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The Influence of Incubator and Accelerator Participation on Nanotechnology Venture Success

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Abstract

This study investigates how venture development programs such as private incubators, university incubators, and accelerators influence the success of participating nanotechnology startups. With the recent growth in such programs, empirical work is needed to compare their impact on participants across programs and with nonparticipants. Using data on firm bankruptcies, liquidation, government grants, and venture capital, we find benefits, but the influence of each venture development program varies greatly. We further investigate the influence of program services and resources to clarify program heterogeneity beyond existing typologies. The results clarify the role of these programs and ecosystem intermediaries.

Keywords

entrepreneurship, startup, new ventures, venture performance, incubators

The proliferation of venture development programs such as startup incubators and accelerators has garnered the attention of entrepreneurs and policymakers alike since these programs are considered valuable for supporting new firm development in entrepreneurial ecosystems. Nascent firms are important for economic health, rejuvenation, and innovation, which influence the competitiveness of cities, countries, and regions (Audretsch & Keilbach, 2007). However, the "liability of newness" plagues nascent firms by limiting their legitimacy, and hence their ability to obtain the resources that they need to survive and thrive (Stinchcombe, 1965). Venture development programs act as ecosystem intermediaries to support nascent entrepreneurship through the provision of services and resources (Clayton et al., 2018; Goswami et al., 2018; Woolley, 2017a). These programs attempt to improve the success of startup firms (Mian et al., 2016), foster communities of innovation (Wright & Drori, 2018) and support regional and national economic development (Fehder & Hochberg, 2017). Entrepreneurs entering venture development programs may gain access to critical resources such as capital, mentoring, and business education

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(Pauwels et al., 2016). Thus, these programs both provide professional services and physical infrastructure resources (Hallen et al., 2020) that “buffer” participating firms from external demands and uncertainty (Thompson, 1967) and “bridge” participants through network relationships, building legitimacy, and access to further resources (Amezcua et al., 2013; Eveleens et al., 2017) that can improve their likelihood of survival and success.

Incubators and accelerators have flourished recently, and scholars are attempting to determine whether and how participating in such programs influences the success of firms. Unfortunately, there is little consensus as to whether participating in incubators or accelerators benefits the firms involved and under what conditions (Bruneel et al., 2012; Cohen, Fehder, et al., 2019; Hausberg & Korreck, 2018). Some studies have shown that such venture development programs can foster innovation (Barbero et al., 2014), positively influence long-term sales revenue (Lukeš et al., 2019; Mian, 1996) and promote firm survival and growth (Colombo & Delmastro, 2002; Rothaermel & Thursby, 2005). However, not all participants of venture development programs benefit, and success is far from guaranteed. For example, participating in an incubator may lower a firm’s sales revenue in the short run (Lukeš et al., 2019) and engaging in a venture development program can increase the likelihood of firm closure and reduce the amount of funding raised (Schwartz, 2013; Yu, 2020). Still other studies have found mixed results depending on the incubator (Chan & Lau, 2005; Schwartz, 2013). Additionally, these results are difficult to compare since much of the work has focused on participants of either incubators or accelerators, but little has compared programs and their influence on participants across programs and with nonparticipants. Thus, our understanding of the effectiveness of venture development programs remains limited and questions persist concerning the *relative* benefits to venture development program participants. With the proliferation of over 10,000 of such programs across over 60 countries (Cohen & Hochberg, 2014; Hathaway, 2016; INBIA, 2018; Mian et al., 2016) and the thousands of participating startups (Autio et al., 2014), additional empirical investigation into their influence is warranted.

In this study, we ask whether participating in a venture development program improves a young firm’s likelihood of success. Using a dataset of nanotechnology firms, we are able to compile a sample of firms most likely (at risk) to enter proximate venture development programs based on geographic location and industry. We examine how the influence of venture development programs differs by comparing outcomes of participants in private incubators, university incubators, and accelerators, as well as nonparticipants across three outcomes important for nascent firms: closure due to bankruptcy, asset sale, or under-performance; obtaining government small business innovation grants; and raising venture capital (VC). We find that the programs increase the likelihood of participants’ success, but in different ways. We then delineate the services and resources provided by each program and analyze how these influence a firm’s outcome. This analysis builds on previous work that considers individual program services and resources (e.g., Aerts et al., 2007; Allen & Mccluskey, 1991; Patton et al., 2009) to provide a more detailed treatment of incubator and accelerator heterogeneity.

We contribute to both theory and practice in several respects. First, we build on entrepreneurship work regarding the role of venture development programs as ecosystem intermediaries by empirically examining the relationship between three of the most prevalent venture development programs and startups outcomes. In doing so, the findings generate critical insights for building theory on how these intermediaries can support high technology entrepreneurship through their portfolio of resources and service offerings (Cohen, Bingham, et al., 2019, Cohen, Fehder, et al., 2019; Goswami et al., 2018). Second, our study leverages a robust sample of nanotechnology firms that includes participants in the different types of programs as well as nonparticipants. As most studies to date have focused on either incubators or accelerators, there is a dearth of work comparing the outcomes of individual firms across program types. The few studies that compare programs tend to do so by aggregating the performance of all program graduates (e.g., Barbero et al., 2012) instead of examining the influence on individual firms. Studies that compare participants and nonparticipant tend to examine one type of program (see Eveleens et al., 2017). Thus, we fill an important gap in our understanding of program influence. Third, by using three event outcomes that entrepreneurs and policymakers consider important, we explore how such programs may exert influence beyond firm survival. The ability to obtain government grants or VC funding is significant to the prosperity of many technology startups and represents a complementary means by which entrepreneurs further their ventures.

This research also contributes to the literature on entrepreneurship and policy by providing insight into supportive programs for new venture and technology growth. Programs that influence the success of technology ventures are important for innovation, employment, and federal funding of related education, research, and development (Clayton et al., 2018). For example, by examining the consequences of participation in private incubators, university incubators, and accelerators, we gain a more holistic view of the context of entrepreneurship (Autio et al., 2014; Welter, 2011; Zahra et al., 2014) and how individual programs may complement each other to strengthen firm success and a region's economic development (Söderblom et al., 2015). Governments at multiple levels have supported incubators and accelerators through grants, loans, and subsidies (Madaleno et al., 2018; OECD, 2019). Understanding the engagement of venture development programs can improve the offerings from both the private and public sectors. In particular, knowledge about the range of venture development programs that exist and how they influence the success of their participants is useful for policymakers at the state, regional, and national levels who are considering ways to support entrepreneurship. Such insight can help shape the choice of and rationale for government support of innovation commercialization, university incubation, and technology transfer. As such, this study has considerable practical implications for entrepreneurs and policymakers alike.

Background and Hypotheses Development

Venture development programs such as startup incubators and accelerators are not new. The first business incubator is thought to have been started in 1959 to help new business owners grow their firms in upstate New York (Lewis et al., 2011). The first programs offered rental space and consulting services provided primarily by private firms and investor groups (Allen & Rahman, 1985). Soon thereafter, universities became interested in providing similar services through commercialization assistance and technology transfer facilities. By and large, venture development programs provide essential services and physical infrastructure resources important for startup development (Clayton et al., 2018; Spigel, 2017).[1]

While each type of venture development program maintains similar goals (i.e., to support the launch of innovative firms), their design and the range of services and resources that they offer varies. Several studies have considered typologies of incubator and accelerator programs. One of the earliest, by Grimaldi and Grandi (2005), used ten characteristics to identify two categories of incubator: nonprofit (including those run by universities) and for-profit. von Zedtwitz and Grimaldi (2006) elaborated on this framework and added competitive scope to determine five categories of incubators: regional business, university, virtual, independent commercial, and company-internal. Synthesizing these, Barbero and colleagues (2012) delineated four archetypes of incubators: economic development (supported by policy initiatives), university business, research (tied to research institutions), and private (either corporate or independent).[2] In terms of accelerators, Cohen, Fehder and colleagues (2019) considered 12 characteristics to create two classification schemes mainly based on managing director experience and sponsor which overlap greatly with Grimaldi & Grandi, 2005's (2005) classification of incubators. Generally, typologies include program sponsorship (corporate, investor, government, and university) as the distinguishing characteristic since it overlaps with scope. Knopp (2012) found that the three most prevalent categories of programs are private incubators, university incubators, and private accelerators. The next section reviews each program before discussing research regarding participants' outcomes.[3] Table 1 summarizes the important business model characteristics and the services and resources commonly offered by the three main program categories from the literature.

Private Business Incubators

Private incubators provide young companies with office space and basic business services including shared administrative support (Bøllingtoft & Ulhøi, 2005; Grimaldi & Grandi, 2005). By 1985, about 60 such facilities existed in the United States (Allen & Mccluskey, 1991; Allen & Rahman, 1985). Bruneel et al. (2012) highlight how the offerings of incubators changed over time from simple office space and shared resources to include mentors (either pro bono or at a reduced cost) and network development. The earliest incubators rarely provided laboratory space, professional services, or training opportunities (Allen & Rahman, 1985), but have evolved to meet the changing needs of entrepreneurs (Feldman & Francis, 2004; Mian et al., 2016). Common attributes of private incubators often, but not always, include an open length of participation time, a rent or nonprofit business model, noncompetitive selection criteria, and ad hoc educational opportunities and training (Cohen, 2013).

Private incubator programs often offer support for regional economic development or the advancement of technology entrepreneurship (Amezcua et al., 2020; Bergek & Norrman, 2008). Although some corporations sponsor incubators to promote entrepreneurship related to their supply chain (Becker & Gassmann, 2006), most private incubator programs do not have corporate sponsors (Knopp, 2012). Amezcua (2010) found that over half of the participants in business incubators were in service industries followed by finance, insurance, and real estate. More recently, some incubators have begun focusing on specific industries or technologies (e.g., cleantech, fintech, hardware, or fashion). Private incubators tend to have few admission requirements (Aerts et al., 2007; Cohen, 2013). The National Business Incubation Association (NBIA) estimated about 800 private incubators in the United States in 2012 (NBIA, 2013) and there are more than 7000 worldwide (Mian et al., 2016).

University Incubators

Universities are creating incubator programs to support nascent ventures (Grimaldi & Grandi, 2005; Mian, 1996). Depending on the program, participation is often limited to firms with a university affiliation. Typically, participation is based on university-owned or licensed intellectual property or nascent work by university research scientists, professors, or students (Link & Scott, 2003). Unlike general business incubators, selection for university incubator participation is competitive and they often have a structured program with access to seminars, advising, and/or mentoring. In addition to the services and resources that private incubators offer, university incubators may also provide access to faculty advisors, student employees, libraries, technology transfer services, and labs (Colombo & Delmastro, 2002; Grimaldi & Grandi, 2005; Mian, 1996). Participating firms may also benefit by gaining legitimacy through their affiliation with a university (Mian, 1996; Rothaermel & Thursby, 2005) and community outreach (Lasrado et al., 2016).

Universities must balance the support required for an incubator with that needed for other programs such as technology transfer offices, sometimes at the sacrifice of academic innovation (Kolympiris & Klein, 2017). Recently, some university incubators have evolved into an accelerator model by funding participants; however, unlike private accelerators, they often do not require equity from the venture (Dempwolf et al., 2014). About 400 university incubators existed in the United States in 2012 (NBIA, 2013) and over 800 university incubator programs existed throughout the world in 2014 (Ubi-Global, 2015).

Private Accelerators

Accelerators are a fairly recent development. Accelerators are considered an evolution of the startup incubation model, emerging with the creation of the first accelerator, Y-Combinator, in 2005 (Pauwels et al., 2016). Private accelerators are for-profit companies that offer some of the same services and resources as incubators, such as shared office space (Cohen, 2013; Mian, 1996). However, the accelerator business model differs greatly from that of private or university incubators. For example, accelerators often make seed-stage investments in exchange for a share of the firm's equity (Dempwolf et al., 2014). Accelerators are typically cohort based, limited-duration programs with intense mentoring that conclude with pitch events or demonstration (demo) days (Cohen, Fehder, et al., 2019; Cohen, 2013). Accelerators also differ from business incubators in their highly competitive selection process and structured requirements for participation and graduation (Pauwels et al., 2016), which helps to validate the quality of their participants (Goswami et al., 2018).

Accelerators are heterogeneous in selection, technology focus, location, and specialization (Cohen, Bingham, et al., 2019; Wright & Drori, 2018). Many accelerators operate according to a workshop model in which classroom-like seminars focus on specific subjects of interest to participants such as marketing, intellectual property, and finance (Wright & Drori, 2018). Accelerators often provide mentors in the participating venture's industry or niche. Indeed, participants benefit from access to a wide range of service providers, potential suppliers, and other stakeholders with which the accelerator has partnered (Hansen et al., 2000). By 2018, 500 private accelerator programs existed in the United States (INBIA, 2018; see also Hathaway, 2016) and over 2000 existed worldwide in 2012 (Cohen & Hochberg, 2014).

How Venture Development Programs Influence Firm Outcomes

As the previous section described, each venture development program has different approaches to how they support participants and the resources that they offer (Barbero et al., 2014; Cohen, Bingham, et al., 2019). Nevertheless, even the simplest private business incubator provides entrepreneurs access to both tangible and intangible benefits (Amezcua et al., 2013). The services and resources that venture development programs offer may be described as buffering and bridging mechanisms. Specifically, incubators and accelerators "buffer" the core operations of the new firm from environmental variability and uncertainty by providing services and physical infrastructure resources that allow them to conserve their existing stocks and optimize their usage (Scott & Davis, 2007; Thompson, 1967). Additionally, venture development programs "bridge" participating firms with other firms and external infrastructure providers, fostering relationships that build legitimacy and access to resources (Amezcua et al., 2013; Soetanto & Jack, 2013; Van Rijnsoever et al., 2017). Work focused on the resource-based view suggests that these programs lower barriers to entry and improve survival rates (Barney, 1991; Cohen, Bingham, et al., 2019; Mian et al., 2016; Schwartz, 2009).

Buffering support takes the form of access to a stock of tangible and intangible services and resources such as offices, meeting rooms, basic administrative support, advice, and mentoring (McAdam & McAdam, 2008; Mian et al., 2016; Patton et al., 2009). These ease the challenge of efficiently and effectively organizing the new firm's operations and service functions. Furthermore,

Table 1. Common Resources and Characteristics of Private Incubators, University Incubators, and Private Accelerators.

		Private incubators	University incubators	Private accelerators
Services and resources	Mentoring	**Common**	**Common**	**Extensive**
	Office space	**Common**	**Common**	Common
	Lab space	**Common**	**Common**	Rare
	Education	Ad hoc	**Classes/Seminars**	**Workshops (cohort-based)**
	University resources	None	**Common**	Little
	Pitch/Demo day	Rare	Varies	**Common**
	Funding	None	Little	**Seed-level**
Business model characteristics	Sponsor	Corporation	University	Investor or corporation
	Organization	Open	Structured	Highly structured
	Selection	Noncompetitive	University affiliation; competitive	Competitive
	Length of participation	Open	Varies	Limited (<6 mo.)
	Venture stage	Early or late	Early or late	Early
	Revenue model	Rent or nonprofit	Rent or nonprofit	Equity investment/for-profit
	U.S. count	800 (2012)	400 (2012)	500 (2018)
	World count	7000 (2012)	800 (2014)	2000 (2012)

Note. Services and resources in bold are included in the bundle of services and resources for the respective program type.

mentors and advisors offer counsel on internal, managerial decisions such as human resources, marketing, or engineering. Although some entrepreneurs may join an incubator or accelerator with educational or work experience relevant to their nascent firm, venture development programs can augment this with entrepreneurship-specific knowledge, information, and support (Cohen, Fehder, et al., 2019; Gonzalez-Uribe & Leatherbee, 2018). For example, Hallen et al. (2020) found that accelerators complement a founding team's human capital and augment a team's prior experiences. Access to these types of services and resources reduces operational costs and mitigates some of the organizing challenges faced by entrepreneurs, freeing them to focus on challenges core to the new firm.

Venture development programs not only furnish services and resources to facilitate the internal organizing of new firms, but also impart bridging support by connecting entrepreneurs with infrastructure providers that build legitimacy and access to external resources along with the knowledge of how to manage those resources (Bøllingtoft & Ulhøi, 2005; Eveleens et al., 2017; Van Rijnsoever et al., 2017; van Rijnsoever, 2020). Nascent ventures need relationships with external stakeholders that offer critical knowledge and resources (Baum & Oliver, 1991; Soetanto & Jack, 2013) and normative alignment (Zimmerman & Zeitz, 2002). New firms affiliated with prominent venture development programs enjoy the endorsement (Stuart et al., 1999) and legitimacy of those programs simply by affiliation (Mian, 1996; Rothaermel & Thursby, 2005). Third parties such as partners, buyers, and investors rely on these affiliations to evaluate new firms with unknown reputations, risky technology, and untested managers. Mentoring and networking opportunities provided by venture development programs increase nascent entrepreneurs' access to additional resources in the local and regional entrepreneurial ecosystems that are critical for survival (Hansen et al., 2000; Soetanto & Jack, 2016). Incubators and accelerators, regardless of type, also offer proximity to other entrepreneurs in shared spaces, training, classes, and events, which may increase the likelihood that participants will exchange useful information with one another (Bøllingtoft & Ulhøi, 2005; Rothschild & Darr, 2005; Rubin et al., 2015). University incubators in particular have been shown to enhance knowledge flow among participants that can increase their learning and support the growth of their firms (Patton & Marlow, 2011). Additionally, pitch competitions and demonstration events provide training and feedback to guide entrepreneurs as they navigate influential conversations with critical external constituents (such as investors). Thus, incubator and accelerator participation increases client firms' network breadth and depth, and learning (Ebbers, 2014; Hansen et al., 2000).

Overall, venture development programs offer a bundle of services and resources that may improve the odds of success for new firms by aiding them in overcoming age-related fragility. In particular, buffering, and bridging services and resources provided by venture development programs reduce variability for core operations, proffer key resources and knowledge sharing, connect entrepreneurs with vital external constituents, and train them in managing those relationships.

> ***Hypothesis 1:*** *Firms that participate in a venture development program are more likely to succeed than those that do not.*

Program offerings vary in quantity of services and resources as well as in the variety. The greater number of services, resources, and network access offered by some venture development programs creates a richer set of resources to the benefit of affiliated entrepreneurs. Given the nascency of startups, a wider range of offerings is more likely to fulfill their needs. Programs match their resources to the often dynamic needs of new firms. Entrepreneurs participating in programs offering a larger bundle of services and resources likely increase the odds of receiving the specific type and quantity of support needed for their firms' stage of development, which may ultimately increase its viability.

> ***Hypothesis 2:*** *Participation in a venture development program with more services and resources improves a firm's likelihood of success.*

As described in the discussion above, venture programs have vastly different designs. To wit, in contrast to private incubators, university incubators and accelerators tend to provide more services, infrastructure connections, and resources. In addition to providing administrative support and office or lab space, these venture development programs also expose entrepreneurs to mentors, industry or technology experts, and networks of specialists in relevant business services (Cohen, Bingham, et al., 2019). Bundles of support with a wider variety of services and resources (not simply a larger set), such as those offered by university incubators and accelerators, may further benefit new firms since they increase the chances that the entrepreneur will be able to utilize both the buffering and bridging offerings. Moreover, access to both novel information and a range of knowledge, in turn, improves job creation (Stokan et al., 2015) and the likelihood of growth and survival. Thus, a broader array of programmatic support services and resources, such as those offered by university incubators and accelerators, enhances the chance of success for participating firms.

> ***Hypothesis 3:*** *Participation in a university incubator or private accelerator improves a firm's likelihood of success more than participation in a private incubator.*

Additionally, there are instances when entrepreneurs engage in multiple venture development programs, rather than just a single program. By participating in more than one venture development program, entrepreneurs gain from both a larger number and a wider variety of offerings. They also benefit from close proximity to a greater number and variety of other entrepreneurs and experts with which they can exchange tacit knowledge (Cooper et al., 2012) and collaborate (Colombo & Delmastro, 2002). When firms access a broader, more heterogeneous resource pool by participating in incubators with a dissimilar foundation, entrepreneurs increase their access to knowledge, broaden their network, and increase their learning opportunities, gaining relevant and novel information to facilitate innovation and growth. In sum, engaging in multiple venture development programs offers benefits in a greater diversity of ideas, resources, and knowledge exchange and thus can improve a venture's likelihood of success.

> ***Hypothesis 4:*** *Participation in multiple venture development programs makes firms more likely to succeed than those that do not.*

Methods

Data and Sample

The study draws on a database on U.S. nanotechnology firms started between 1997 and 2011 to compare the participation in venture development programs. One challenge to studying the relative success of venture development program participants and startups that do not participate is the difficulty in obtaining a sample that includes all potential types of startups (Stokan et al., 2015). Most research on the influence of participation in venture development programs has examined only the outcomes of firms that participate in such programs but lacks control groups of comparative nonparticipants from the same population of potential ventures. This limitation arises due to difficulty in obtaining data. One technique for overcoming this challenge is to use a matched sample of firms (e.g., Lasrado et al., 2016; Schwartz, 2013); however, this approach limits the size of the sample to the number of treated and untreated firms. We are able to overcome this issue by using the database of firms based on a common technology that are potential participants in venture development programs. Nanotechnology became a viable technology for corporate development in 1981 with the invention of the first instrument that provided scientists the capability of moving or modifying matter less than 100 nanometers in three dimensions (Rothaermel & Thursby, 2007; Smalley, 1999). To identify startups with nanotechnology capabilities, we examined over 10,000 pages of industry lists, directories, press releases, university websites, scientific publications, and web sites related to nanotechnology. We analyzed the products and intellectual property of each firm to determine whether the company could develop, produce, and sell nanotechnology products, and whether over 50 percent of its activities (R&D, sales, etc.,) were dedicated to nanotechnology. Sources of data included white papers, patents, press releases, scientific reports, news articles, and website descriptions. Previous studies also used this process to identify nascent technology firms (e.g., Schoonhoven et al., 1990; Woolley, 2017b). An extensive search was performed to capture all firms; however, those without technical, scientific, or industrial association presence (e.g., Nano Science and Technology Institute, government programs, journal publications) or nanotechnology-related patents (e.g., USPTO) may have been missed and excluded from this database. Given the exhaustive review of archives from the 1980s through 2019, it is unlikely that many nanotechnology firms have been overlooked. The final database consists of 670 firms with verified nanotechnology capabilities.[4]

Data collected for each firm include location, industry, products, services, intellectual property, accelerator and incubator participation, and outcomes. The data were triangulated across multiple sources such as industry listings, accelerator, and incubator listings (current and prior years), association profiles, web searches, press releases and online presence. Outcome data were gathered through 2017 and include business closure (cessation of operations), bankruptcies, asset sales, obtaining government grants and VC funding.

The firms were analyzed to determine the dates when they began participating in venture development programs. Before 1997, fewer than two nanotechnology firms participated in incubators or accelerators each year. Thus, to avoid skewing results with outliers, we used firms that started during or after 1997, which eliminated 53 firms from our sample. Next, we considered the location of the firms and their proximity to incubators and accelerators. Work has shown that firm founders are willing to relocate up to 60 miles to participate in an incubator or accelerator (Bone et al., 2017; Cohen, Fehder, et al., 2019; Stam, 2007). For each firm, we identified whether or not it was located within 60 miles of an incubator or accelerator. We compared zip codes and used Google Maps to assess locations. A total of 52 firms that were not proximate were eliminated from the analysis.

Next, the data were analyzed to determine which industries were most prevalent in accelerators and incubators by year. This step enabled us to examine participation trends and to concentrate on those industries most generalizable to incubator participation. We calculated the average percentage of firms by industry (about 30%) and included those firms from industries with average or above participation including biotechnology, materials, medical devices, pharmaceuticals, and energy. We eliminated 146 firms in other industries from analysis (e.g., very few optics firms participated in incubators and were therefore excluded), which provided a final sample of 419 firms.

Independent Variables

As mentioned, data on incubator and accelerator participation were collected for each firm from firm websites, news articles, incubator and accelerator websites, university listings, and industry listings. For each firm, individual dichotomous variables were constructed for participation in

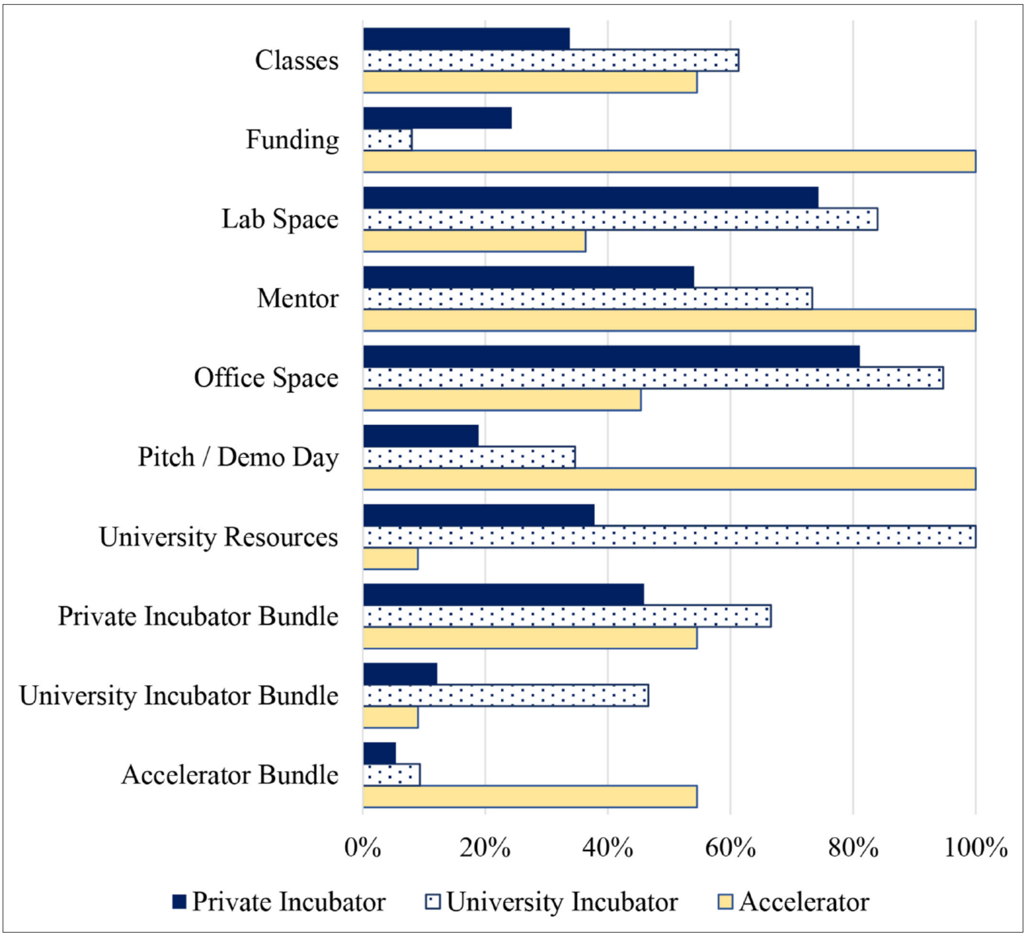

Figure 1. Percentage of venture development program offering listed components.

each type of program: private incubator, university incubator, and accelerator. These designations were based on the main business model variables identified by previous scholars including sponsor, organization, selection, length of participation, venture stage, and revenue model (e.g., Cohen, 2013; Cohen, Bingham, et al., 2019; Grimaldi & Grandi, 2005; Knopp, 2012). Table 1 summarizes the common characteristics for each type of program's business model. For example, incubators are typically sponsored by a company, do not have competitive selection or cohorts, have an open duration of engagement, include ventures at any stage, and use a rental revenue model (or nonprofit if appropriately sponsored); while accelerators typically have an investor or corporate sponsor, a highly structured organization, competitive selection, limited duration programs with fixed-term cohorts, and investment-based revenue models. University incubators typically have academic affiliations and sponsorship and a mix of business model characteristics. No accelerators in the samples were affiliated with a university. A binary variable also identified firms that participated in more than one venture development program.

To determine if any influence of program was due to the individual services and resources that they provided, we reviewed both the literature on services and resources provided by venture development programs and the archival data describing the programs themselves. As discussed

Table 2. Descriptive Statistics and Correlation Matrix.

	Variable	Mean	Std. Dev.	Min	Max	1	2	3	4	5	6	7	8	9	10	11
1	Negative failure	0.32	0.47	0	1	1.00										
2	SBIR/STTR	0.59	0.49	0	1	−0.16	1.00									
3	VC	0.45	0.50	0	1	−0.16	0.07	1.00								
4	Founder count	2.04	1.00	0	5	−0.02	0.08	0.25	1.00							
5	Patent	0.55	0.50	0	1	−0.24	0.17	0.35	0.16	1.00						
6	Founding team entrepreneur	0.37	0.48	0	1	0.00	−0.07	0.15	0.26	0.12	1.00					
7	Founding team PhD	0.85	0.36	0	1	−0.07	0.20	0.08	0.24	0.09	−0.06	1.00				
8	U.S. funding nano ($MM)	1649	161.4	989	1912	−0.37	0.12	0.06	0.05	0.07	−0.07	0.06	1.00			
9	U.S. firm closures (K)	413.5	24.4	362	486	−0.22	0.02	−0.04	−0.12	−0.03	−0.04	−0.05	0.11	1.00		
10	U.S. VC funding ($MM)	84.6	41.1	20	130	−0.65	0.18	0.10	0.02	0.18	−0.04	0.15	0.52	0.04	1.00	
11	Private incubator	0.18	0.38	0	1	−0.05	0.10	0.10	0.10	0.12	0.07	−0.03	0.09	−0.04	0.04	1.00
12	University incubator	0.18	0.38	0	1	−0.05	0.15	0.03	0.03	−0.06	−0.01	0.06	0.08	−0.03	0.11	−0.02
13	Accelerator	0.03	0.16	0	1	−0.11	0.05	−0.03	−0.01	−0.09	−0.03	0.03	0.06	0.01	0.11	−0.04
14	Multiple programs	0.05	0.21	0	1	−0.10	0.10	0.09	0.08	0.05	−0.01	−0.06	0.09	−0.02	0.08	0.45
15	Mentors	0.24	0.43	0	1	−0.11	0.16	0.02	0.09	−0.03	0.00	0.08	0.13	0.01	0.13	0.36
16	Classes	0.18	0.38	0	1	−0.06	0.10	0.02	0.03	−0.02	−0.01	0.00	0.06	0.00	0.11	0.26
17	Office space	0.31	0.46	0	1	−0.09	0.19	0.03	0.10	−0.02	0.06	0.05	0.14	−0.02	0.15	0.55
18	Lab space	0.28	0.45	0	1	−0.07	0.19	0.01	0.09	−0.02	0.04	0.07	0.12	−0.02	0.13	0.52
19	University resources	0.22	0.41	0	1	−0.04	0.15	0.03	0.03	−0.04	0.03	0.03	0.06	−0.03	0.09	0.18
20	Pitch/Demo day	0.12	0.33	0	1	−0.08	0.16	−0.03	0.06	−0.13	0.00	0.03	0.10	−0.01	0.13	0.13
21	Funding	0.08	0.28	0	1	−0.04	0.10	0.06	0.01	−0.05	−0.02	0.01	0.03	−0.07	0.04	0.31
22	Sum of resources	1.45	2.22	0	9	−0.10	0.19	0.03	0.08	−0.05	0.02	0.04	0.12	−0.02	0.15	0.45
23	Private incubator bundle	0.19	0.40	0	1	−0.07	0.17	0.01	0.14	−0.04	0.01	0.09	0.12	−0.01	0.10	0.31
24	University incubator bundle	0.10	0.30	0	1	−0.05	0.11	−0.02	0.06	−0.04	−0.04	0.05	0.07	0.04	0.07	0.04
25	Accelerator bundle	0.03	0.18	0	1	−0.01	0.10	0.02	−0.06	−0.10	−0.06	0.04	−0.02	−0.01	0.05	0.05

	Variable	12	13	14	15	16	17	18	19	20	21	22	23	24	25
12	University incubator	1.00													

(Continued)

Table 2. Continued

	Variable	12	13	14	15	16	17	18	19	20	21	22	23	24	25
13	Accelerator	−0.04	1.00												
14	Multiple programs	0.28	0.10	1.00											
15	Mentors	0.59	0.29	0.27	1.00										
16	Classes	0.55	0.16	0.16	0.69	1.00									
17	Office space	0.66	0.12	0.31	0.71	0.58	1.00								
18	Lab space	0.60	0.10	0.28	0.66	0.54	0.93	1.00							
19	University resources	0.89	−0.05	0.29	0.64	0.60	0.75	0.70	1.00						
20	Pitch/Demo day	0.40	0.44	0.12	0.49	0.45	0.43	0.39	0.34	1.00					
21	Funding	0.13	0.54	0.34	0.40	0.20	0.23	0.18	0.15	0.42	1.00				
22	Sum of resources	0.75	0.27	0.41	0.86	0.77	0.89	0.85	0.82	0.59	0.44	1.00			
23	Private incubator bundle	0.56	0.15	0.26	0.87	0.58	0.73	0.79	0.64	0.35	0.27	0.82	1.00		
24	University incubator bundle	0.58	0.00	0.08	0.59	0.71	0.49	0.53	0.63	0.32	0.07	0.65	0.67	1.00	
25	Accelerator bundle	0.16	0.47	0.15	0.33	0.40	0.11	0.06	0.13	0.50	0.62	0.36	0.11	0.16	1.00

earlier, incubators and accelerators provide different bundles of services and resources. Private incubators tend to offer the least robust set of support structures such as office space with shared administrative support or laboratory space (Bøllingtoft & Ulhøi, 2005; Grimaldi & Grandi, 2005). Some find that incubators offer mentor opportunities and ad hoc training (Bruneel et al., 2012; Cohen, 2013). University incubators tend to include those services and resources provided by private incubators as well as access to university specific resources such as advanced laboratories and access to faculty mentors/advisors (Barbero et al., 2014; Colombo & Delmastro, 2002; Grimaldi & Grandi, 2005; Mian, 1996).[5] Accelerators are distinguished from incubators and angel investors by their robust educational workshops, dedicated mentorship, pitch presentations or demonstration days, and funding (Cohen, 2013; Cohen, Fehder, et al., 2019; Dempwolf et al., 2014; Wright & Drori, 2018).[6] See Table 1 for a summary.

Together, previous work and program descriptions aggregated into a list of common services and resources: dedicated mentorship, office space, lab space, education, university resources, pitch presentations or demonstration days, and funding. Figure 1 shows the percentage of each type of program that offered each component. Mentorship, classes, office space, lab space, and funding manifest as buffering mechanisms for new firms. Each of these efforts eases the challenge in efficiently and effectively organizing the new firm's core operations and service functions. Mentoring activities that buffer a new firm come in the form of counsel on internal, managerial decisions, such as human resources, marketing, or engineering. On the other hand, bridging mechanisms include mentorship, public presentations/competitions, and funding as these types of activities connect entrepreneurs to infrastructure providers, build legitimacy by affiliation, and provide access to external resources and knowledge flows. Note that both mentorship and funding are unique in that they can play both bridging and buffering roles.

Binary variables indicating the availability of each type of service and resource were coded for each program at the time of the firm's participation. These data were available through historical archival reports, brochures, articles, and archived websites (e.g., internet Archive). Although these services and resources were expected to play different roles, there may be a cumulative effect. Thus, we calculated the number of services and resources that the firm had access to in the program in which they participated at the time of their participation.

Venture development programs are also highly heterogeneous in their offerings (Hausberg & Korreck, 2018). To avoid the problem of misidentification, we analyzed the bundles of services and resources offered by each program in our sample. This enabled us to determine if it is the participation in a type of program determined by business model, despite the heterogeneity of services and resources offered, that influences firm outcomes or if it is the specific *combination* of services and resources most typically associated with a program type that drives any effect. There is a wide range of programs in existence; programs that align with a particular type of program business model (e.g., ownership, selectivity, revenue model) may not offer the support that is most commonly attributed to that type. Thus, we analyzed the services and resources irrespective of program business model. Since the number of programs (96) did not provide a large enough sample size for an effective structural equation model (Kline, 2016), we examined the correlations between component variables for each type of program and in aggregate (shown in Table 2 and described in Table 1). Next, we examined the percentage of each type of program that offered the various components as shown in Figure 1. Using the correlations and component breakdown by program, we determined that private incubators were indeed highly associated with mentoring, office space, and lab space. Thus, we considered these three offerings together to be a private incubator bundle of offerings. Over half of the private incubators offered all three. This indicated the soundness of using this type of analysis because it meant that almost half of the incubators did not fit the traditional definition of private incubator (e.g., Cohen, 2013; Hausberg & Korreck, 2018). We repeated the process with university incubators and found that mentors, classes, office space, lab space, and university-specific resources were highly associated, and that over half of these incubators offered all five. Thus, we considered these five offerings together to be a university incubator bundle. Repeating the process with accelerators, we found that mentors, classes, pitch/demo days, and funding were the most associated, again with over 50% offering all four. These four offerings together made up the accelerator bundle. Next, we coded each firm with a binary variable signifying if it had participated in a program with all of the components common to the respective bundle. These measures enabled us to examine the influence of both the individual components and those often offered in each type of program regardless of their business model.

Dependent Variables

The study used multiple outcome variables to provide deeper discernment of the dynamics of firms and venture development programs: closure due to bankruptcy, asset sale, or poor performance, obtaining Small Business Innovation Research (SBIR) or Small Business Technology Transfer (STTR) grants, and VC funding. These offer proxy measurements of startup success as they are important milestones for entrepreneurs. Financial data on small or young firms are notoriously difficult to obtain, particularly in the United States (Hope et al., 2013). Instead, scholars have used firm survival as a measure of success and closure as a measure of failure (Wennberg et al., 2010). However, not all firms that close do so in distress and therefore not all should be considered failures (Bates, 2005; DeTienne et al., 2015; Fortune & Mitchell, 2012; Greve, 2011; Wennberg et al., 2010; Woolley, 2017b). We attempt to distinguish closing from potentially positive performance from those that are definitely a negative closure. For example, firms that are acquired often have positive performance records or valuable resources, while firms that close due to bankruptcy or asset sale do so because of poor performance. In fact, firms with knowledge and IP valued by the industry and other firms are likely to be the target of an acquisition (Arora & Nandkumar, 2011; DeTienne et al., 2015; Furr & Kapoor, 2018). Thus, we disaggregated firms that cease operations due to bankruptcy, asset sale, or poor performance, which we call negative closure, from those that closed due to acquisition or merger with another firm. These outcomes indicated the extent to which a venture development program buffers a startup from environmental threat.

Another milestone by which entrepreneurs measure success is obtaining competitive government grants (Stevenson et al., 2021). Government sponsorship of nascent ventures often takes the form of capital conservation programs that encourage entrepreneurship by lowering the amount of resources and assets needed to start a firm and reducing other barriers to entry (e.g., R&D funding and tax subsidies). Science and innovation policy in the United States has long supported the development of new technology-based ventures. Two of the largest programs created by the U.S. government to help nascent ventures are the SBIR and the STTR programs. These programs provide financing that increases a firm's ability to improve staff skills and conduct long-term research (Cooper, 2003). By providing funding for R&D activities that are often expensive, and at times beyond the means of small, nascent ventures (Bonvillian, 2011; Link & Scott, 2003), these programs enable young firms to better compete with larger firms that have more resources. Entrepreneurs seek these grants not only for the financial resources that they provide, but also to increase their legitimacy and credibility. SBIR and STTR programs select awardees based on their ability to further innovations and commercialize technologies. Thus, obtaining such a grant may have a "certification" effect that enhances a firm's image and validity in the eyes of external stakeholders (Lerner, 1999; Toole & Czarnitzki, 2007; Toole & Turvey, 2009). Indeed, Lerner (1999) argues that SBIR and STTR programs parallel VC funding. For these reasons, high-technology entrepreneurs often seek SBIR and STTR grants (Woolley, 2017b). In addition to supporting R&D in small firms, these programs attempt to help firms cross the "valley of death" period during which growth is stymied due to a lack of working capital. While both programs fund R&D, the SBIR program focuses on innovation in small businesses while the STTR program focuses on innovation in public/private collaborations, particularly between small businesses and nonprofit research institutions. The U.S. Small Business Administration coordinates both programs, with the SBIR program starting in 1982 and the STTR program in 1992. Through 2019, the SBIR and STTR programs have provided over $48 billion to small businesses (Small Business Administration, 2020). The programs are competitive with annual acceptance rates for Phase I or initial awards averaging between 15% and 20%.[7] The SBIR database provides detailed information about each SBIR and STTR grant provided since the inception of each program.

Raising VC refers to an investment by a VC investment company in exchange for partial equity ownership of the focal firm. Venture capitalists carefully consider the firms in which they invest and obtaining VC indicates investor confidence in the firm (Aldrich & Ruef, 2006). VC funding is also a positive signal to external stakeholders such as potential employees, suppliers, and customers (Davila et al., 2003) and is a positive milestone for many entrepreneurs. In 2019, venture capitalists in the United States invested in 6094 deals totaling over $100 billion (PricewaterhouseCoopers, 2020). VC funding data for each firm were collected through multiple sources including Crunchbase, VC firm websites and announcements, and PR Newswire. VC funding and government grants offer insight into shorter-term milestones that are significant to entrepreneurs.

We followed each firm through 2017 to determine if it had experienced the outcomes of interest. For each type of outcome, we constructed a dichotomous variable of outcome attainment, year of outcome, and the amount of time in years between firm founding and outcome. If the firm achieved the outcome before participating in a venture development program, it was eliminated from the sample for the respective models.

Control Variables

The models included controls for firm-level variables known to influence firm outcomes including: year of founding (Singh et al., 1986), the number of founding team members (Beckman, 2006), the firm's industry, and patenting activity (Cefis & Marsili, 2006; Wagner & Cockburn, 2010).[8] In terms of patenting activity, for each firm we obtained the year of the company's first patent (if any) from the U.S. Patent and Trademark Office (USPTO) and compared this to each of the dependent variables. Three binary variables were constructed indicating if the firm was awarded a patent before each of the dependent variables of interest and these were included in the respective analysis (patenting before negative closures was included in the negative closure models, patenting before government grants was included in grant models and patenting before VC was included in VC models). To control for the influence of founder experience and education we included two binary variables, one for previous entrepreneurial experience of any founder (e.g., Blank, 2020) and another for any founder obtaining a doctorate before starting the firm (e.g., Woolley, 2019). Work has shown that firms with stronger founding teams and ideas are less likely to apply to participate in accelerators, which leads to accelerated firms raising less VC funding (Yu, 2020). Thus, these controls help reduce the potential influence of self-selection bias in the results. Founder data were obtained from multiple sources including LinkedIn, Crunchbase, databases, faculty profiles, curriculum vitae, and firm websites. To control for the influence of the general economy, models included the annual amount of funding provided for nanotechnology research by the U.S. government, the annual number of U.S. firm closures (Hannan & Freeman, 1988), and the annual amount of VC funding in the U.S. Annual macro-level control variables were standardized.[9]

Analysis

Since the dependent variables are events and the time span to the occurrence of those events, we used survival analysis or event history analysis in STATA with maximum likelihood estimation and robust standard errors, clustered by firm. Since the hazard rates observed in these data were not constant over time, the Weibull distribution was used (see Box-Steffensmeier & Jones, 1997). A comparison of the log-likelihood ratios showed that the best fitting distribution for the data were the Weibull failure (event) time model (Blossfeld & Rohwer, 2002).[10] The equation for the Weibull distribution (Allison, 2014) is:

$$\log \mathrm{h(t)} = \mathrm{b}_0 + \mathrm{b}_1\mathrm{x}_1 + \mathrm{b}_2\mathrm{x}_2 + c \log t$$

where h(t) is the hazard function, b_0, b_1, b_2, and c are constants, and t indicates time. Hazard ratios greater than one indicate an increase in the likelihood that the variable influences the dependent variable, and those below one indicate a lower likelihood of influence.

Robustness Checks

Several robustness checks were conducted to determine alternative findings or weaknesses in the models. First, control variables for macro-economic influences indicated by stock market fluctuations (NASDAQ and DJIA at year end) were tested but were highly correlated with federal funding of nanotechnology research, and VC funding and were excluded from the models. Also, controls for a firm's geography, such as state and R&D intensity per state in which the firm resided, were tested to account for the more immediate resource munificence of the firms' surroundings, but the variables were not significant in any models. We analyzed the data using a control for the density of nanotechnology firms, but the variable was highly correlated to U.S. VC funding and contributed less to the models, so it was also excluded from analysis.

Results

Over one-third of nanotechnology firms founded between 1997 and 2011 or 146 firms in the sample of 419 firms, participated in an incubator or accelerator program. Equivalent proportions participated in private incubators (18%) and university incubators (18%). In addition, approximately 3% of firms participated in accelerator programs and 3% of firms participated in more than one program. Figure 2 shows the number of nanotechnology firms that entered a venture development program by the year and program type. The composition changes over time with the highest number entering private incubators in 2007, university incubators in 2006, and accelerators in 2010. On average, startups that joined venture development programs did so within 3 years of their founding. Table 2 summarizes the descriptive statistics and correlations of the variables. Of the sample, 32% experienced a negative closure, 59% obtained at least one SBIR or STTR grant, and 45% received VC funding. Figure 3 shows the percentage of firms achieving each outcome by participation in a venture development program. Notably, firms that did not participate in a program were more likely to suffer a bankruptcy or asset sale and less likely to obtain a government grant. The event history analysis provides additional detail on this high level observation.

Tables 3–5 exhibit the event history analysis for the relationship between program participation and each of the outcomes with the first model including only control variables. Table 3 shows the models for experiencing a bankruptcy, asset sale, or other negative closure. Models 2 and 5 indicate that there is no significant benefit to participating in a private incubator, while firms participating in a university incubator were over 50% less likely to experience a negative

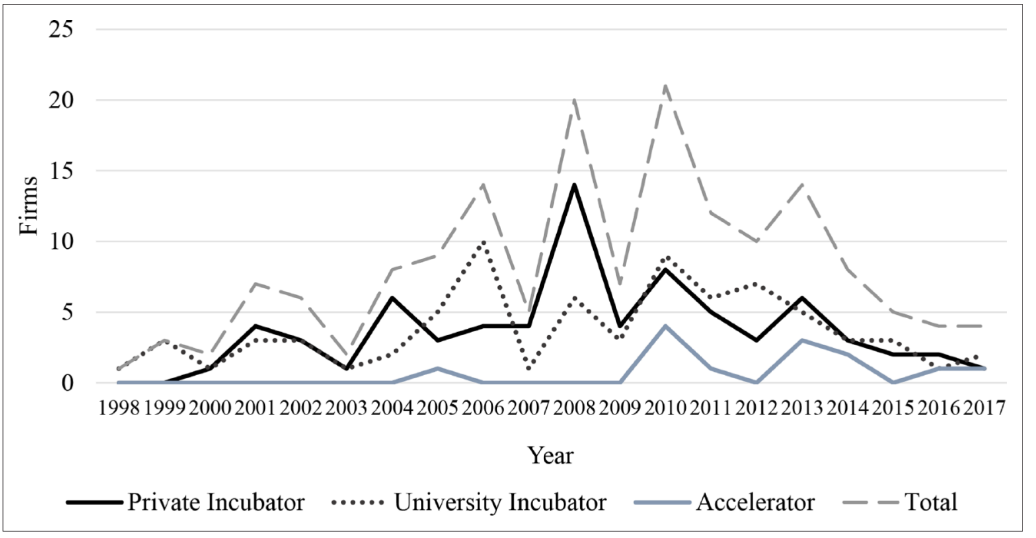

Figure 2. Composition of sample by venture development program and year entered.

closure than other firms (Models 3 and 5), supporting Hypotheses 1 and 3. Models 4 and 5 show that virtually no firm participating in an accelerator experienced a negative closure by the end of 2017, further supporting Hypotheses 1 and 3 in terms of avoiding bankruptcies and assets sales as a measure of success. Model 6 shows that participating in more than one program also reduced the likelihood of experiencing a negative closure, supporting Hypothesis 4.

Results for firms obtaining SBIR and STTR grants are shown in Table 4. Models 8 and 11 indicate that participants in private incubators were more likely to obtain government grants than other startups, supporting Hypothesis 1. Models 9 and 11 reveal that university incubator participants were almost twice as likely to obtain government grants than other startups (Model 9) or nonincubated/accelerated firms (Model 11), supporting Hypotheses 1 and 3. Model 10 show that participating in an accelerator did not significantly influence a firm's likelihood of obtaining a grant compared to startups generally, but Model 11 shows that accelerator participants were more likely to obtain grants than nonincubated/accelerated firms. Model 12 shows that firms participating in more than one program were over twice as likely as other firms to obtain grants. Thus, the data show benefits to participating in private or university incubators or in multiple programs in terms of obtaining grants (Hypotheses 1, 3 and 4), but not for accelerators.

Table 5 shows the models for obtaining VC. Model 14 shows marginally significant benefit for participating in private incubators compared to all other firms ($p < .1$), but Model 17 indicates these firms are over 70% more likely to obtain VC than nonincubated/accelerated firms. Models 15 through 17 show no support for a relationship between university incubator or accelerator participants and VC. Thus, in terms of VC as an indicator of success, Hypothesis 1 was supported for private incubator participants, but there was no support for Hypotheses 1 and 3 in terms of university incubator or accelerator participants and there was no support for Hypothesis 4.

Tables 6–8 exhibit the event history analysis for the influence of individual and aggregated bundles of service and resources on firms' outcomes. Table 6 focuses on experiencing a negative closure, with Model 19 indicating that firms in programs with mentors were 62% less likely to close, but other resources were not a significant influence. Model 20 shows that firms participating in venture development programs with more services and resources were 15% less likely to close negatively, supporting Hypothesis 2. Models 21 through 23 show the results from services

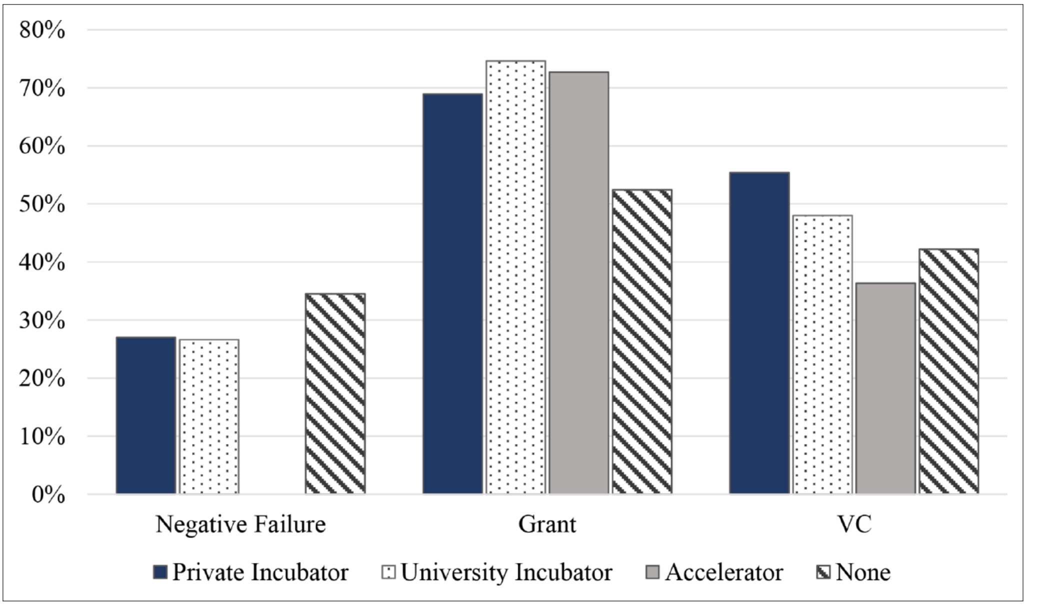

Figure 3. Outcomes of firms founded 1997–2011 by participation in venture development program.

and resource bundles and reveal that firms participating in programs with bundles typically found in private incubators (mentors, office space, and lab space) were 50% less likely to experience a negative closure compared to other firms and that participants in programs with bundles typically found in university incubators (mentors, classes, office space, lab space, and university-specific resources) were over 65% less likely to experience a negative closure compared to other firms. Contrary to expectations, bundles of services and resources typically found in accelerators (mentors, pitch / demo day, and funding) were not significant.

Table 7 exhibits the models for program service and resources and obtaining government innovation grants. Model 24 shows that firms participating in venture development programs with office space were more than three times as likely to obtain grants, while those with access to labs were about half as likely. Model 25 indicates that firms in programs with more services and resources were over 15% more likely to obtain a grant providing additional support for Hypothesis 2. Models 26 through 28 show the results from component bundles and reveal that each type of bundle improved a firm's likelihood of grants; firms participating in programs with a combination of service and resource bundles similar to private incubators or accelerators were over twice as likely.

Table 8 exhibits the models for program service and resource components and obtaining VC funding. Model 29 reveals that only office space had a significant effect on VC funding. Model 30 shows that firms in programs with more components were almost 10% more likely to obtain VC funding; however, the significance was marginal ($p < .1$). None of the compilations of services and resources was particularly beneficial for obtaining VC.

Discussion

The objective of this study was to expand our knowledge about how venture development programs influence participants' success. So far, studies have posited that venture development

Table 3. Event History Analysis for Bankruptcies, Asset Sales, and Closures Without Acquisition by the End of 2017, Nanotechnology Firms Founded 1997–2011.

	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6	
	H.R.		H.R.		H.R.		H.R.		H.R.		H.R.	
Founder count	0.98		0.99		0.98		0.98		1.00		0.97	
	(0.11)		(0.11)		(0.11)		(0.11)		(0.11)		(0.11)	
Founding team entrepreneur	1.00		1.02		0.94		1.01		0.96		0.96	
	(0.21)		(0.21)		(0.19)		(0.21)		(0.2)		(0.2)	
Founding team PhD	0.86		0.86		0.82		0.89		0.87		0.74	
	(0.23)		(0.23)		(0.22)		(0.24)		(0.23)		(0.19)	
Patent	0.39	***	0.40	***	0.39	***	0.40	***	0.41	***	0.44	***
	(0.08)		(0.08)		(0.08)		(0.08)		(0.08)		(0.09)	
U.S. funding nano	0.47	***	0.47	***	0.45	***	0.47	***	0.45	***	0.46	***
	(0.08)		(0.08)		(0.08)		(0.08)		(0.08)		(0.08)	
U.S. firm closures	1.52	***	1.53	***	1.55	***	1.52	***	1.58	***	1.52	***
	(0.11)		(0.11)		(0.12)		(0.11)		(0.11)		(0.11)	
U.S. VC funding	0.04	***	0.04	***	0.04	***	0.04	***	0.04	***	0.03	***
	(0.01)		(0.01)		(0.01)		(0.01)		(0.01)		(0.01)	
Private incubator			0.79						0.73			
			(0.20)						(0.19)			
University incubator					0.44	**			0.42	**		
					(0.13)				(0.12)			
Accelerator							0.00	***	0.00	***		
							(0.00)		(0.00)			
Multiple programs											0.14	*
											(0.12)	
Constant	0.00	***	0.00	***	0.00	***	0.00	***	0.00	***	0.00	***
	(0.00)		(0.00)		(0.00)		(0.00)		(0.00)		(0.00)	
Observations	419		419		419		419		419		419	
No. of failures	133		133		133		133		133		133	
Time at risk	3996		3996		3996		3996		3996		3996	
Wald chi-sq	265.96	***	281.8	***	303.01	***	819.05	***	919.88	***	327.12	***
df	24		25		25		25		27		25	
Log pseudo-LL	−67.97		−67.61		−63.67		−65.95		−60.56		−64.98	

Note. Includes year founded and industry controls. ^$p < .1$, *$p < .05$, **$p < .01$, ***$p < .001$. Robust standard errors in parentheses.

programs are beneficial for participants since these programs provide services and resources that buffer them from environmental uncertainty and bridge them with infrastructure providers that are necessary for their success (Cohen, Bingham, et al., 2019; Cohen, Fehder, et al., 2019; Goswami et al., 2018). However, results have painted an unclear picture and tended to focus on one type of program. Leveraging a robust sample of nanotechnology firms, our analysis builds on previous work by comparing the outcomes for firms that participated in three types of programs—private incubators, university incubators, and accelerators—and nonparticipants. By examining firms with a similar foundational technology and controlling for geography and industry, we consider only those firms most at risk for participating in such programs. We

Table 4. Event History Analysis for Obtaining SBIR and STTR Grants by the End of 2017, Nanotechnology Firms Founded 1997–2011.

	Model 7		Model 8		Model 9		Model 10		Model 11		Model 12	
	H.R.		H.R.		H.R.		H.R.		H.R.		H.R.	
Founder count	1.23	**	1.20	*	1.22	**	1.22	**	1.16	^	1.18	*
	(0.09)		(0.09)		(0.09)		(0.09)		(0.09)		(0.09)	
Founding team entrepreneur	0.75	^	0.75	^	0.75		0.76		0.77		0.78	
	(0.13)		(0.13)		(0.13)		(0.13)		(0.14)		(0.14)	
Founding team PhD	2.57	**	3.15	***	2.57	**	2.55	**	2.87	***	2.74	***
	(0.83)		(1.03)		(0.81)		(0.82)		(0.89)		(0.84)	
Patent	2.58	***	2.69	***	2.52	***	2.61	***	2.69	***	3.06	***
	(0.54)		(0.55)		(0.56)		(0.54)		(0.61)		(0.66)	
U.S. funding nano	0.20	***	0.20	***	0.19	***	0.20	***	0.19	***	0.21	***
	(0.03)		(0.04)		(0.03)		(0.03)		(0.04)		(0.04)	
U.S. firm closures	1.56	***	1.57	***	1.58	***	1.57	***	1.56	***	1.50	***
	(0.13)		(0.13)		(0.13)		(0.13)		(0.14)		(0.13)	
U.S. VC funding	0.26	***	0.23	***	0.24	***	0.26	***	0.22	***	0.24	***
	(0.05)		(0.05)		(0.05)		(0.05)		(0.05)		(0.05)	
Private incubator			1.81	***					1.81	***		
			(0.33)						(0.31)			
University incubator					1.96	***			1.96	***		
					(0.28)				(0.29)			
Accelerator							1.27		1.75	*		
							(0.4)		(0.47)			
Multiple programs											2.26	***
											(0.51)	
Constant	0.22	***	0.16	***	0.19	***	0.21	***	0.15	***	0.20	***
	(0.09)		(0.06)		(0.08)		(0.09)		(0.06)		(0.08)	
Observations	419		398		408		415		391		391	
No. of failures	246		225		235		242		218		218	

(Continued)

Table 4. Continued

	Model 7		Model 8		Model 9		Model 10		Model 11		Model 12	
	H.R.		H.R.		H.R.		H.R.		H.R.		H.R.	
Time at risk	2695		2667		2669		2688		2650		2650	
Wald chi-sq	349.75	***	294.73	***	344.09	***	348.12	***	289.38	***	292.21	***
df	24		25		25		25		27		25	
Log pseudo-LL	−438.05		−404.73		−416.68		−433.48		−389.51		−397.66	

Note. Includes year founded and industry controls. ^$p < .1$, *$p < .05$, **$p < .01$, ***$p < .001$. Robust standard errors in parentheses.

Table 5. Event History Analysis for Obtaining Venture Capital by the End of 2017, Nanotechnology Firms Founded 1997–2011.

	Model 13		Model 14		Model 15		Model 16		Model 17		Model 18	
	H.R.		H.R.		H.R.		H.R.		H.R.		H.R.	
Founder count	1.41	***	1.40	***	1.42	***	1.41	***	1.38	***	1.37	***
	(0.11)		(0.11)		(0.11)		(0.11)		(0.12)		(0.11)	
Founding team entrepreneur	0.86		0.90		0.84		0.86		0.86		0.84	
	(0.17)		(0.19)		(0.17)		(0.17)		(0.18)		(0.17)	
Founding team PhD	1.78	^	2.00	*	1.75	^	1.79	^	1.82	^	1.83	^
	(0.58)		(0.69)		(0.58)		(0.58)		(0.61)		(0.61)	
Patent	3.26	***	3.32	***	3.35	***	3.26	***	3.39	***	3.26	***
	(0.7)		(0.75)		(0.71)		(0.70)		(0.76)		(0.71)	
U.S. funding nano	0.32	***	0.32	***	0.32	***	0.32	***	0.32	***	0.33	***
	(0.04)		(0.05)		(0.04)		(0.04)		(0.05)		(0.05)	
U.S. firm closures	1.35	***	1.35	***	1.33	***	1.35	***	1.32	**	1.28	**
	(0.11)		(0.12)		(0.11)		(0.11)		(0.12)		(0.11)	
U.S. VC funding	0.22	***	0.22	***	0.21	***	0.22	***	0.20	***	0.22	***
	(0.05)		(0.06)		(0.05)		(0.05)		(0.05)		(0.06)	
Private incubator			1.53	^					1.71	**		
			(0.36)						(0.37)			
University incubator					1.28				1.38			
					(0.27)				(0.30)			
Accelerator							1.05		1.20			
							(0.59)		(0.64)			
Multiple programs											1.84	*
											(0.58)	
Constant	0.04	***	0.03	***	0.04	***	0.04	***	0.03	***	0.04	***
	(0.02)		(0.02)		(0.02)		(0.02)		(0.02)		(0.02)	
Observations	419		400		413		419		400		400	
No. of failures	188		169		182		188		169		169	

(Continued)

Table 5. Continued

	Model 13		Model 14		Model 15		Model 16		Model 17		Model 18	
	H.R.		H.R.		H.R.		H.R.		H.R.		H.R.	
Time at risk	3424		3383		3415		3424		3389		3389	
Wald chi-sq	248.29	***	232.35	***	243.25	***	248.72	***	228.65	***	240.89	***
df	24		25		25		25		27		25	
Log pseudo-LL	−373.22		−341.75		−364.53		−373.22		−340.83		−342.70	

Note. Includes year founded and industry controls. ^$p < .1$, *$p < .05$, **$p < .01$, ***$p < .001$. Robust standard errors in parentheses.

Table 6. Event History Analysis for Venture Development Program Components and Bankruptcies, Asset Sales, and Closures Without Acquisition by the End of 2017, Nanotechnology Firms Founded 1997–2011.

	Model 19		Model 20		Model 21		Model 22		Model 23	
	H.R.		H.R.		H.R.		H.R.		H.R.	
Founder count	1.03		1.05		1.03		1.05		0.98	
	(0.12)		(0.12)		(0.12)		(0.12)		(0.11)	
Founding team entrepreneur	0.89		0.94		0.96		0.94		0.97	
	(0.19)		(0.20)		(0.20)		(0.20)		(0.20)	
Founding team PhD	0.81		0.87		0.88		0.83		0.88	
	(0.23)		(0.24)		(0.24)		(0.22)		(0.23)	
Patent	0.44	***	0.40	***	0.40	***	0.39	***	0.39	***
	(0.08)		(0.08)		(0.08)		(0.08)		(0.08)	
U.S. funding nano	0.45	***	0.46	***	0.47	***	0.46	***	0.46	***
	(0.08)		(0.08)		(0.08)		(0.08)		(0.08)	
U.S. firm closures	1.65	***	1.61	***	1.59	***	1.64	***	1.53	***
	(0.12)		(0.11)		(0.12)		(0.12)		(0.11)	
U.S. VC funding	0.04	***	0.04	***	0.04	***	0.04	***	0.04	***
	(0.01)		(0.01)		(0.01)		(0.01)		(0.01)	
Mentor	0.38	*								
	(0.18)									
Classes	0.84									
	(0.46)									
Office space	0.88									
	(0.56)									
Lab space	1.59									
	(0.83)									
University resources	0.76									
	(0.41)									
Pitch/Demo day	1.01									
	(0.44)									
Funding	1.38									
	(0.54)									
Sum of resources			0.85	***						
			(0.04)							
Private incubator bundle					0.49	**				
					(0.13)					
University incubator bundle							0.32	**		
							(0.12)			
Accelerator bundle									0.55	
									(0.21)	
Constant	0.00	***	0.00	***	0.00	***	0.00	***	0.00	***
	(0.00)		(0.00)		(0.00)		(0.00)		(0.00)	
Observations	419		419		419		419		419	
No. of failures	133		133		133		133		133	
Time at risk	3996		3996		3996		3996		3996	
Wald chi-sq	409.73	***	361.89	***	350.77	***	333.86	***	280.06	***

(Continued)

Table 6. Continued

	Model 19	Model 20	Model 21	Model 22	Model 23
	H.R.	H.R.	H.R.	H.R.	H.R.
df	31	25	25	25	25
Log pseudo-LL	−59.64	−62.45	−64.29	−62.71	−67.27

Note. Includes year founded and industry controls. ^$p < .1$, *$p < .05$, **$p < .01$, ***$p < .001$. Robust standard errors in parentheses.

recognize that a program's business model (the typical basis of identification) may differ from how it enacts its business model through services and resources. Thus, we dive into the specific services and resources provided by the programs to determine if there are any essential components that are particularly important for program efficacy. Instead of examining only firm survival, which is problematic because it includes closures with both positive and negative performance (Wennberg et al., 2010; Woolley, 2017b), we examine more specific milestones that technology entrepreneurs commonly find important: avoiding negative closure (e.g., bankruptcy or asset sales), government grants, and VC. Although avoiding a bankruptcy or asset sale is generally seen as a positive outcome, these three milestones are not significant to all entrepreneurs nor mutually exclusive. In fact, although 28% of the sample obtained both grants and VC, other firms may target one over the other. The results, thus, provide insight into different conceptualizations of success indicating that some programs increase the likelihood of participants' success, but in different ways, which are summarized in Table 9.

Implication for Theory

Prompted by previous research, we argue that participating in any venture development program would improve a firm's likelihood of success in Hypothesis 1. The analysis provided mixed results in that private incubator participation improved the likelihood of obtaining a grant or VC, university incubator participation supported firms to avoid negative closures and obtain grants, and accelerator participation helped avoid experiencing a negative closure. In other words, if an entrepreneur's goal is to avoid a negative closure, university incubators or accelerators are most helpful, but if grants or VC funding is the goal, private and university incubators are most helpful. Hypothesis 3 argues that university incubator and accelerator participation improves a firm's changes of success, mainly based on the breadth of services and resources provided by the programs. The results support Hypothesis 3 in terms of university incubators, but accelerators supported success only related to avoiding a negative closure. Hypothesis 3 was not supported in terms of VC funding.

To unpack this a bit more, we looked at the outcomes for firms that participated in more than one program in Hypothesis 4 and found support in that that this helped across all success measures. This result suggests that the benefits from participating in multiple programs with dissimilar foundations can be useful (Soetanto & Jack, 2013) in terms of heterogeneous tacit knowledge (Cooper et al., 2012) and collaboration (Colombo & Delmastro, 2002). We looked at individual cases and noted that over half of these multi-program firms participated in private and university incubators suggesting that these two types of programs may complement each other. Unfortunately, the sample size is too small to provide anything beyond hints at these dynamics, but these findings suggest a fascinating avenue for future research.

To consider our research question further, we also examined the influence of program service and resource offerings on firm outcomes. While we do not hypothesize the influence of

Table 7. Event History Analysis for Venture Development Program Components and Obtaining SBIR and STTR Grants by the End of 2017, Nanotechnology Firms Founded 1997–2011.

	Model 24		Model 25		Model 26		Model 27		Model 28	
	H.R.		H.R.		H.R.		H.R.		H.R.	
Founder count	1.16	*	1.17	*	1.20	**	1.22	**	1.25	**
	(0.09)		(0.09)		(0.09)		(0.09)		(0.09)	
Founding team entrepreneur	0.75	^	0.76		0.78		0.75	^	0.78	
	(0.13)		(0.14)		(0.14)		(0.13)		(0.14)	
Founding team PhD	2.79	***	2.95	***	3.12	***	2.54	**	2.54	**
	(0.88)		(0.91)		(1.02)		(0.80)		(0.81)	
Patent	3.08	***	2.68	***	2.63	***	2.74	***	2.47	***
	(0.72)		(0.58)		(0.52)		(0.57)		(0.49)	
U.S. funding nano	0.19	***	0.19	***	0.20	***	0.19	***	0.20	***
	(0.04)		(0.04)		(0.04)		(0.03)		(0.03)	
U.S. firm closures	1.54	***	1.55	***	1.58	***	1.55	***	1.57	***
	(0.13)		(0.13)		(0.13)		(0.13)		(0.13)	
U.S. VC funding	0.22	***	0.21	***	0.23	***	0.25	***	0.25	***
	(0.05)		(0.05)		(0.05)		(0.05)		(0.05)	
Mentor	1.21									
	(0.32)									
Classes	0.83									
	(0.20)									
Office space	3.74	**								
	(1.61)									
Lab space	0.52	*								
	(0.16)									
University resources	1.02									
	(0.24)									
Pitch/Demo day	1.23									
	(0.26)									
Funding	1.08									
	(0.22)									
Sum of resources			1.18	***						
			(0.03)							
Private incubator bundle					2.00	***				
					(0.29)					
University incubator bundle							1.60	**		
							(0.29)			
Accelerator bundle									2.41	***
									(0.64)	
Constant	0.15	***	0.14	***	0.12	***	0.20	***	0.19	***
	(0.06)		(0.06)		(0.05)		(0.09)		(0.08)	
Observations	391		391		398		408		415	
No. of failures	218		218		225		235		242	
Time at risk	2650		2650		2667		2669		2688	
Wald chi-sq	295.5	***	281.18	***	273.93	***	347.69	***	365.17	***
df	31		25		25		25		25	

(Continued)

Table 7. Continued

	Model 24	Model 25	Model 26	Model 27	Model 28
	H.R.	H.R.	H.R.	H.R.	H.R.
Log pseudo-LL	−387.67	−389.52	−400.80	−421.10	−430.94

Note. Includes year founded and industry controls. ^$p < .1$, *$p < .05$, **$p < .01$, ***$p < .001$. Robust standard errors in parentheses.

individual services and resources, Hypothesis 2 argues that access to a greater number of offerings improves a firm's likelihood of success. The findings strongly support this hypothesis in terms of avoid negative closures and obtain grants. When we deconstructed the offerings by archetypes of bundles, additional insight emerged. For example, at first glance, participating in a private incubator did not affect the likelihood of avoiding negative closures; however, programs that provided bundles of services and resources commonly associated with private incubators supported participants' ability to avoid bankruptcy and liquidation and obtain government grants. In contrast, the private incubator bundle of services and resources did not influence the likelihood of VC funding, while participating in a program with a private incubator business model did improve the likelihood. This may indicate that venture capitalists perceive the signal of the private incubator business model favorably, but that the programs' actual buffering and bridging resources did not enhance their VC prospects. Furthermore, private and university incubator bundles differed in the inclusion of classes, training, and university resources in the latter. Participation in university incubators or programs with similar bundles did not influence VC, which suggests that the inclusion of formal training programs and classes did not significantly influence this type of success of nanotechnology venture participants, which is also indicated in the models breaking out individual offerings.

The results for accelerator participation are mixed. On the one hand, accelerator participants were less likely to suffer a negative closure. On the other hand, and contrary to expectations, we found no significant relationship between accelerator participation and obtaining government grants or VC funding. These results are found despite these accelerator programs offering some of the most robust portfolios of services and resources among the venture development programs. In this sample, accelerators provided a higher number of services and resources (5.1 on average compared to 5.0 from university incubators and 3.6 from private incubators), and participants in programs with more services and resources are less likely to suffer a negative closure and more likely to obtain grants. One potential explanation is the small sample size; 3% of the firms in this study participated in an accelerator. This small sample limits the strength of the findings and curbs our enthusiasm for the results. Nevertheless, these findings are significant and useful. When we consider participation in programs with accelerator-related bundles of services and resources (mentors, classes, pitch/demo days, and funding), we see support for a firm's ability to obtain government grants, but not avoiding a negative closure or obtaining VC. Hallen et al. (2020) witnessed variance in accelerators' influence on participants' ability to raise funding, while Yu (2020) argued that potential accelerator participants self-select out of applying when the founders perceive that their idea is strong. Unfortunately, the small sample size of accelerators prohibits reaching additional conclusions, but this does highlight an interesting avenue for further study.

We recognize that the success of these ventures may be an artifact of self-selection of participants or the program's selection criteria for participation instead of the experience of the entrepreneurs while in the program and the buffering and bridging resources that they receive. For example, it could be the case that entrepreneurs choosing to participate into venture development

Table 8. Event History Analysis for Venture Development Program Components and Obtaining Venture Capital by the End of 2017, Nanotechnology Firms Founded 1997–2011.

	Model 29		Model 30		Model 31		Model 32		Model 33	
	H.R.		H.R.		H.R.		H.R.		H.R.	
Founder count	1.38	***	1.38	***	1.40	***	1.42	***	1.41	***
	(0.11)		(0.11)		(0.12)		(0.11)		(0.11)	
Founding team entrepreneur	0.82		0.86		0.89		0.83		0.87	
	(0.17)		(0.18)		(0.18)		(0.16)		(0.17)	
Founding team PhD	1.83	^	1.79	^	1.91	^	1.81	^	1.78	^
	(0.62)		(0.6)		(0.66)		(0.60)		(0.58)	
Patent	3.66	***	3.36	***	3.34	***	3.30	***	3.19	***
	(0.81)		(0.72)		(0.73)		(0.70)		(0.69)	
U.S. funding nano	0.32	***	0.33	***	0.32	***	0.33	***	0.32	***
	(0.05)		(0.05)		(0.05)		(0.05)		(0.04)	
U.S. firm closures	1.30	**	1.31	**	1.34	***	1.31	***	1.35	***
	(0.11)		(0.12)		(0.12)		(0.11)		(0.11)	
U.S. VC funding	0.21	***	0.20	***	0.22	***	0.22	***	0.22	***
	(0.05)		(0.06)		(0.06)		(0.05)		(0.05)	
Mentor	0.88									
	(0.31)									
Classes	0.85									
	(0.27)									
Office space	2.96	*								
	(1.55)									
Lab space	0.50									
	(0.25)									
University resources	1.10									
	(0.34)									
Pitch/demo day	0.99									
	(0.35)									
Funding	1.06									
	(0.45)									
Sum of resources			1.07	^						
			(0.04)							
Private incubator bundle					1.07					
					(0.23)					
University incubator bundle							0.86			
							(0.26)			
Accelerator bundle									1.26	
									(0.55)	
Constant	0.03	***	0.03	***	0.03	***	0.04	***	0.04	***
	(0.02)		(0.02)		(0.02)		(0.02)		(0.02)	
Observations	400		400		400		413		419	
No. of failures	169		169		169		182		188	
Time at risk	3389		3389		3383		3414		3424	
Wald chi-sq	246.98	***	231.56	***	242.6	***	243.03	***	244.4	***
df	31		25		25		25		25	

(Continued)

Table 8. Continued

	Model 29	Model 30	Model 31	Model 32	Model 33
	H.R.	H.R.	H.R.	H.R.	H.R.
Log pseudo-LL	−340.95	−342.89	−343.04	−365.02	−373.07

Note. Includes year founded and industry controls. ^$p < .1$, *$p < .05$, **$p < .01$, ***$p < .001$. Robust standard errors in parentheses.

programs are in themselves more likely to be successful due to their initiative, motivation, or other unobserved characteristics (van Weele et al., 2020). Indeed, founding teams with at least one person with a doctorate were more likely to obtain a government grant and VC (although only marginally significant). On the other hand, Yu (2020) argues that entrepreneurs with the best ideas do not apply for accelerator programs, which leads to accelerated firms raising less VC funding. The findings of this study do not show a relationship between accelerator participation and VC funding–either positive or negative. Although we control for the number of founders and their education and entrepreneurial experience, without additional information about program applications, it is impossible to eliminate the possibility of such endogeneity (Amezcua et al., 2020).

Participants in accelerators not only self-select to apply for the program, but also compete through a vetting process that generates a more homogeneous cohort than other venture development programs while setting a bar for the quality of the venture itself (Pauwels et al., 2016). This selection process may itself increase the likelihood that a firm survives such that if incubator programs use a similar vetting procedure, the results may be similar in the case of private incubators and heightened in the case of university incubators. However, other components of the incubator business model may constrain its ability to use such stringent selection criteria. Comparing programs with different business models, but similar vetting criteria would provide important insight into the role of preprogram selection versus during-program experience.

University programs tend to select firms related to the institution by way of intellectual property or founders. As university spin-offs tend to be focused on cutting-edge technology (Wennberg et al., 2011) and founders with advanced education and technical knowledge (Clarysse et al., 2011; Ding & Choi, 2011), the university affiliation selection requirement that these programs tend to use may favor firms that fit with government grant program requirements.

Table 9. Summary of Significant Findings.

		Event		
Hypotheses	Variable	Negative closure	Government grant	Venture capital
H1	Private incubator	0	+	+
	Private incubator bundle	-	+	0
H1 & H3	University incubator	-	+	0
	University incubator bundle	-	+	0
H1 & H3	Accelerator	-	0	0
	Accelerator bundle	0	+	0
H4	Multiple programs	-	+	+
H2	Sum of services & resources	-	+	0

Participants in venture development programs hope to cultivate critical tangible and intangible skills leading to greater success for their young firms. Most incubators and accelerators attempt to develop these idiosyncratic and intangible skills with features such as individualized mentoring and classes (Figure 1). The resulting managerial and entrepreneurial skills constitute a specialized form of human resources held by the firm founders. These strategic human resources are viewed as valuable, rare, and nonsubstitutable resources because they are scarce, specialized, and hold tacit knowledge (Coff, 1997). In so much as these result in high-quality human resources, such as specialized entrepreneurial skills, a competitive advantage may arise for these firms (Barney, 1991; Holcomb et al., 2009; Shaw et al., 2013). Our conclusions, thus, reveal a connection between program participation and the development of valuable, rare, and nonsubstitutable resources for startups.

We take the view that it is not simply the act of participating in a venture development program itself that influences a firm's success, but the access to and use of services and resources therein. Whether selection or treatment effects predominate, the findings highlight the variation in long-term outcomes experienced by participants. The difference in the results between program archetypes and component bundles for private incubators and accelerators further suggests that additional work regarding venture development program heterogeneity is needed. The typologies tend to account for business model and/or design features (Barbero et al., 2014; Cohen, Fehder, et al., 2019; Grimaldi & Grandi, 2005), distinct from resource bundles. University incubators and its bundle did not vary in their influence across success measures suggesting that the inclusion of academic resources, its main distinguishing feature, is a strong factor in accurately identifying this type of program. It is possible that *individual* components of a program's business model (sponsor, organization, selection, length of participation, venture stage, and revenue model) may be a specific explanatory factor. For example, the selection criteria, or lack thereof, may be more important than revenue model. Datasets with larger samples of startup intermediaries would be useful in comparing the typology criteria and services and resource bundles, which could provide insight into the spectrum of programs and strengthen the typologies.

These findings also hold implications for research regarding the buffering and bridging value of venture development programs as ecosystem intermediaries (Hausberg & Korreck, 2018; McAdam & McAdam, 2008; Patton et al., 2009). Extant research suggests that the set of services and tangible and intangible resources that venture development programs offer can improve outcomes for participant firms (Cohen, Bingham, et al., 2019; McAdam & McAdam, 2008; Patton et al., 2009; Stokan et al., 2015). The results here indicate that access to more services and resources does support firm success. However, not all resources are the same and increasing the volume of services and resources offered does not necessarily ensure long-term success. Examining outcomes of participants in different types of venture programs as well as nonparticipants allows us to show that university incubators may both bridge participants with government funders while buffering them from negative outcomes—functions that are unmatched by other programs. As universities shift from an incubator to an accelerator model (Dempwolf et al., 2014), research may find that their bridging and buffering capabilities change as well.

The growing literature on ecosystems and context of entrepreneurship underscores the important role that venture development programs play in startup support, innovation (Clayton et al., 2018) job creation, and economic growth (Hochberg, 2016; McAdam et al., 2016; Woolley, 2017a). Related work largely has analyzed private incubators, university incubators, and accelerators separately (Clayton et al., 2018; Mian et al., 2016), as each type of program uses different business models (Cohen, Fehder, et al., 2019). Our findings highlight the reality that the differences in business models influence participants' experiences while involved with the program, as well as their long-term outcomes. Moreover, ecosystem intermediaries such as venture development programs that support startups obtaining funding, such as government grant programs and venture capitalists, also support ecosystem additionality that builds long-term competence, expertise, and networks (Goswami et al., 2018; Söderblom et al., 2015). Therefore, when considering participation in a venture development program, entrepreneurs should consider the totality of additional access to domain expertise, relationship networking, operating resources, and funding opportunities, as well as the interplay among these benefits and the intermediaries offering them, in light of their own short and long-term business goals.

Implication for Practice

This study has important practical implications for entrepreneurs and policymakers. Entrepreneurs have many options for how to develop their firms and they often turn to startup intermediaries to bolster their chances for success (Clayton et al., 2018). Knowing that engaging in different programs may result in varying consequences is critical for a well-informed decision to participate. The findings of this study provide entrepreneurs who are active in nanotechnology and similar high technology fields with empirical evidence on the relationship between program participation and the likelihood of achieving various outcomes, which can improve their ability to match their own goals with the performance of the venture development program. Similarly, those who design and operate incubators and accelerators should consider how their programs influence the outcomes of their participants. Should the goals of the program not match the likely outcomes, a redesign may be necessary to align the services and resources available with those of competing programs that have desired track records.

The success of nascent firms is a goal not only for their founders, but also for policymakers who strive to improve the economic and technological competitiveness of their local and regional economies. Instead of focusing on top programs, the data follow participants in any program, building on earlier work to provide more generalizable results (Cohen, Bingham, et al., 2019). As not all policymakers can attract top programs to start incubators or accelerators in their regions, examining venture development programs more broadly can provide insight to improve decisions regarding funding allocations and other program support. For example, if policy makers view obtaining VC as an important criterion for program success, they may want to focus their efforts on bolstering private incubator programs.

Limitations and Avenues for Future Research

As with any study, we are limited by the constraints of our sample and data availability. In our endeavor to find the most appropriate data related to our research question, we made tradeoffs that limited to generalizability and scope of the study. For example, since not all industries are conducive to incubator or accelerator participation, we narrowed our focus to those industries with at least an average likelihood of participation. In eliminating firms from other sectors though, we may have overlooked critical data that may provide novel findings. We also concentrated on those firms that are geographically close to existing business development programs since it is unlikely that a firm's founders would move a company to an incubator or accelerator more than 60 miles away (Bone et al., 2017; Stam, 2007). Although this limited our sample, the resulting dataset is more generalizable to firms likely to participate in venture development programs. It would, nevertheless, be interesting to assess how firms that relocate to participate in such programs fare in the long run. Given their initial isolation, these firms may benefit more than firms already surrounded by strong entrepreneurial ecosystems.

As our study focused on a specific type of high technology firm, these findings may not be generalizable to all firms that participate in venture development programs, such as those involving consumer products or software. Nanotechnology firms operate in science-based industries, a setting that requires an abundance of knowledge, training, and resources. Incubators and accelerators are often populated with ventures that arguably require fewer resources to launch such as service, software and platform based firms (Amezcua, 2010). However, nanotechnology is a general purpose technology used in many industries (Youtie et al., 2008) including biotechnology, materials, medical devices, pharmaceuticals, and energy (e.g., Woolley, 2010). By and large, the startup resources that nanotechnology firms require to launch are similar to other technology firms that make up the bulk of incubator and accelerator participants. However, the technology-specific needs of nanotechnology firms may explain the influence of university incubators on the outcomes for the firms in this study. Additional research that examines the outcomes of a wider sample of firms that is able to capture a more diverse set of experiences from participation in venture development programs will help clarify the generalizability of these findings.

Another limitation of this study is, as mentioned, the small sample of firms that participated in accelerator programs. Indeed, we considered removing this analysis from the study all together but determined that the findings provided contrast with those of the private and university incubators. Also, this led to the examination of services and resources that are more typical for accelerators, but not incubators such as pitch/demo days and funding. We hope that the findings, while limited, provoke additional research to clarify the influence of incubators and accelerators further.

We cannot speculate about the influence of types of programs not observed here such as economic development incubators supported by policy initiatives that are more prevalent outside of the United States (Barbero et al., 2014) or the recently developed university accelerator programs. These programs may offer similar services and resources with different sponsors and goals, but we do not have data for such activity. Although beyond the scope of this study, a comprehensive comparison of venture development program participants would enable the development of a more holistic understanding of intermediaries' role in startup success.

In conclusion, we show that not only are venture development programs heterogeneous in their business model, services, and resource offerings, but also in the outcomes of the participants. While the heterogeneity of objectives, business models, and selection criteria certainly makes comparative assessment of efficacy challenging, we hope that this study contributes to furthering theory building in this line of research. There are many opportunities for investigation into the efficacy of venture development programs such as incubators and accelerators, and we hope that this work simulates further exploration.

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Notes

1. Science parks are related structures that lease office and research space to firms. However, they do not focus on supporting nascent ventures and have few dedicated entrepreneurship-related support structures. Thus, we do not include science parks in this study.
2. Economic development and research incubators are not as prevalent in America and we did not have firms participating in these types of programs in our sample. Thus, we concentrate on private and university incubators.
3. Given the time frame of this study, our sample did not find university accelerator programs, which are a more recent development. Thus, we do not discuss university accelerators as a separate category.
4. A subset of these data were compared with that from researchers who used a similar process to identify nanotechnology firms. Resulting inter-rater agreement was almost 90% (see Wang & Shapira, 2012 and Woolley, 2017b). Any firms not in agreement were analyzed. No additional firms met the criteria.
5. University incubators may also provide access to student employees, libraries, and technology transfer services (Colombo & Delmastro, 2002; Grimaldi & Grandi, 2005; Mian, 1996).
6. Some accelerators provide access to partnered service providers (Hansen et al., 2000); however, this tends to be idiosyncratic.
7. www.sbir.gov/awards/annual-reports. In 2019, over 16,000 firms applied for SBIR and STTR Phase I grants.
8. Research has shown that patenting activity of nascent firms is positively associated with their survival (Cefis & Marsili, 2006; Wagner & Cockburn, 2010) since they are a signal of innovation and can protect firms from rapid imitation (Arora et al., 2001; Scotchmer, 2005). Recent work (e.g., Woolley, 2017b) finds that patenting activity influences the closure of firms and the likelihood of obtaining VC.
9. As a robustness check, we analyzed models with 1 and 2 year lags for the macro-level control variables. The finding variations were not significant.
10. As a robustness check, all models were compared to their equivalent using the exponential distribution. The findings did not vary.

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