0.38	0.49	0	1
21	University founders (proportion)	0.38	0.44	0	1
22	Business founders (proportion)	0.55	0.45	0	1
23	Government founders (proportion)	0.05	0.19	0	1
24	Other founders (proportion)	0.01	0.08	0	1

VIF was 3.94 indicating a lack of multicollinearity (Belsley, Kuh, & Welsch, 1980; Greene, 2012).

The event history analysis models for each of the dependent variables are presented in Tables 7–11. The tables are organized by the outcome and referent group. The outcome of firm closure is shown in Model 1, negative closure is shown in Model 2, acquisition is indicated in Model 3, VC funding in Model 4, and SBIR/STTR funding in Model 5. The models designated with an "A" are the control models for each dependent variable (Table 7), "B" models are those using firms with internally developed IP as the referent group (Table 7). For comparison and robustness, Tables 8–10 provide the models using different referent groups: "C" models use university-based firms as the referent (Table 8), "D" models use firm-based start-ups as the referent (Table 9), "E" models use government-based firms as the referent (Table 10). Although showing tables for all four referent groups may appear redundant, their inclusion provides for easier comparisons. Table 11 summarizes the findings.

Since the independent variables are modeled over multiple outcomes, the interpretation of the models must be adjusted for the increased likelihood of type I errors or false positives. Several methods to adjust for multiple outcomes include the Bonferroni correction, Sidak method, Tukey–Ciminera–Heyse, Dubey/Armitage-Parmar, R^2 adjustment, and Holm and Hochberg methods. The most widely used adjustment is the Bonferroni correction, which evaluates the significance based on the number of tests being performed. This study uses five tests/dependent variables and thus the threshold for significance is divided by five. For example, if the threshold is typically a p value of less than .05, the Bonferroni correction requires that the threshold for significance

Author's voice:
Figure 1 - Origins and Outcomes

Author's voice:
Table 9 - Origins and Outcomes

Author's voice:
Table 8 - Origins and Outcomes

Author's voice:
Table 10 - Origins and Outcomes

TABLE 6
Correlation Matrix

	Variable	1	2	3	4	5	6	7	8	9	10	11	12
1	Closed	1.00											
2	Negative failure	0.30	1.00										
3	Acquired	0.57	−0.04	1.00									
4	VC	0.03	0.07	0.12	1.00								
5	SBIR or STTR funding	−0.12	−0.07	−0.06	0.11	1.00							
6	Year founded	0.05	−0.04	−0.02	0.16	−0.06	1.00						
7	Nanotech firms (density)	−0.84	−0.25	−0.49	0.04	0.17	0.02	1.00					
8	U.S. funding nano	−0.56	−0.16	−0.32	0.03	0.14	0.11	0.88	1.00				
9	U.S. firm closures	0.35	0.07	0.26	0.06	−0.06	0.07	−0.06	0.32	1.00			
10	U.S. VC funding	−0.05	0.03	−0.06	0.15	−0.08	0.01	0.03	−0.06	0.01	1.00		
11	Instrumentation	0.01	−0.11	0.27	−0.12	−0.02	−0.12	−0.01	−0.03	−0.01	0.07	1.00	
12	Materials	−0.17	−0.01	−0.19	−0.15	0.11	−0.13	0.10	0.05	−0.09	0.02	-0.36	1.00
13	Bio pharma medical	0.02	−0.01	−0.09	0.13	0.12	0.17	0.00	0.02	0.01	−0.10	−0.31	−0.43
14	Electronics semi optics	0.16	0.17	0.06	0.20	−0.20	0.06	−0.16	−0.15	0.05	0.05	−0.19	−0.26
15	Founder count	0.01	−0.03	0.02	0.08	0.01	0.16	0.00	0.00	−0.05	−0.03	0.09	−0.11
16	Patent	−0.01	0.01	0.16	0.22	0.14	−0.25	0.04	0.05	0.02	−0.07	−0.01	−0.11
17	Academic IP	−0.02	0.02	−0.05	0.15	0.18	0.09	0.06	0.05	−0.01	0.09	−0.01	−0.04
18	Firm IP	0.03	−0.03	0.11	0.05	−0.10	−0.03	−0.09	−0.07	0.04	−0.08	−0.06	−0.01
19	Government IP	0.10	0.03	0.16	−0.08	−0.01	−0.04	−0.12	−0.12	−0.03	−0.06	0.01	0.04
20	Internal IP	−0.03	−0.02	−0.08	−0.12	−0.11	−0.05	0.04	0.06	0.01	−0.02	0.03	0.00
21	University founders (proportion)	−0.12	−0.07	0.00	0.07	0.19	−0.01	0.08	0.02	−0.11	0.03	0.01	−0.03
22	Business founders (proportion)	0.11	0.16	0.02	0.00	−0.18	0.03	−0.08	−0.02	0.13	-0.05	−0.01	0.00
23	Government founders (proportion)	0.05	−0.05	0.06	−0.02	0.05	0.02	−0.04	−0.04	−0.02	−0.03	−0.02	0.04
24	Other founders (proportion)	0.02	0.03	0.03	−0.06	0.00	−0.11	−0.04	−0.04	0.01	0.07	−0.02	0.08

be a *p* value of less than .01. However, the Bonferroni correction tends to be the most conservative method such that by reducing the likelihood of a type I error with a higher *p* value threshold, the likelihood of a type II error is increased (Gelman, Hill, & Yajima, 2012). Tables 7–11 show the original significance levels reported by STATA. To present the most conservative results, the following findings section highlights the variables that meet the Bonferroni correction threshold of a *p* value of less than .01 as significant and notes those variables that meet the threshold of .02 as moderately significant. I also identify marginally significant covariates that may not meet the Bonferroni correction threshold, but have a *p* value of less than .05 when not adjusted.

As discussed earlier, the literature suggests that start-ups benefit from using IP from another firm compared to start-ups that are based on internally generated IP. Thus, start-ups based on firm IP would be less likely to close and be more attractive to VCs compared to non-spin-offs. Firm-IP based start-ups should also be more attractive acquisition targets compared to non-spin-offs. The data tell a different story. Table 7 shows that firms based on university and firm IP are more than four and five times as likely to suffer a negative closure (respectively, Model 2B, marginal significance), whereas those based on government IP are half as likely to close than non-spin-offs (Model 1B, marginal significance). Government IP-based firms are also three times more likely to be acquired than non-spin-offs (Model 3B, marginally significant). Firms based on academic IP are twice as likely to obtain a government grant than non-spin-offs, whereas those based on government IP are 63 percent less likely (Model 5B).

Turning to firm founders, the data show that firms with more academic founders or business founders are over eight times more likely to be acquired and over three times more likely to obtain VC funding than non-spin-offs (Models 3B and 4B, respectively). However, firms with business founders are 30 times more likely to suffer a negative closure than non-spin-offs (Model 2B). Compared to non-spin-offs, start-ups with a higher proportion of government founders are much more likely to close and suffer a negative closure (Models 1B and 2B). Conversely, firms with government founders are more likely to obtain VC and government grants (Models 4B and 5B, respectively).

Table 8 shows the analysis using academic IP and university founders as the referent. Start-ups based on government IP are 81 percent less likely to obtain government funding (Model 5C), 53 percent less likely to close (Model 1C, marginal significance), and three times more likely to be acquired than academic-based firms (Model 3C, marginal significance). In contrast, start-ups with more government founders are six times more likely to obtain government funding (Model 5C). Firms with more government or business founders are also more likely to suffer a negative closure (Model 2C, moderate significance).

TABLE 6
Correlation Matrix (continued)

	Variable	13	14	15	16	17	18	19	20	21	22	23	24
13	Bio pharma medical	1.00											
14	Electronics semi optics	−0.22	1.00										
15	Founder count	0.03	0.05	1.00									
16	Patent	0.11	0.05	0.08	1.00								
17	University IP	0.12	−0.01	0.11	0.05	1.00							
18	Firm IP	−0.02	0.07	−0.09	0.09	−0.30	1.00						
19	Government IP	−0.11	0.09	−0.04	−0.08	−0.19	−0.11	1.00					
20	Internal IP	−0.03	−0.07	−0.04	−0.05	−0.68	−0.30	−0.23	1.00				
21	University founders (proportion)	0.10	−0.07	0.05	0.09	0.56	−0.21	−0.20	−0.34	1.00			
22	Business founders (proportion)	−0.09	0.08	−0.03	−0.07	−0.49	0.25	−0.05	0.37	−0.83	1.00		
23	Government founders (proportion)	−0.02	0.05	−0.02	0.05	−0.08	−0.10	0.56	−0.15	−0.19	−0.24	1.00	
24	Other founders (proportion)	−0.07	0.04	0.03	0.00	−0.02	−0.05	0.06	0.01	−0.08	−0.13	0.04	1.00

However, firms with a higher proportion of business founders are more likely to obtain government funding than academic firms (Models 5C, moderate significance). Table 9 uses firm IP and business founders as the referent and shows that start-ups based on government IP are 55 percent less likely to close than business-based start-ups (Model 1D, moderate significance) and 73 percent less likely to obtain government grants (Model 5D). Notably, firms based on academic IP are more likely to obtain government grants, whereas those with academic founders are less likely to obtain such funding than business-based start-ups (Model 5D). Start-ups with government founders are three times more likely to obtain SBIR/STTR funding, but also much more likely to close operations compared to business-based firms (Models 5D and 1D, respectively). Table 10 uses government IP and founders as the referent and shows that firms with academic IP are four times more likely to obtain SBIR or STTR funding, and start-ups based on firm IP are over twice as likely to obtain this funding (Model 5E, moderate significance). Firms with more academic founders are 80 percent less likely to close and 64 percent less likely to obtain SBIR or STTR funding than government-based firms (Models 1E and 5E, respectively). Firms with business founders are much more likely to suffer a negative closure than government-based firms (Model 2E).

DISCUSSION

Spin-offs are an important segment of entrepreneurship. This study shows that over half of the nanotechnology firms started in the United States

FIGURE 1
Number of U.S. nanotechnology firms by origin from 1988 to 2002

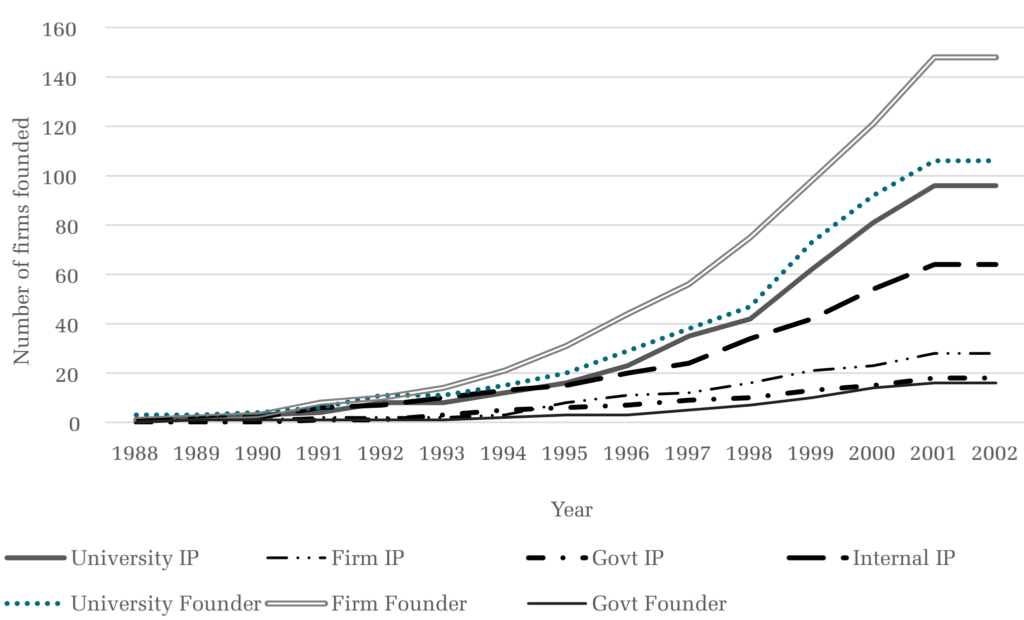

TABLE 7
Event History Analysis of Firm Origins, Control Models, and Models Using Non-Spin-Offs as Referent

	Closure		Negative Closure		Acquisition		VC		SBIR/STTR	
	Model 1A	Model 1B	Model 2A	Model 2B	Model 3A	Model 3B	Model 4A	Model 4B	Model 5A	Model 5B
	Hazard Ratio	Hazard Ratio	Hazard Ratio	Hazard Ratio	Hazard Ratio	Hazard Ratio	Hazard Ratio	Hazard Ratio	Hazard Ratio	Hazard Ratio
Academic IP		0.92		4.01^		1.11		1.07		2.40**
University founders		1.35		3.85		8.58**		3.55**		0.57
Firm IP		0.97		5.57^		1.17		1.16		1.45
Business founders		1.77		30.25**		9.39**		3.57**		1.12
Government IP		0.45^		1.82		3.66*		1.75		0.37**
Government founders		14.40**		95.70**		7.55		5.86**		3.66**
Year founded	0.99 ***	0.99***	0.99***	0.99***	1.00***	1.00***	1.00***	1.00***	1.00***	1.00***
Nanotech firms	0.85	0.71	0.03	0.23	1.15	1.51	0.49	0.48	1.09	1.43
Nanotech firms sq	0.04***	0.04***	1.62	0.17	0.91	0.87	0.03***	0.03***	0.02***	0.02***
U.S. funding Nano	2.76**	2.88**	3.99^	2.99	0.24	0.18	2.67	2.43	2.19	1.53
U.S. firm closures	0.70**	0.68**	0.87	0.86	1.30	1.38				
Founder count	1.26**	1.27**	1.51^	1.80*	1.12	1.11	1.14^	1.16^	1.14^	1.11
Patent	0.42***	0.33***	0.83	0.33	0.93	1.00	0.49*	0.46**	1.07	0.86
VC	2.02**	2.05**	2.76	4.07^	1.99	1.95			1.02	1.00
SBIR/STTR	1.08	1.08	1.09	0.65	0.94	0.92	1.19	1.18		
U.S. VC funding							0.98	0.97		
Wald chi square	394.09	446.48	272.80	311.21	297.98	301.10	361.31	393.72	410.85	402.11
df	13	19	13	19	13	19	12	18	11	17
Log pseudo-log likelihood	−53.26***	−46.15***	−19.54***	−11.62***	−124.38***	−118.62***	−112.52***	−110.56***	−160.43***	−148.82***
No. of failures	111	111	31	31	60	60	105	105	142	142
Time at risk	2,801	2,801	3,327	3,327	2,361	2,361	2,377	2,377	1,707	1,707

Notes. $n = 226$. Fixed effects for industry are included in the models, but not shown here.
* $p < 0.02$.
** $p < 0.01$.
*** $p < 0.001$.
^ $p < 0.05$.

TABLE 8
Event History Analysis of Firms Origins Using Academic IP and Founders as Referent

	Closure Model 1C Hazard Ratio	Negative Close Model 2C Hazard Ratio	Acquisition Model 3C Hazard Ratio	VC Model 4C Hazard Ratio	SBIR/STTR Model 5C Hazard Ratio
Firm IP	1.00	1.03	1.05	1.12	0.63
Business founders	1.29	18.49*	1.17	0.95	1.83^
Government IP	0.47^	0.75	3.28^	2.60	0.19***
Government founders	11.31***	36.98^	0.98	1.63	5.97***
Internal IP	1.03	0.13**	0.97	1.02	0.43**
Other founders	0.11	4.74	0.18	0.01***	2.06
Year founded	0.99***	0.99***	1.00***	1.00***	1.00***
Nanotech firms	0.77	0.28	1.87	0.68	1.31
Nanotech firms sq	0.04***	0.12	0.75	0.02***	0.02***
U.S. funding Nano	2.79**	3.44	0.16	2.13	1.61
U.S. firm closures	0.70**	0.79	1.39		
Founder count	1.30**	1.73	1.11	1.17*	1.11
Patent	0.32***	0.34	1.05	0.45**	0.87
VC	2.03**	5.29^	1.80		1.01
SBIR/STTR	1.04	0.75	0.99	1.15	
U.S. VC funding				0.99	
Wald chi square	472.67	199.80	321.73	470.13	410.72
df	19	19	19	18	17
Log pseudo-log likelihood	−44.86***	−11.48***	−121.02***	−109.19***	−149.50***
No. of failures	111	31	60	105	142
Time at risk	2,801	3,327	2,361	2,377	1,707

Notes. $n = 226$. Fixed effects for industry are included in the models, but not shown here.
* $p < 0.02$.
** $p < 0.01$.
*** $p < 0.001$.
^ $p <$ 0.0.5.

before 2002 were spun off from other organizations, using IP or founders as an indicator (Table 4). Extant work has neglected spin-offs from organizations outside of universities and corporations. Analysis that also includes spin-offs from government labs along with non-spin-offs provides insight into the role of knowledge-based resources gained at founding. Furthermore, few studies have compared outcomes for different types of spin-offs. As such, this study builds on the knowledge-based view and top management team literatures by clarifying the heterogeneity of spin-offs and how our conceptualization of firm origins may shape the outcomes that we observe. Also, by deconstructing the definition of spin-off, I challenge the prevailing practice of broadly classifying spin-offs as firms with any previous ties to other organizations (Clarysse & Moray, 2004; Mustar et al., 2006). This study empirically examines the fates of nanotechnology firms with different origins in terms of IP source and founding team composition. The results are provocative, showing that the origins of a high-technology spin-off do influence its likelihood of closing, going bankrupt or liquidating, being acquired, obtaining VC, and receiving government funding. By distinguishing that IP and founding teams are different types of knowledge transfer mechanisms and that as such have different roles in firm outcomes, this study contributes to our understanding of the microfoundations of entrepreneurship and entrepreneurial outcomes. These discoveries open new territories for research and practice, which are elaborated below.

Firm Origins, the Supply-Side Perspective

As discussed, spin-offs can be created with IP that is transferred from one organization to a newly established firm. Table 11 summarizes the findings of this study. Using the traditional outcome measure of firm closure, the findings show that firms based on government IP are surprisingly less likely to close, whereas start-ups with government founders are more likely to close, across referent groups. Additionally, firms based on academic or firm IP are generally more likely to suffer a negative closure than non-spin-offs. These findings are intriguing given that academic and government IP tends to be farther from commercialization than market-driven R&D created in firms (Chatterji, 2009; Jensen & Thursby, 2001; Rothaermel & Thursby, 2005; Shane, 2000; Thursby et al., 2001; Wennberg et al., 2011). Additionally, start-ups based on government IP are more likely to be acquired than non-spin-offs and university-based firms. The focus and application of government technologies (Rogers et al., 2001) may prove attractive as acquisition targets

TABLE 9
Event History Analysis of Firms Origins Using Firm IP and Founders as Referent

	Closure Model 1D Hazard Ratio	Negative close Model 2D Hazard Ratio	Acquisition Model 3D Hazard Ratio	VC Model 4D Hazard Ratio	SBIR STTR Model 5D Hazard Ratio
Academic IP	0.97	0.77	1.14	0.94	1.70^
University founders	0.74	0.23	1.05	1.10	0.51*
Government IP	0.45^	0.42	3.88	2.48	0.27***
Government founders	8.55***	3.42	0.88	1.73	3.19**
Internal IP	0.98	0.19^	1.14	0.96	0.69
Other founders	0.08^	0.31	0.14	0.01***	1.10
Year founded	0.99***	0.99***	1.00***	1.00***	1.00***
Nanotech firms	0.79	0.14	1.94	0.65	1.42
Nanotech firms sq	0.04***	0.28	0.71	0.02***	0.02***
U.S. funding nano	2.74**	3.53	0.16	2.18	1.55
U.S. firm closures	0.70**	0.82	1.43		
Founder count	1.31**	1.60	1.12	1.17^	1.10
Patent	0.32***	0.52	1.09	0.45**	0.87
VC	2.02**	4.14^	1.72		1.02
SBIR/STTR	1.05	0.80	0.96	1.13	
U.S. VC funding				0.99	
Wald chi square	482.88	245.69	321.29	464.55	398.33
df	19	19	19	18	17
Log pseudo-log likelihood	−44.70***	−15.31***	−121.07***	−109.19***	−148.79***
No. of failures	111	31	60	105	142
Time at risk	2,801	3,327	2,361	2,377	1,707

Notes. $n = 226$. Fixed effects for industry are included in the models, but not shown here.
* $p < .02$.
** $p < .01$.
*** $p < .001$.
^ $p < .05$.

compared to firms with technologies that are either too close or too far from the market, which is more likely in those based on corporate or academic IP. A driving factor in such acquisitions may be the development stage of government IP, which tends to bridge basic science and commercial application (Bozeman, 2000). These results indicate that our current understanding of negative closures and acquisition dynamics for spin-offs is incomplete and in need of research on the characteristics and commercialization of technologies from different sources. Additionally, work is needed to examine other outcomes related to technological adoption and advancement. For instance, the type and life-cycle phase of a spin-off's technology may limit the firm's scalability and thus initial public offering (IPO) prospects. Further deconstruction of foundational technology will explicate the role of resource stocks in start-up success (Agarwal et al., 2004; Clarysse et al., 2011; Druilhe & Garnsey, 2004; Wiklund & Shepherd, 2003).

Firms based on academic IP are more likely to obtain SBIR or STTR grants than all other categories of start-ups, whereas firms based on government IP are universally less likely to obtain such funding. However, start-ups with government IP can improve their chances compared to non-spin-offs by including founders with business or government experience. Indeed, IP and founder have different types of influence depending on the outcome of interest.

Previous work on founding teams tends to look at founders' backgrounds and experiences as indicators of conduits for knowledge transfer and firm success (e.g., Agarwal et al., 2004). Yet, previous experience only tells the story of the past, not the future. Although work has examined personal motivations to start a firm, few studies explore how individual or team objectives for the firm influence its outcomes [a notable exception being Dahl and Sorenson (2014)]. The findings here show that academic founders tend to obtain VC and be acquired more often than non-spin-offs. This suggests that academic founders of nanotechnology firms tend to enjoy positive outcomes on multiple fronts. Shane (2004) found that scientist-entrepreneurs are driven by wealth, the desire to commercialize their technologies, and independence. These motivations are in line with the ability to attract funding to stay in business and may help to explain this study's findings. The findings do not support the general argument in the literature that university founders lack an industry network that facilitates VC funding (Shane & Stuart, 2002). Research examining entrepreneurs' motivations and firm outcomes is fraught with challenges

TABLE 10
Event History Analysis of Firms Origins Using Government IP and Founders as Referent

	Closure Model 1E Hazard Ratio	Negative close Model 2E Hazard Ratio	Acquisition Model 3E Hazard Ratio	VC Model 4E Hazard Ratio	SBIR/STTR Model 5E Hazard Ratio
Academic IP	1.51	0.93	0.34	0.57	4.24***
University founders	0.20**	1.71	2.14	0.62	0.36**
Firm IP	1.45	1.07	0.35	0.63	2.77*
Business founders	0.26*	20.30**	2.37	0.60	0.62
Internal IP	1.58	0.16	0.31*	0.55	1.88
Other founders	0.03**	5.76	0.73	0.01***	0.67
Year founded	1.00***	0.99***	1.00***	1.00***	1.00***
Nanotech firms	1.06	0.19	1.05	0.60	1.44
Nanotech firms sq	0.03***	0.21	0.97	0.02***	0.02***
U.S. funding nano	2.24*	3.28	0.25	2.28	1.55
U.S. firm closures	0.75*	0.85	1.31		
Founder count	1.33**	1.72^	1.11	1.16^	1.11
Patent	0.36***	0.43	1.03	0.47**	0.90
VC	1.92*	4.10	2.02		1.00
SBIR/STTR	1.07	0.77	0.93	1.14	
U.S. VC funding				1.00	
Wald chi square	463.34	300.83	311.67	457.16	403.10
df	19	19	19	18	17
Log pseudo-log likelihood	−47.44***	−13.00***	−122.11***	−110.47***	−151.62***
No. of failures	111	31	60	105	142
Time at risk	2,801	3,327	2,361	2,377	1,707

Notes. $n = 226$. Fixed effects for industry are included in the models, but not shown here.
* $p < 0.02$.
** $p < 0.01$.
*** $p < 0.001$.
^ $p < 0.05$.

since study requires information about the founders' initial conceptions of their objectives as well as long-term firm performance data. The increased use of social media and improvements in datamining capabilities provide the opportunity to gain insight into the motivations and goals of founders with less retrospective bias than interviews conducted years after launch. These tools will prove exciting in the endeavor to further explicate the microfoundations that influence entrepreneurial outcomes.

A founder's prior experience may influence firm outcomes beyond what is captured in the literature.

TABLE 11
Summary of Findings

		Referent Group			
		Non-Spin-Offs	University Based	Firm Based	Government Based
Start-up foundation	**Academic IP**	**+ Obtain SBIR/STTR** + Negative closure		+ Obtain SBIR/STTR	**+ Obtain SBIR/STTR**
	University founders	**+ Acquired** **+ VC**		**− Obtain SBIR/STTR**	**− Obtain SBIR/STTR** **− Close**
	Firm IP	+ Negative closure			**- Obtain SBIR/STTR**
	Business founders	**+ Negative closure** **+ Acquired** **+ VC**	+ Negative closure **+ Obtain SBIR/STTR**		**+ Negative closure** **− Close**
	Government IP	− Close **− Obtain SBIR/STTR** + Acquired	− Close **− Obtain SBIR/STTR** + Acquired	− Close **− Obtain SBIR/STTR**	
	Government founders	**+ Close** **+ Negative closure** **+ Obtain SBIR/STTR** **+ VC**	**+ Close** + Negative closure **+ Obtain SBIR/STTR**	**+ Close** **+ Obtain SBIR/STTR**	

Note. Bold font indicates relationships that are significant after using the Bonferroni correction. + indicates an increased likelihood of the outcome, − indicates a decreased likelihood.

This study shows that firms with founders that have business backgrounds are more likely to experience a negative closure than all other referent groups. One explanation is that business founders may be more familiar with and therefore more comfortable with negative outcomes such as bankruptcy. In fact, their familiarity reduces their perception of any stigma associated with the closure of a firm. If the possibility of closing a firm by bankruptcy or liquidation is not perceived as potentially harmful to one's career, the founder may be more likely to follow this course of action. Similarly, founders who lack industry experience may fear these types of business cessation as potentially career ending or resulting in increased difficulty reentering their previous profession. Thus, these founders may avoid closure, even if this means survival with low firm performance. Furthermore, founders with business backgrounds have industry networks (Higgins & Gulati, 2003; Sapienza et al., 2004; Shane & Stuart, 2002; Yli-Renko et al., 2001). Instead of enhancing the firm's likelihood of survival, an extensive industry network may provide alternative career opportunities should an entrepreneur's venture be performing poorly. The attractiveness of these opportunities is heightened in the face of the stress and challenges of entrepreneurial life. Current work identifies industry experience and networks as positive assets for founding teams (Colombo & Grilli, 2005; Phillips, 2002); however, these may provide access to many opportunities and alternatives beyond the continuation of a start-up. Future research is needed to consider the founder's perception of success as it relates to opportunity enactment and potential outcomes.

Government founders are more likely to obtain government funding, in contrast to firms based on government IP that are less likely, across all referent ! groups. This may be due to their experience with the government system, particularly funding opportunities for nascent ventures. Thus, the relationship between firms with government founders and government funding could simply be that founders with such experience and knowledge may be more likely to seek this funding. These findings highlight the mechanisms of prior experience and knowledge in the shaping of firm outcomes. What is particularly valuable from this finding is the relevance of outcome-specific experience and knowledge. Specifically, previous work has looked at experience and knowledge as it applies to firm performance such as survival and growth. Here, we see that a founder's background is also tied to other outcomes such as the recognition and development of certain funding opportunities. Future research bridging entrepreneurial agency, experience, and motivations with firm outcomes will prove valuable for both theory and practice.

The difference in outcomes found here also may be due to differences in the founders' time horizon—a factor largely unexplored in current research (Bluedorn & Martin, 2008). For example, founders who previously worked at firms may be more concerned with the fast pace of the investment community who typically want to cash out within 5–10 years. These founders may make decisions to optimize short-term returns and attractiveness to potential acquirers. Indeed, spin-offs with business founders are more likely to be acquired than non-spin-offs. Alternatively, researchers who work on projects that require years for results may see no urgency to cash out. For example, it took 32 years for NASA to launch the Space Infrared Telescope Facility in 2003 (Rottner, 2010). Founders with experience in long-term projects may make decisions with a longer term conceptualization of success in mind. Thus, it is important for start-up founders and early investors to identify the outcomes they are seeking. Furthermore, aligning these goals may influence the success of their venture, by any measure.

Firm Outcomes, Stakeholders, and Outcomes

Another unique contribution of this study is the use of five types of outcomes, one of which is considered negative. The findings suggest that our current state of understanding based on survival models may be inadequate given that firms close for many different reasons. Just as we have treated all closures as negative in the past, work tends to treat all firm survival as a positive outcome. However, this provides a limited view of firm outcomes since it does not account for closures when a firm is performing well, such as an acquisition (Fortune & Mitchell, 2012). By differentiating between negative and positive outcomes, I show that the use of closures as an outcome measure is extremely problematic. For example, firms founded using government IP are more likely to be acquired and less likely to close than other firms, whereas government founders are more likely to have a firm that suffers a negative closure. As stated earlier, being acquired is a positive outcome that would be lost if closure were the only outcome of interest. Similarly, although business founders are less likely to close their firms than government-based firms, they are more likely to go bankrupt or liquidate. Differentiating between the types of outcomes provides much needed clarity.

The inclusion of acquisitions, VC, and government funding as indicators of success also provides insight about outcomes from multiple angles. This is particularly useful since success means different things to different stakeholders. For some founders, being acquired after achieving breakeven or a considerable market share is what they want for themselves and the company. Even so, founders and investors may have different and sometimes conflicting objectives (Graebner & Eisenhardt, 2004), such as when founders want to continue organic growth and investors need to realize monetary gains from their investment. Some founders find that they have investors who push for the firm to be acquired since they want to obtain a return on their investment or "cash out." From the founders' perspective, firm survival and growth may signify success. From the investor's perspective, a firm's success is not only measured by sales or market share, but also in the firm's ability to provide a return to its investors, usually by acquisition or IPO. Thus, it is important to include the role of the investor in our analysis of firm outcomes.

We can also look at the results concerning acquisitions from the lens of the acquirer. In particular, it is useful to consider how the motivations and objectives of an acquiring company drive its choice of targets. For example, firms often use acquisitions to obtain capabilities (Capron, Dussauge & Mitchell, 1998; Nelson & Winter, 1982) and complementary assets such as technology (Ruckman, 2005). A recent phenomenon seen mainly in the technology sector is acqui-hiring or acqhiring: the purchase of a company primarily for their employees (Chatterji & Patro, 2014; Helft, 2011). Indeed, it is not solely the performance of a firm that is of interest to a potential acquirer, but also its IP and employees. The findings of this study point to government IP as a particularly valuable asset of interest for acquisition. Firms founded using government IP are especially valuable to firms seeking cutting edge, albeit nascent technologies that are closer to application and commercialization than basic science from universities. As such, government IP may also be at the stage at which other firms can integrate it into complementary product development. Additionally, start-ups based on government IP are attractive acquisition targets when their products have been adopted by the government market. Experience in the development of government contracts is a valuable asset given the considerable market size. Surprisingly, firms with government IP are not more likely to obtain SBIR funding, but firms with government founders are more likely. This suggests that these firms' experience with the government provides knowledge about the requirements of such funding programs. From the demand side, the agencies providing the SBIR grants may use this experience as a measure of familiarity with the program and an understanding of what is necessary for success.

In terms of VC investment, it is interesting that the findings did not show a relationship between corporate IP and VC funding. Instead, firms with founders with experience, seemingly any experience, are more likely to obtain VC support than non-spin-offs (Table 7). Arguably, government founders have the least industry experience compared to other founders. However, their background may be tied to the opportunity being enacted and should not be discounted. At the same time, academic founders have the in-depth knowledge base needed to cultivate nascent technologies. Should the VC firm have investments in other high-technology firms in complementary fields, the addition of academic spin-offs to the portfolio is strategically pragmatic. Thus, it is useful to consider the motivations and needs of the VC firm in the interpretation of VC as a dependent variable.

Limitations

As with any empirical study, several limitations provide caveats for interpreting this work. For one, this study focuses on nanotechnology firms across all industries. Such a specialized field requires specific knowledge related to the technology. The sample of firms here represents what are considered the "hard sciences" such as engineering, physics, chemistry, and biology. Thus, this study is limited to only a portion of potential spin-offs, excluding those from the "soft sciences" such as psychology, humanities, and business. An interesting line of research could compare the types of spin-offs in terms of product or service sector. Further research should attend to the different types of spin-offs as well as the wide variety of outcomes, good and bad, to provide a richer understanding of the dynamics at play.

The study may also be limited by the nascency of the technology. As described, nanotechnology emerged in the early 1980s. Although it has developed over the last five decades, this may be too short of a time period to observe the full dynamics of the market and the results observed here may be different from those in more mature settings. Although we are certainly not able to examine the dynamics of a mature technology with these data, the nascency of the technology provides insight into the spin-offs that develop during market emergence. As such, work comparing the roles of IP and founders across early and mature markets can illuminate the temporal aspects of entrepreneurial origins and outcomes.

Although the findings are thought-provoking, the data cannot provide further insight into the motivations

Author's voice:
What was the most difficult or challenging aspect of this research project and paper?

of founders, investors, and acquiring firm executives. Although research has shown that entrepreneurial intention can help predict the likelihood that someone starts a new venture (Krueger, Reilly, & Carsrud, 2000), work regarding the influence of intention and objectives on new venture growth are mixed (Birley & Westhead, 1994; Cliff, 1998; Davidsson, 1991; Delmar & Wiklund, 2008). Thus, questions concerning the role of an entrepreneur's personal motivations and agency remain. Similarly, the empirical analysis here uses only a subset of variables that could unpack different types of spin-offs, IP, and founders. I hope that this article stimulates further research that appreciates the nuances of spin-off heterogeneity and explores ways to further unpack these differences.

Another limitation of this study is that it includes only firms from the United States. Given that methods and laws regarding IP transfer vary around the world, it would be useful to examine how regulations and industry norms influence spin-offs based on different types of IP across countries. Increasingly, work is examining the context-specific factors that influence entrepreneurship, particularly as it relates to national systems (Acs, Autio, & Szerb, 2014). These context-specific factors will surely prove useful in explaining the variance in firm outcomes by location.

CONCLUSIONS

The practice of transferring knowledge and technology into new ventures to create spin-offs is an important phenomenon with deep implications for both theory and practice. This study advances the literature by building on the knowledge-based view and top management team perspectives to explore the heterogeneity of spin-off origins. First, the study includes government origins in the analysis, an area underdeveloped in the literature. Second, five outcome variables are analyzed to provide insight into both positive and negative results. Third, the study examines two different knowledge transfer mechanisms that create spin-offs: IP and founders. Fourth, I provide further depth by explicating the employment backgrounds of these founders.

The findings confirm that the current treatment of spin-offs as a homogenous group is misleading such that academic, corporate, and government spin-offs differ greatly in their long-term prospects. The results also show that the use of survival rates as an outcome variable is limited, particularly if more information about how a firm closes is available. Moreover, I show that how we define a spin-off, using its source of IP or its founding team, shapes the results concerning outcomes that we observe.

These discoveries open several avenues for new research. Specifically, work is needed that examines the relationship between the type of foundational IP and firm outcomes. Research is also needed to better understand how the initial goals and motivations of founders shape the outcomes of their actions. We need to consider the founder's perception of success, as it relates to subsequent opportunity enactment and potential outcomes. By unpacking the categorization of spin-off firms and highlighting the relationship between types of knowledge transfer mechanisms, founder motivations, and firm outcomes, this study provides an initial step to further our understanding of the microfoundations of entrepreneurship and entrepreneurial outcomes.

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