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Location choice of academic entrepreneurs: Evidence from the US biotechnology industry

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ABSTRACT

Where knowledge-based firms are located is important because entrepreneurship, firm creation and innovation are typically associated with regional economic development, wealth creation and increased employment. In this paper we examine where academic entrepreneurs locate their firms. We begin by developing a theoretical model that examines the location choice of the academic entrepreneur within the standard utility maximization theory. Academic entrepreneurs are assumed to maximize their utility by allocating their efforts between academic and entrepreneurial pursuits which, in turn, determine their future streams of income and end-period wealth. Optimal allocation turns out to be a function of both personal and external factors that condition the relevant payoffs and such factors can be empirically observed. We then use several candidate explanatory variables to examine those factors that may influence the firm location choice for 187 biopharmaceutical firms started by 275 academic entrepreneurs in the US. From our empirical analysis we find that location-specific factors such as proximity to certain knowledge assets and to the funding venture capital firms, affect the firm location choice of academic entrepreneurs. Nevertheless, entrepreneur-specific characteristics, such as their age, seem to dominate the choice of firm location.

1. Executive summary

Where firms choose to locate is important since entrepreneurial activity and firm creation are associated with regional economic development, increased employment and wealth. In recent years increased attention has been paid to the location of high technology firms as technical innovation and clusters of innovative firms have become engines of economic growth. Because many innovative firms have been spawned from research universities, the location of university spinoffs and the role of academic entrepreneurs that start them are of interest.

Partially prompted by the limited treatment in the academic entrepreneurship literature, in this paper we develop a theoretical model and examine the location choice of the academic entrepreneur within the standard utility maximization theory. The academic entrepreneur is assumed to maximize her utility by allocating her effort between academic and entrepreneurial pursuits which, in turn, determines her future streams of income and end-period wealth. Our theoretical model shows that the optimal allocation is a function of both personal and environmental factors that condition the relevant payoffs of entrepreneurial

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efforts, and that such factors can be empirically observed. Guided by our theoretical model and prior literature we then specify and measure a set of factors that could have influenced the firm location choice of 187 venture-capital backed biopharmaceutical firms started by 275 academic entrepreneurs in the US. We show that using an ordered logit model to examine these choices is both theoretically consistent and empirically relevant.

Based on this empirical model, we conclude that proximity to knowledge assets, (e.g. a medical school), as well as access to capital markets (e.g. through proximity to the funding venture capital firms), affect the location choice of academic entrepreneurs. Nevertheless, we also conclude that the influence of entrepreneur-specific characteristics, such as her age and professional experience, dominates the choice of firm location in our sample. In particular, we find that academic entrepreneurs at later stages of their career are considerably more likely to start their firm away from their academic homes.

Our findings, therefore, suggest that a deeper understanding of the location choice of firms spawned by universities may require more research and increased attention to the characteristics and incentives of the academic entrepreneurs that establish them. Our findings may, thus, be relevant to the ongoing debate about policies designed to create "entrepreneurial" local environments. While broad capital investments in local research infrastructure may help to attract new firms, our results suggest that the personal characteristics of academic entrepreneurs as well as the various incentives they face may be equally important for the creation of local firms.

2. Introduction

Where firms choose to locate is important since entrepreneurial activity and firm creation are associated with regional economic development, increased employment and wealth (Autio and Renko, 1998; Gordon and McCann, 2005). In recent years increased attention has been paid to the location of high technology firms as technical innovation and clusters of innovative firms have become engines of economic growth (Doeringer and Terkla, 1995; OECD, 2007). Because many innovative firms have been spawned from research universities, the location of such firms and the role of academic entrepreneurs that start them have also attracted some attention (Audretsch et al., 2005; Markman et al., 2004; Powers and McDougall, 2005; Zucker et al., 2002). Academic entrepreneurs are defined as university faculty that engage in entrepreneurial activity in order to exploit knowledge that originates at the university and is sometimes formally assigned to it through patents or other forms of intellectual property rights[1] (Di Gregorio and Shane, 2003; Lockett et al., 2005; Louis et al., 1989; Stuart and Ding, 2006).

Some of the firms started by academic entrepreneurs locate close to their academic institutions but many do not. The factors that drive this location choice, however, have been previously examined by very few studies and even then mostly indirectly. Zucker et al. (1998) observed that some US biotechnology firms had been started by academic scientists and examined whether such observation could be generalized. While the authors did not specifically identify the academic entrepreneurs or their firms in their analysis, they used aggregate data to test whether the density of preeminent scientists in different US regions predicted a high density of biotechnology startups. Their results, indeed, revealed a strong association between the location of star scientists and the birth of nearby biotechnology firms. Audretsch and Stephan (1996) examined the location choice of certain US biotechnology firms that were affiliated with academic scientists. A few of the affiliated scientists were founders of the firms but most were members of advisory boards and other consulting bodies. In this context, Audretsch and Stephan (1996) analyzed the probability that the firms and their affiliated academic scientists were located in proximity to one another. They found that the specific role of the scientist in the affiliated firm and her personal characteristics were important determinants. Firms and affiliated scientists were more likely to be located in proximity if the scientists were preeminent or they were the firm founders rather than members of advisory and other boards. Audretsch and Stephan also found that older academic scientists were more likely to have links with biotechnology firms that were not geographically bound. Finally, Egeln et al. (2004) examined how regional characteristics (e.g. urbanization and localization economies) as well as certain firm attributes (e.g. size, industrial sector) prompted academic spinoffs in Germany to locate close to or at a distance from their affiliated universities. They found that larger academic spinoffs, especially in knowledge intensive industries, were more likely to locate farther away while smaller spinoff firms using the university's infrastructure tended to locate closer to the parent institution. Spinoffs were also attracted to regions with strong urbanization economies but localization economies did not influence their location choice. Egeln et al. (2004), did not identify the academic entrepreneurs and did not examine their influence on the firm location choice.

The location of high technology firms is a longstanding topic of interest in the literature. Given that, the lack of attention to the location choice of academic entrepreneurial firms is curious; academic spinoffs appear to be numerous and strong economic performers (Dahlstrand, 1997; Mustar, 1997; Shane, 2004). According to the annual surveys of the Association of University Technology Managers (AUTM), in 2012 some 700 academic spinoffs were created in the US alone and the number of such spinoffs has been growing steadily over time. Furthermore, Audretsch et al. (2013) found that almost 13% of the 9000 scientists that had received grants from the US National Science Foundation from 2005 to 2012 had started a new firm and concluded "…that university scientist entrepreneurship is considerably more prevalent than would be indicated by the data compiled by the AUTM". There is also growing evidence that academic spinoffs are durable (e.g. Wobbekind et al. (2012)) and their high

[1] While academic spinoffs often originate from patented inventions they may also start on "a body of unpatented expertise" (pp 2. Perkmann et al., 2013; Shane, 2004)).

survival rate supports their strong development contribution in their local economies (e.g. O'Shea et al., 2008; Vincett, 2010; Steffensen et al., 2000).[2]

In this study we are interested in the factors that influence academic entrepreneurs' choices regarding the location of the firms they found. Given the paucity of the existing literature, we begin our inquiry by developing a theoretical model in order to guide our empirical work and we examine the location choice of the academic entrepreneur within the standard utility maximization theory. The academic entrepreneur is assumed to maximize her utility by allocating her available time (effort) between her academic and entrepreneurial pursuits which, in turn, determine her future streams of income and end-period wealth. Alternative location choices for the academic entrepreneurial firm yield different payoffs and can affect the entrepreneur's allocation of effort. As such, the choice of location is integral to the academic entrepreneur's decision process. The optimal location choice turns out to be a function of the personal characteristics of the entrepreneur as well as characteristics of pertinent locations, many of which can be empirically observed. Next, we specify a theoretically consistent empirical model, showing that a discrete choice model can adequately represent the location choice of the academic entrepreneur.

We implement our proposed approach by analyzing the location choice of 187 biopharmaceutical firms started by 275 US-based academic entrepreneurs between 1983 and 2008, all of which were backed by venture capital.[3] For our empirical analysis, we construct a novel data set that includes information on certain personal characteristics of the academic entrepreneurs and on factors that characterize the economic and institutional environment of the locations where their firms were started.

Our study contributes to the literature in several ways. First, it deepens the academic entrepreneurship literature which has evolved around three main lines of inquiry: What are the characteristics of academics that become entrepreneurs? How do they balance their research and business duties? And how is their academic performance influenced by their involvement in entrepreneurial firms, if in any way? (Azoulay et al., 2009; Bercovitz and Feldman, 2008; Czarnitzki and Toole, 2010; Jain et al., 2009; Krabel and Mueller, 2009; Lam, 2011; Landry et al., 2006, 2010; Louis et al., 1989; Lowe and Gonzalez-Brambila, 2007; Stuart and Ding, 2006; Zucker et al., 2002). The firm location choice of the academic entrepreneur has not been examined in any significant depth and we inform the literature on the factors that can shape such choice, both through our theoretical model and through our empirical results.

Second, our theoretical and empirical results clarify an issue that seems intuitive but has attracted little attention in the literature of firm location choice. There is a long tradition for studies that examine firm location choice by focusing either on the characteristics of the region in which the firms locate or on the traits of the entrepreneurs.[4] A similar approach has been followed by the few studies that have examined the location choice of academic entrepreneurial firms, which were reviewed above. Yet, starting from the academic entrepreneur's decision process, in this study we show that economic theory predicts that the personal characteristics of the entrepreneur as well as the economic and institutional environments of pertinent locations can simultaneously influence her firm location choice. Our empirical results confirm that both sets of factors may matter and that some may matter more than others. Specifically, we find that proximity to knowledge assets, (e.g. a medical school), as well as access to capital markets (e.g. through proximity to the funding venture capital firms), affect the firm location choice of academic entrepreneurs. Nevertheless, we also find that the influence of entrepreneur-specific characteristics, such as age, dominates the choice of firm location in our sample. Our empirical results, therefore, suggest that understanding the location of firms spawned by universities may require increased attention to the characteristics and incentives of the academic entrepreneurs.

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[2] There is accumulating evidence that academic spinoffs are durable. Wobbekind et al. (2012), find that out of the 114 academic spinoffs they studied over an 18 year period, 91 were still in operation at the completion of the study and only 23 had ceased operations. Out of the 91 surviving firms, 7 had gone public and 10 had been acquired by other companies. We find similar durability among the firms we study here. As of the end of our analysis, almost all of the firms in our dataset were in business for at least 7 years after their births and some were merged or acquired. The high survival rate of academic spinoffs adds an important dimension to their development contribution to their local economies. Such contributions have been highlighted in a number of studies (e.g. O'Shea et al., 2008; Vincett, 2010). Specific examples of the local economic gains from academic spinoffs in terms of wealth generation and increased employment in Boston, MA and Albuquerque, NM from academic spinoffs of the Massachusetts Institute of Technology and the University of New Mexico respectively are reported in BankBoston (1997) and Steffensen et al. (2000).

[3] Comprehensive data on the total number of academic spinoffs, the number of spinoffs that are focused on the development of biotechnologies, and the number of biotech academic spinoffs that are funded by venture capital is not available in the US or elsewhere. Some indirect indicators seem to suggest, however, that a large number of academic spinoffs are biotechnology firms and that a large share of those are supported by venture capital. For instance, while the annual AUTM surveys do not provide details about the industrial focus of academic spinoffs, evidence from the few universities that do report such details as well as from occasional surveys suggests that biotech firms constitute a large majority of academic spinoffs (Wobbekind et al., 2012; Zhang, 2009). Similarly, existing literature indicates that venture capitalists are more likely to invest in academic spinoffs as compared to other types of firms (Munari and Toschi, 2011; Ortín-Ángel and Vendrell-Herrero, 2010) and this observation is supported by datasets that report on biotech firms that have received venture capital in the US, like the SDC Platinum. Leveraging the feature of SDC Platinum that lists firm founders, we estimate that approximately 30% of all biotech firms in the SDC dataset which have received venture capital over the years were academic spinoffs.

[4] Singular attention either on the characteristics of the region where firms are located or the characteristics of the entrepreneur is common in the firm location choice literature (for notable exceptions see Green and McNaugthon (1995) and McNaughton and Green (2002)). Following the seminal contributions of Marshall (agglomeration economies), Weber (transportation costs), Von Thünen (land use model), Cristaller (central place theory) and Alonso (central business district), the stream of firm location studies has evolved around three main traditions: the neoclassical, the institutional and the behavioral (Hayter, 1997). Studies following the neoclassical tradition stress the importance of regional characteristics, such as agglomeration externalities and proximity to customers that minimize transportation and other costs and advance the firm's efficiency, often through knowledge spillovers (Audretsch et al., 2005; Figueiredo et al., 2002; Guimaraes et al., 2000). Studies following the institutional tradition also emphasize the importance of regional characteristics but mainly the ones that are shaped by local institutions/governments and can be influenced by firms. Such characteristics may involve taxes, local wages or other factors that form the regional economic environment and provide monetary gains that may assist the formation of sustained supplier and client networks (Bartik, 1985; Carlton, 1983; Coughlin et al., 1991; Glaeser and Kerr, 2009). Studies following the behavioral tradition focus more on the characteristics of the entrepreneur who they consider as the main driver in the choice of firm location (Dahl and Sorenson, 2012; Wright et al., 2008).

Despite its simplicity, this last result has important practical implications. Starting from the premise that firm creation is a driver of local, regional, and national economic development, various policies have been designed and implemented in order to create local environments conducive to entrepreneurship (Hart, 2003; Wennekers and Thurik, 1999). Policies of this sort include buildup of infrastructure, attraction or development of local labor and capital pools, attraction of complementary industries and others (Audretsch and Beckmann, 2007; Minniti, 2008; Storey, 2003). While such investments may be important, our results suggest that the personal characteristics of academic entrepreneurs as well as the various incentives and disincentives they face may be equally important for the creation of local firms. Complementary policies that align incentives and minimize disincentives inside and outside the university may therefore have high payoffs.

We organize the rest of the paper as follows: In Section 2 we develop a theoretical model of the academic entrepreneur's firm location decision process and we draw conclusions about the factors that might shape such a decision. In Sections 3 and 4 we present our empirical methods and explain our data sources. In Section 5 we present the empirical results of our study and we summarize and conclude in Section 6.

3. A utility approach to the academic entrepreneur's firm location choice

We begin the development of our theoretical model by placing it in the context of the broader theoretical literature of entrepreneurship and the location choice of the entrepreneurial firm. Whether to become an entrepreneur and where to locate a firm are important decisions and there are several studies that have developed the theoretical underpinnings of such decisions. Douglas and Shepherd (2000), Levesque et al. (2002), and Levesque and Minniti (2006) developed economic models of the binary choice to become an entrepreneur or seek employment within the standard utility theory. Individuals are assumed to maximize their utility which is a function of leisure, income, wealth and other personal factors. Levesque and Minniti (2006) also clarified the importance of lifecycle considerations in the individual decision to become an entrepreneur and described a threshold age beyond which interest in entrepreneurship wanes.

There are also several studies that have developed economic models of the location choice for the entrepreneurial firm (Chung and Alcácer, 2002; Figueiredo et al., 2002). In these studies, entrepreneurs/firms are assumed to maximize their utility/profit by choosing the location with the most desirable characteristics such as agglomeration economies and market demand. These studies clarify that different locations influence the success of firms and yield different payoffs to entrepreneurship. This holds in large part because certain locations offer advantages, such as access to technical knowledge and reduced search costs. The direct implication from these findings then is that the decision of whether to become an entrepreneur and where to locate may not be independent. That is, insofar as location characteristics influence the expected payoff from entrepreneurship, the location of the newly founded firm and the decision to enter entrepreneurship are intertwined. Nevertheless, these two decisions have been treated, in large part, separately in both the theoretical and empirical literature and hence the implicit assumption is that they are separable.

In this study we are interested in the location choice of the firm established by the academic entrepreneur. We recognize that such a choice might be made jointly with the decision whether to start a firm or not. To begin, we note that the academic entrepreneur's decision to start a firm is not a binary choice of self-employment and that an academic's decision to become an entrepreneur does not necessarily imply the need to abandon her academic position. Rather, the academic entrepreneur will likely continue to perform teaching and research at her current institution in addition to her role at the new firm, so the initial choice actually involves the allocation of her efforts to these two roles (Jain et al., 2009). To represent this choice, we define $\theta \in [0, \infty)$ as the intensity of effort devoted to the new firm, which equals zero if the academic professional does not start a new firm. The entrepreneur's initial decision at time $t = 0$ is to allocate her efforts between her current academic career (with payoff W_1) and her prospective entrepreneurial career (with payoff W_2). The combined return from the professional's academic and entrepreneurial careers is then $W_1(\theta) + W_2(\theta)$ where $W_2(0) = 0$, and we assume $\partial W_1(\theta)/\partial\theta < 0$ and $\partial W_2(\theta)/\partial\theta > 0$ to represent the career trade-offs facing the academic entrepreneur.

The other important choice variable for the entrepreneur is the location of the new firm, if $\theta > 0$, and we denote the distance of the new firm from the academic professional's current institution at time t with $d(t) \geq 0$. The distance variable is time-specific because the location of the firm may change over time as the business evolves or as the economic conditions facing the business change. In this paper, we focus on the initial location of the firm $d(0)$ and, for example, $d(0) = 0$ would imply that the firm is founded at the entrepreneur's current location.

To simplify exposition and the derivations that follow, we make a number of assumptions without loss of generality. We assume that the academic career payoff (W_1) is not risky, but the entrepreneurial career payoff is risky and provides an unknown rate of return. These payoffs are conditional on the academic professional's characteristics, such as age and professional eminence, and the entrepreneurial career payoff depends on the characteristics of the firm's location. We treat these conditional factors as time-varying state variables that are denoted $s(t)$. In typical optimal control problems, the state variables represent the characteristics of the dynamic system at time t, which may be influenced by the values of the choice or control variables $d(t)$. However, the state variables in this instance are generally predetermined (e.g., age, location characteristics), so we treat all of the state variables as exogenous to the location choice (control) variable.

We also assume that the intensity of effort decision is made prior to the location decision, so the career payoffs relevant to the location decision are conditional on θ. Accordingly, we suppress the role of θ and simply denote the combined payoff at time t as $W_1(d(t), s(t), t) + W_2(d(t), s(t), t)$. To further refine the role of distance in the academic entrepreneur's decision, we assume that the direct payoff from the academic career may be diminished if the entrepreneur founds a new firm in a more distant location such that $\partial W_1(d(t), s(t), t)/\partial d(t) < 0$. In contrast, we recognize that $\partial W_2(d(t), s(t), t)/\partial d(t)$ is difficult to sign a priori. Although the entrepreneur may find more profitable locations for the firm as she moves beyond her campus location so that $\partial W_2(d(t),$

$s(t),\ t)/\partial d(t) > 0$, the opposite sign may also hold true for several plausible reasons: the effective entrepreneurship effort is diminished as the distance of the firm from her academic institution increases due to travel and other use of time; the effectiveness of her professional network declines as she operates farther from her current institution (e.g. Breschi and Catalini (2010) and Cockburn and Henderson (1998)); and travel expenses and other opportunity and transaction costs increase with distance. Finally, we recognize that the personal characteristics of the academic entrepreneur may affect her risk preferences, so her utility function may be conditional on entrepreneur-specific risk factors. Accordingly, two entrepreneur candidates who face the same potential career payoffs may make different choices due to differences in their risk preferences. However, we suppress the role of such state variables in the academic entrepreneur's utility function because these features do not substantially alter the qualitative results of our analysis.

We model the academic professional's problem as an optimal control problem in which the academic entrepreneur chooses the sequence of $d(t)$ values to maximize her expected utility from the present discounted value of the net payoff. The general form of the prospective academic entrepreneur's utility maximization problem is to choose $d(t)$ to maximize

$$\int_0^{T-A_o} E[u(W_1(d(t),s(t),t)+W_2(d(t),s(t),t))]e^{-\rho t}dt \tag{1}$$

subject to the time path of the state variables or state equation, $s(t+dt)=s(t)+g(s(t),t)$. Here, T is the maximum working age for an academic entrepreneur, A_0 is the age at which the academic entrepreneur starts their firm, and ρ is the intertemporal discount factor. To explicitly solve this problem, we would have to adopt many strong assumptions about the entrepreneur's utility structure, the probability model for the risky payoffs, and the state equation. However, these steps are not necessary in our case because we only focus on the first firm location choice taken at time $t=0$, which may be characterized by the optimal value function

$$V(s(0),0)=\max_{d(0)}\{u(W_1(d(0),s(0),0)+W_2(d(0),s(0),0))+E[V(s(dt),dt)]\} \tag{2}$$

where $E[V(s(dt),\ dt)]$ is the expected value function at some point in the near future.

The first-order necessary conditions for this optimal control problem are based on the derivatives of the associated Hamiltonian equation

$$H(d(t),s(t),t,\lambda(t))=E[u(W_1(d(t),s(t),t)+W_2(d(t),s(t),t))]e^{-\rho t}+\lambda(t)'g(s(t),t) \tag{2a}$$

where $\lambda(t)$ is the vector of costate variables. The associated necessary conditions are

$$H_d=E\left[u'\{W_{1d}+W_{2d}\}\right]e^{-\rho t}=0 \tag{2b}$$

$$H_s=E\left[u'\{W_{1s}+W_{2s}\}\right]e^{-\rho t}+\lambda(t)'g_s(s(t),t)=0 \tag{2c}$$

plus the state equation. In these conditions, $u'>0$ is the marginal utility; W_{1d} and W_{2d} are the partial derivatives of the return components with respect to distance; while W_{1s}, W_{2s}, and g_s are the partial derivatives of the return components and the state equation with respect to the state variables. It is worth noting that the derivative of the state equation does not enter Eq. (2b) because the state variables are exogenous to the decision so that $\partial g(s(t),\ t)/\partial d(t)=0$.

With these conditions in hand, we can now evaluate the potential impact of a change in the state variables on the firm's location choice at time $t=0$. Such marginal effects could then be used to develop specific hypotheses about the influence of relevant factors on the academic entrepreneur's choice. The marginal effects are derived here based on the familiar methods of comparative static analysis for constrained optimization problems, which is appropriate in this application because we have conditioned the results at a particular time, $t=0$.

To simplify the demonstration, we consider an optimal control problem with just one state variable, say φ, and we derive the bordered Hessian matrix from the necessary conditions in Eqs. (2b) and (2c), and the state equation forming the following system of equations

$$\begin{bmatrix} H_{dd} & H_{ds} & 0 \\ H_{sd} & H_{ss} & g_s \\ 0 & g_s & 0 \end{bmatrix}\begin{bmatrix} \partial d(0)/\partial\varphi \\ \partial s(0)/\partial\varphi \\ \partial\lambda(0)/\partial\varphi \end{bmatrix}=\begin{bmatrix} -H_{d\varphi} \\ -H_{s\varphi} \\ -H_{\lambda\varphi} \end{bmatrix}$$

The general form of the marginal effect of changes in φ on the initial location $d(0)$ is then

$$\frac{\partial d(0)}{\partial\varphi}=\frac{-H_{ds}H_{\lambda\varphi}g_s+H_{d\varphi}[g_s]^2}{-H_{dd}[g_s]^2}$$

by Cramer's rule. The denominator is unambiguously positive because $H_{dd}<0$ is required under the sufficient conditions for the maximization problem, but the numerator terms are difficult to sign under most conditions.

For example, we consider the case where the state variable is $\varphi=A_0$, the academic entrepreneur's age (or years of working experience) at the time the firm is founded. Here, $H_{\lambda\varphi}$ in the first numerator term represents the marginal change in the state equation with respect to the entrepreneur's age, and we may be willing to assume that $H_{\lambda\varphi} = 0$ (i.e., the temporal change in the state variables is not affected by the entrepreneur's age at $t = 0$). Under this simplification, the marginal effect of changes in the founder's age (φ) on $d(0)$ is

$$\frac{\partial d(0)}{\partial \varphi} = -\frac{H_{d\varphi}}{H_{dd}}$$

The sign on this derivative is still generally ambiguous–the denominator is clearly negative because $H_{dd} < 0$, but the numerator sign depends on $H_{d\varphi}$, which is the cross-partial derivative of the maximum Eq. (2b) with respect to the state variable. In words, this term represents the change in the expected marginal utility of distance with respect to a change in the founder's age, which is uncertain. Indeed, the a priori signs on these cross-partial derivatives are difficult to assess for most of the state variables and other parameters in the model, which suggests that we cannot rely on the analytical properties of the optimal control problem to predict the role of the exogenous variables on the firm location decision. Therefore, despite all the simplifying assumptions we have made about the decision process of the academic entrepreneur, hypotheses regarding the influence of exogenous factors on her firm location choice are difficult to derive analytically. Nevertheless, the structure of the marginal effects does clarify that both her personal characteristics and the characteristics of the potential firm locations enter her decision process together and must be considered jointly. The above analytical results also place added emphasis on the empirical analysis of such influences and as such we turn our attention next to deriving an empirical model that is consistent with the decision process we have described so far.

Before deriving the model we will be using for our empirical analysis below, it is worth emphasizing the role of factors that might enter the location choice of the academic entrepreneur and which have not been considered so far. Admittedly, the effort allocation/ location decision model presented above is, by its nature, highly stylized. Entrepreneurial scientists do not make lifetime decisions based purely on financial rewards (Hayter, 2011; Lam, 2011). Other factors can be important considerations and such factors might include: academic achievement and non-monetary rewards (e.g. honors, awards, reputation); quality of life and lifestyle considerations and factors that might shape those (e.g. leisure, proximity to recreation, proximity and time availability for friends and family); personal and family financial security considerations and others. The utility maximization framework proposed here is general enough to facilitate these considerations and such factors could be explicitly incorporated in the optimal control model presented above. This would add to the complexity of the formulation and of the marginal effects but it would not change the essence of the conclusions drawn so far. It would, however, highlight the inherent heterogeneity in the decision process of the academic entrepreneur and would emphasize the significance of individual preferences and circumstances.

3.1. Deriving a theoretically consistent empirical model for location choice

With an eye to our empirical application that follows, we are now interested in a theoretically consistent and empirically tractable model we can use. Under the theoretical model presented in the previous section, the firm's optimal location is a continuous choice variable, but some complications with this model specification may arise in empirical applications. In particular, the degree of heterogeneity among candidate locations may be difficult to control in multiregional data sets, so it may not be possible to construct an empirical model in which a continuous location variable is suitably identified. To overcome this problem, we follow the existing empirical literature on location choice and adopt a finite and discrete specification for location in our model. For example, we may consider location alternatives $d \in \{1, 2, \cdots, N\}$ where $d = 1$ identifies firms founded at or near the entrepreneur's current institution, and sequential increases in d indicate candidate locations that are more distant from the current institution (e.g., same city, same state or region, different state or region). However, in contrast to unordered location choice models (Chung and Alcácer, 2002; Figueiredo et al., 2002), we construct an empirical model in which the optimal location is an ordinal choice selected from a finite and discrete set of alternatives (e.g., ordered logit).

More specifically, we assume that the academic entrepreneur considers the following $N = 4$ options: (1) locating her firm on or within walking distance to her academic institution's campus, (2) locating her firm outside campus but within or around her institution's city, (3) locating outside her institution's city but within the same state, and (4) locating her firm outside her institution's state at a distant location. Note that because the difference among the four ordered location options is not necessarily consistent across the choice categories, an ordered multinomial response model can be used for modeling purposes (Bartik, 1985).[5]

Not only is the proposed ordered response model empirically tractable but it is also consistent with the theoretical choice model we presented in the previous section. To demonstrate this we note that the value function in Eq. (2) may be approximated by a first-order Taylor series expansion about the state variables

$$v^* = V(s(0), 0) = V(0, 0) + s(0)' V_s(0, 0) + \varepsilon = \mathbf{x}\beta + \varepsilon \tag{3}$$

That is, we can approximate the firm's value function as a (latent) linear regression model of the initial state variables, $s(0)' = \mathbf{x}$ where the vector of slope coefficients for the linear model are the shadow prices of the state variables at time $t = 0$,

[5] In certain cases the location choices made by academic entrepreneurs may not have an ordered meaning (for example for scientists who do not live in their institution's city). However, these cases likely represent exceptions. In order to test the robustness of our results on the assumption that the location choices are ordered we also estimated an unordered logit model and obtained qualitatively similar results.

$V_s(0,0) = \beta$ and the intercept coefficient is the value function evaluated at $s(0) = 0$ and time $t = 0$, $V(0,0)$. Eq. (3) therefore clarifies that while v^* is not observable it can be linearly approximated with a set of explanatory (state) variables that affect the firm location choice of the academic entrepreneur.

And while v^* is unobserved the location choices of the academic entrepreneurs are observable and under the proposed ordered multinomial response model the location choice variable d takes four values

$$d = 1\ (\textit{on campus location}) \quad \textit{if} \quad v^* \leq \mu_1 \tag{4}$$

$$d = 2\ (\textit{within city location}) \quad \textit{if} \quad \mu_1 \leq v^* < \mu_2 \tag{5}$$

$$d = 3\ (\textit{outside city but within state location}) \quad \textit{if} \quad \mu_2 \leq v^* < \mu_3 \tag{6}$$

$$d = 4\ (\textit{out of state location}) \quad \textit{if} \quad v^* \geq \mu_3 \tag{7}$$

Under this specification, $\mu_1 < \mu_2 < \mu_3$ are unknown threshold parameters that separate the expected utility levels for the four adjacent location choices. Intuitively, μ_1, μ_2 and μ_3 represent the expected utility levels at which the entrepreneur chooses to locate at more distant locations. If we assume that the entrepreneur-specific component of the latent expected utility is distributed as $\varepsilon \sim \text{Logistic}(0,1)$, then the probability that d equals a particular choice category is based on cumulative distribution for the standard logistic model. Given this probability model specification, the unknown model parameters (μ_1, μ_2 and μ_3) can be jointly estimated by maximum likelihood (ML) conditional on the observed location choices and relevant explanatory (state) variables.

3.1.1. Location attributes, entrepreneur characteristics and firm location choice

Our theoretical model clarifies that the explanatory (state) variables in Eq. (3) must include both location and entrepreneur characteristics. In turn, existing literature can be used to inform the selection of relevant location attributes and entrepreneur characteristics that might influence firm location choice. We consult the literature for such factors and pay particular attention to those that have been found to be important in the context of the biotechnology industry and can be measured through secondary data.

It is generally understood that firms succeed when they possess superior resources (Barney, 1991; Conner, 1991; Mahoney and Pandian, 1992; Penrose, 1959; Wernerfelt, 1984). The academic entrepreneur will therefore tend to choose locations with access to capital, specialized labor, knowledge and other necessary resources that improve the chance of financial success for her firm.

Access to capital is a critical asset for most firms but it is particularly so for entrepreneurial biotechnology firms which depend on large capital resources to finance expensive research and development efforts without the benefit of internal revenue streams (Deeds et al., 1997). It follows that we might expect the reliance on external capital to hold for biotechnology firms started by academic entrepreneurs (Wright et al., 2006). Popular modes of financing, such as debt arrangements (Carpenter and Petersen, 2002), are typically not available for newly founded dedicated biotechnology firms (DBFs) because of lengthy research and product development cycles, the strict regulatory environment and associated high costs (DiMasi and Grabowski, 2007; Haussler and Zademach, 2007). As a result, DBFs must often attract financing from venture capital firms (VCFs) that seek high returns, typically in the form of performance-based compensation schemes (Gompers and Lerner, 2001; Timmons and Bygrave, 1986). In order to maximize their compensation, VCFs not only provide finance to the DBFs but they also assume advisory roles and may be involved in their day-to-day management and operations (Bygrave and Timmons, 1992; Florida and Kenney, 1988).

Because of such involvement, the relationship between venture capitalists and the founder-entrepreneur is often described as a principal–agent relationship (Sapienza and Villanueva, 2007). Similar to many principal–agent relationships, VCFs need to align their goals with those of the entrepreneur (Jensen, 1986; Jensen and Meckling, 1976; Rasmusen, 1987). To alleviate agency issues, VCFs monitor their target firms (Gorman and Sahlman, 1989) and, in order to facilitate monitoring, they show a strong preference towards local investments (Sahlman, 1990; Sorenson and Stuart, 2001; Zook, 2002).

Whether close proximity to VCFs matters to biotechnology firms started by academic entrepreneurs is not clear as the issue has not been explored in the literature. Nevertheless, the above studies clarify the potential benefits from the co-location of DBFs and their funding VCFs. Previous studies also confirm that close involvement of VCFs is largely beneficial to the success and valuation of the DBFs (Bertoni et al., 2011; De Bettignies and Brander, 2007; Kortum and Lerner, 2000). Therefore, it may be reasonable to expect that being in close proximity to the funding VCFs could increase the chances of a DBF's financial success and the expected wealth of the academic entrepreneur. As a result, we hypothesize that:

H1. The probability that academic entrepreneurs start their biotechnology firms in their institution's location increases when the funding venture capital firm is also located in close proximity to the institution.

An alternative means through which firms in knowledge-intensive industries, such as biotechnology, can augment their performance is by locating in proximity to firms in the same or supporting industries that can improve access to new knowledge and specialized inputs. Knowledge is a crucial resource for biotechnology firms but knowledge generated internally is often not sufficient and firms need to look for external resources to solve technical problems and cope with scientific complexities (Cohen and Levinthal, 1990; Grant, 1996). Relevant knowledge can diffuse locally through social and professional networks when actors working in similar problems are in proximity (Liebeskind et al., 1996; Saxenian, 1996; Sorenson and Stuart, 2001). For instance, the so called, "local buzz" allows valuable knowledge transfers, such as failures in scientific experiments, to diffuse mainly locally (Asheim and Gertler, 2005;

Bathelt et al., 2004; Storper, 1997). It follows that DBFs may exploit knowledge spillovers when they locate close to relevant actors (e.g. VCFs and other biotechnology firms) that generate useful, often tacit, knowledge (Owen-Smith and Powell, 2004).

VCFs typically form networks with other VCFs in order to circulate knowledge about investment targets, promising research avenues and market needs (Bygrave, 1988). Because these networks rely heavily on interpersonal contacts, tacit knowledge from the networks often leaks in local circles and can become a valuable knowledge input for nearby DBFs (Gompers, 1995; Shane and Cable, 2002). Likewise, proximity to other biotechnology firms can make knowledge spillovers available to DBFs by promoting more frequent face to face interactions among employees in the industry (Asheim and Gertler, 2005). These sorts of interactions act as conduits of knowledge transfer that can eventually lead to higher firm performance (Liebeskind et al., 1996; Saxenian, 1990, 1994).

Agglomerations of firms working on similar problems may also increase the availability of specialized labor pools and other service providers (lawyers, consultants) (Duranton and Puga, 2004). This likely occurs because of demand and supply factors. On the demand side, labor and service providers are attracted to potential customers and as a result they agglomerate creating local pools of resources while on the supply side agglomerations of similar firms and other actors can enhance such pools through employee turnover (Kim and Marschke, 2005).

A number of studies have confirmed the potential performance benefits by showing, for instance, that proximity to VCFs is associated with large sums of venture capital funds raised by DBFs (Acs et al., 2002; Audretsch and Feldman, 1996; Jaffe, 1989; Jaffe et al., 1993; Kolympiris and Kalaitzandonakes, 2013a; Kolympiris et al., 2011; Rosenthal and Strange, 2003; Wetzel, 1983).[6] Similarly, proximity to other DBFs has also been shown to improve the performance of entrepreneurial biotech firms, including their pool of research funds and their valuation at IPO (Deeds et al., 1997; Folta et al., 2006; Kolympiris and Kalaitzandonakes, 2013b; McCann and Folta, 2011). Importantly, some studies, which do not focus on firms founded by academic entrepreneurs, show that the benefits of spatial proximity may not automatically arise from simple co-location with relevant actors but rather they may be conditional on the quality of those actors (Beaudry and Breschi, 2003; Kolympiris et al., 2011).

Proximity to many and well performing related firms can increase access to knowledge spillovers and provide a greater labor pool, thereby improving the chances of a DBF's financial success and the expected wealth of the academic entrepreneur. Therefore, it may be reasonable to expect that academic entrepreneurs may prefer locations that host many high quality related firms. Hence we hypothesize that:

H2. The probability that academic entrepreneurs start their biotechnology firms in their institution's location increases with the number and quality of related firms that are also located in proximity to the institution.

The affiliated university of the academic entrepreneur can also provide access to critical knowledge and other resources that can improve the expected financial performance of the new firm. Universities produce knowledge that is not perfectly appropriated. Accordingly, evidence from previous studies suggests that firms located in proximity to universities are often more innovative and productive (Anselin et al., 1997; Fischer and Varga, 2003). This holds, in part, because physical proximity between firms and universities can promote the exchange of ideas through formal and informal networks (Deeds et al., 2000). Further, university graduates tend to enhance the local labor pool and act as conduits of locally confined knowledge spillovers (Acosta et al., 2009; Pouder and St. John, 1996). Indeed, there are university-specific characteristics that mediate the intensity of such spillovers (e.g. O'Shea et al., 2005; Powers and McDougall, 2005).

In all, the larger the amount of biotechnology research and knowledge produced by universities, the greater the expected knowledge spillovers and local labor pools available to the local firms. Therefore, academic entrepreneurs employed at universities with significant biotechnology research activities may prefer to start their DBFs in proximity to their institutions so that their firms can benefit from the knowledge and labor resources of the university. As such, we hypothesize that:

H3. The probability that academic entrepreneurs start their biotechnology firms in their institution's location increases with the institution's level of biotechnology research activity and associated infrastructure.

As clarified in the theoretical model we presented above, the firm location choice of the academic entrepreneur may also be influenced by a number of personal characteristics; her age/stage of academic career is one. For faculty at early stages in their academic career, effort spent for the creation and support of a new firm is effort not spent on publishing academic papers and securing research grants. A decrease in the effort devoted to academic responsibilities can therefore hamper professional advancement because it is at these early stages of their careers that younger faculty tend to create a reputation (Audretsch and Stephan, 1996). Consequently, starting up firms at distant locations might imply reduced academic effort. This can limit professional advancement and reduce the long term associated academic income stream, making such a choice unattractive for this cohort of academic entrepreneurs.

Limited professional networks may also restrict the success of distant firms started by younger and less experienced academic entrepreneurs. Previous contributions focusing on research-intensive industries such as biotechnology have shown that, largely due to the immediate application of basic research in such fields, there is significant overlap between academic and industry communities through frequent formal and informal interactions, joint authorship of scientific papers, and co-patenting of inventions

[6] The presence of local knowledge spillovers is not uniformly supported in the literature. Among others, Breschi and Lissoni (2001) and Håkanson (2005) present a more skeptical view. The main arguments in this strand of literature are that in spatial agglomerations competition for resources can be intense and the chances of useful knowledge spillovers are overstated. Nevertheless, on balance, the persistent sustainability and growth of spatially connected clusters implies that the benefits of co-location often exceed relevant costs.

(Breschi and Catalini, 2010; Cockburn and Henderson, 1998). Accordingly, academic networks in biotechnology can augment the exchange of scientific knowledge but may also assist with the formation of entrepreneurial ideas and commercialization efforts. Extensive personal and professional networks may also be important in troubleshooting, hiring decisions, and other factors that can assist firm creation and improve firm performance (Cross and Sproull, 2004; Kijkuit and van den Ende, 2010; McEvily and Marcus, 2005). For younger and less experienced faculty, professional networks are typically geographically constrained (Audretsch and Stephan, 1996) because these scientists are at the beginning of their career and often lack a nexus of contacts.[7] Taking these observations into account, younger academics with less experience and narrower personal and professional networks may, in turn, derive more limited payoffs from firm creation at distant locations. Accordingly, we expect younger scientists to choose more proximate locations for their new firms.

Of course, some academics may achieve eminence earlier in their career. Eminent academic entrepreneurs are expected to risk less of their future academic income from engaging in distant firm locations as the marginal effect of a foregone grant or publication tends to be more limited in their case (see Antonelli, 2008; Czarnitzki et al., 2011 for discussions that point towards such conclusions).[8] As well, eminent scientists are expected to have broader academic and personal networks which they can employ to maximize the value of their new firms. As a result, the potential payoffs from new firms may not depreciate as much with increasing distance from their academic institution. Accordingly, we expect eminent scientists to be less bound to proximate locations. For all these reasons, we hypothesize that:

H4. The probability that academic entrepreneurs start their biotechnology firms in their institution's locations decreases as the academic entrepreneur's age, professional experience and eminence increase.

Other personal characteristics that can condition the mobility of the academic entrepreneur may also influence her firm location choice and it may be possible to control for such characteristics in an empirical context. Certain personal and family conditions may be important but they may also be difficult to observe. Still, it may be feasible to approximate all such personal conditions with the entrepreneur's historical propensity to relocate across academic jobs. Previous experience in starting a firm and ownership of patents may also influence the academic entrepreneur's mobility and firm location options.

Academic entrepreneurs with previous firm founding experience ("serial entrepreneurs") may manage their division of effort between entrepreneurial and academic duties effectively even when they locate their firms at distant locations. Serial entrepreneurs may also be more efficient in their entrepreneurial efforts and may have a broader nexus of contacts in academia and in industry. As a result, their contributions to the success of their firms may not be affected as much by distance. In this sense, serial entrepreneurship may increase the mobility of the academic entrepreneur and her firm.

Possession of patents by the academic entrepreneur may also influence her mobility and her firm location choice but whether more patents favor a distant or proximate location is not clear a priori. Possession of a large number of patents may indicate highly codified knowledge and hence increased independence of a distant firm from the ongoing presence and effort of the academic entrepreneur. Alternatively, entrepreneurs with secure property rights to inventions with commercial potential may be able to attract the necessary resources and start their firms close to their institutions.

In the case of firms founded by more than one academic entrepreneur, the location of co-founder(s) may also influence the location of the firm. For instance, firm founders may prefer to stay close to co-founders who may not necessarily be involved in the day-to-day operations of the firm but whose knowledge and expertise are important for the firm. Such cases may, for instance, involve eminent scientists who start firms together with their PhD advisees, with the latter being more actively involved in the firm.

4. Methods and model specification

To empirically test the stated hypotheses and examine the influence of the various control variables we specify an ordered logit[9] model, estimated through maximum likelihood procedures.[10] The spatial relationship between the location of the funding VCF and the institution of the academic entrepreneur (as described in H1) is represented with the straight line distance between the two places (*VCF_Distance*). However, several VCFs are often involved in the funding of a DBF through syndication. One of the motives of syndicated venture capital investment is the minimization of transaction costs that emanate from investing in non-familiar regions. Under syndicated investments the closest VCF to the target firm often carries most of the monitoring and

[7] Recent PhDs may still be actively tied to their prior institution and hence may have active distant networks. However, such networks are likely to be confined to small numbers of people with whom these early career scientists interact as their networks link back to one or few institutions. More seasoned academics typically have networks that span different institutions, regions and people and as such their exposure to entrepreneurial ideas is expected to be broader.

[8] For evidence on the effect of opportunity cost on entrepreneurship (growth) see Cassar (2006).

[9] The normal distribution (ordered probit model) was also tested and provided analogous results to the logistic distribution (logit model). For parsimony we only report the logit estimates here.

[10] We also considered a logit panel estimation to control for unobserved heterogeneity across institutions. However, as Table 1 illustrates more than half of the institutions in our sample had only one firm birth and only a handful had more than five. Consequently, efforts to control for unobserved heterogeneity across academic institutions via panel data methods were difficult to implement because the final dataset was highly unbalanced. The usual computations for an unbalanced panel were not feasible with one observation, so we could not estimate separate university effects for many of the cross-sectional observations. It is also worth noting that the asymptotic properties for most panel data estimators are based on large numbers of cross-sectional observations and a fixed time dimension, so adding university-specific fixed effects for all cross-sectional units would not be consistent because the number of parameters would increase with the cross-sectional sample size.

consulting responsibilities. Accordingly, for DBFs in our sample that received funds from more than one VCF, we measure the distance between the academic institution and the closest funding VCF to it.

We represent the potential benefits from knowledge spillovers and specialized labor market (as described in H2) to the academic entrepreneurial firms with four variables. The first variable measures the number of VCFs located within a 10-mile radius of the entrepreneur's academic institution (*VCFs10*). In order to better approximate the venture capital funds available to local biotechnology firms only VCFs that had invested in at least one biotechnology firm (any biotech firm, not just those in our sample started by academic entrepreneurs) were included in the count. The second variable accounts for the quality of those VCFs by measuring the total amount they have invested in DBFs over time (*10M_VCFs_size*). We approximate the quality of VCFs with their overall size under the premise that VCFs grow only if they make successful investments. The total number of DBFs located within a 10-mile radius of the entrepreneur's academic institution (*DBFs10*) is used to account for the presence of similar firms in proximity. Finally, the potential influence of the quality of proximate DBFs is measured by the total amount of round 1 venture capital funds raised by DBFs in a 10-mile radius of the entrepreneur's academic institution (*Round1*). Large amounts of round 1 financing are taken as a signal of higher quality proximate DBFs. Note that the DBFs used to construct the *Round1* variable include firms founded by academic entrepreneurs and by other individuals or organizations.

Next, we use three variables to represent the potential knowledge spillovers and labor market benefits produced by research activities in the academic entrepreneur's institution, as described in H3. In particular, we measure the institution's biotechnology research activity and its contributions to local labor markets through two separate indicators. Academic institutions that produce more graduates in the life sciences are expected to have a greater amount of relevant research and to create a larger local pool of labor. As such, they may be more prolific in spawning new firms (Audretsch and Lehmann, 2005). Hence, we include a variable that measures the average number of PhD graduates in biosciences at the entrepreneur's institution for the 5-year period before firm birth ($BioGraduates_{t\text{-}1\ to\ t\text{-}5}$).[11] We also include a dummy variable that equals 1 if the entrepreneur's institution has a medical school on campus and 0 otherwise (*Medical*) to account for the fact that a significant amount of biopharmaceutical-related research originates from medical schools (Cooke (2001); Siontorou and Batzias (2010)).

The academic institution of the entrepreneur may also influence firm location through auxiliary infrastructure and services as well as institutional support that facilitate the creation of new firms. In order to control for various institutional characteristics (e.g. infrastructure, rules, culture, availability of technical assistance) that might condition the creation of local spinoffs by academic entrepreneurs across different institutions, we use the average number of startup firms associated with the founder's institution for the five year period before firm birth ($Startups_{t\text{-}1\ to\ t\text{-}5}$) as a proxy.[12]

The relationship between the academic entrepreneur's age and professional experience with the firm location choice described in H4 is represented by two variables, included separately in the empirical models. The first variable measures the entrepreneur's age at firm founding (*Age*) and the second variable measures the number of years that have elapsed between the year the entrepreneur received his PhD and the year of firm founding (*SincePhD*). Further, to capture the potential influence of professional eminence on the academic entrepreneur's firm location choice (as described in H4) we include a dummy variable that equals 1 if the founder had won a Nobel Prize, was a member of the National Academy of Sciences, had an endowed chair professorship, or had a distinguished professor title at firm birth, and 0 otherwise (*Eminence*).

To approximate the effects of previous entrepreneurial experience on firm location choice we add a dummy variable that equals 1 if the academic entrepreneur had founded at least one other firm before firm birth and 0 otherwise (*Serial Entrepreneur*). As well, we add a dummy variable that equals 1 if the entrepreneur worked at another academic institution before the one he was affiliated with at firm birth and 0 otherwise (*Previouswork*) in order to account for the entrepreneur's tendencies to relocate. To incorporate the effects of patenting activity as a proxy for codified and marketable knowledge, we include a variable that measures the total number of patents awarded before firm birth in which the academic entrepreneur is listed as a (co)inventor (*Patents*). To account for the potential effect that academic firm co-founders may have on the location decision of the academic entrepreneur we include a dummy variable that takes the value of 1 if at least one of the academic co-founders is located within 10 miles of the location of the firm and the firm was founded either on campus or within the city limits of the affiliated institution and 0 otherwise (*Co-founder*).

In order to account for the possibility that the relationship between firm location and agglomeration of VCFs is curvilinear, we include a variable that measures the number of proximate VCFs in quadratic form (*VCFs10s*). We also account for the size of the funding VCF with a variable that measures the total amount invested by the closest funding VCF to other DBFs over time (*Funding_VCF_Size*). Finally, largely because of a general decline in communication costs over time, an increase in the size and

[11] For an alternative proxy of the institutions' biotechnology infrastructure we also collected data on bioscience R&D expenditures for each institution in the dataset. When using the variables in question the parallel slope assumption of the ordered logit model was not satisfied and the partial proportional odds model showed that the violation had significant effects in the estimated coefficients. Further, the sample size was reduced considerably. For these reasons, R&D expenditures were not used for the empirical models presented here.

[12] Note that while an institution's overall startup rate is indeed a function of academic entrepreneurs starting firms, we do not expect this relationship to hamper the empirical execution of the study in estimating the impact of the overall startup rate of the institution on the location choice of the entrepreneur. We subscribe to previous works that also examine firm location decisions (Jofre-Monseny et al., 2011; Rosenthal and Strange, 2003), in that the characteristics of the university are seen as fixed by the entrepreneur when she makes her location decision, which then indicates that concerns of a simultaneity are mitigated. Relatedly, the same line of reasoning should reduce similar concerns about location attributes that can be influenced by the location choice of the academic entrepreneur. For instance, a high quality university can prompt quality startups to locate close and in turn lead the academic entrepreneur to also locate nearby, inducing in turn more entrepreneurs (or VCFs or any other relevant actor) to also locate nearby creating an iterative feedback loop. But, in most cases we expect the entrepreneur to see the location attributes as a snapshot in time when she makes her location decision and without the previously described feedback process entering her decision process.

reach of research collaborations and networks has been previously reported (e.g. Johnson and Lybecker, 2012). As such, academics that start firms in more recent years maybe more inclined to start them at a distance from their institution. Accordingly, we construct a variable that takes the value of 1 if the firm was founded between 1983 and 1985 (including 1983 and 1985), the value of 2 if the firm was founded between 1986 and 1988 and so on (*Year_trend*).[13]

Before we present our data and sources in detail, we discuss here three considerations that relate to our modeling choices. As we indicated above, for the $BioGraduates_{t\text{-}1\ to\ t\text{-}5}$ and the $Startups_{t\text{-}1\ to\ t\text{-}5}$ variables, we use the observed averages for the 5 years that preceded firm birth. The choice of the lag structure is not a trivial issue but there is limited theoretical guidance for a preferred lag structure, though some previous studies have also used 5-year lags (e.g. Acs et al., 2009; Baum et al., 2000). We opt for the 5-year lag structure because we expect the effects of the relevant variables to be better approximated with recent values. By using a 5-year lag structure, recent effects are emphasized and short-term variations in the number of startups and bioscience graduates are smoothed out. We tested the sensitivity of our results to this assumption by using alternative lag structures and the overall results were qualitatively similar.[14]

Another modeling choice was the spatial unit under which we build the variables that measure the agglomeration of VCFs and DBFs. This choice was also not trivial because such firms are located in both rural and urban areas, hence the relevant geographic area for spatial relationships can vary across regions. However, a number of contributions have shown that relationships based on knowledge exchange are generally confined within narrow distances (Aharonson et al., 2007; Rosenthal and Strange, 2003). Specifically for the biotechnology industry in the US, there is evidence that such spatial relationships hold for a 10-mile radius (Kolympiris et al., 2011). Accordingly, we define the variables in question with a 10-mile radius. As a robustness check we tested radii of 5, 15, and 20-miles and found results similar to those presented here.

Finally, because we use two measures of the entrepreneur's age and professional experience, we build two specifications where all remaining variables are the same and the variables that test H4 (*Age* and *SincePhD*) are included separately (Models 1 and 2).

5. Data sources and presentation

Due to the large number of data sources used to construct the variables described in Section 3, we provide a detailed description of those sources in Appendix Table 1. In this section we focus on the construction of the variables and make general references to the data sources.

We used Thomson's Financial SDC Platinum Database (SDC), Zoominfo web-based database, the Moneytree web-based report and information from InKnowVation, Inc. to identify biotechnology firm births. Each firm's founder(s) were generally available in all data sources. To ensure that the involved academic scientist was part of the founding team (or sole founder) and fill in any missing information, we visited the website of each firm. We also consulted biographical information for each academic entrepreneur from sources outlined in Appendix Table 1.

Each firm's address was also generally available in all data sources; we used that information to construct the variables that measure the agglomeration of VCFs and DBFs around the entrepreneur's institution. In order to form these variables we converted the address of each VCF and DBF to geographic coordinates (longitude and latitude). We then used the ArcView software to calculate the distance between the institution of the entrepreneur and each firm as well as to identify the firms located within a 10-mile radius from the academic institution. We used a similar procedure to calculate the distance between the closest funding VCF and the entrepreneur's academic institution (*VCF_Distance*) as well as the variable that indicates whether a co-founder in the firm is located within 10 miles from the firm (*Co-founder*).

For the variable that indicates whether a medical school is located on campus (*Medical*) we visually assessed whether medical schools were part of the university campus using Google Earth®. For entrepreneurs employed at medical research institutes (e.g. Salk Institute, Scripps Institute) the variable took the value of 1.

The dependent variable measures whether founders started their firms on or around campus, in their institution's city, in their state or out of state at a distant location. Cities were defined at the Metropolitan Statistical Area (MSA) level and we used Google Earth® to visually identify and assign the firm location. Firms located within three blocks of the campus boundary were also included in the "on-campus" category. The three-block threshold level was chosen because of an empirical regularity observed in our sample under which most of the firms in close proximity to campus were located within a three-block radius. To ensure robustness of our results to the three-block threshold level we ran models with those firms excluded from the "on campus" category and found qualitatively similar results.

For the purpose of this paper, academic institutions are defined by campus; all relevant variables ($Startups_{t\text{-}1\ to\ t\text{-}5}$, $BioGraduates_{t\text{-}1\ to\ t\text{-}5}$, *Medical*) are measured against these academic units. Academic entrepreneurs are matched with institutions whenever their name appeared in the institutions' departmental listings. The final dataset is composed of 301 observations on 187 biotechnology firms founded by 275 academic entrepreneurs from 1983 to 2008.

Table 1 shows the institutions included in the dataset and other relevant information while Table 2 details the location, age and amount of venture capital raised by firms originating from the institutions with the most firm births in our dataset. The map presented in Fig. 1 classifies the institutions included in Table 1 according to the number of academic entrepreneurs they employ.

[13] Alternatively we could include year dummies but such option would reduce the degrees of freedom considerably, which can be too limiting when the sample size is fairly small.

[14] Note that instead of an average value we could include separate lags. While appealing, this choice had the drawback of decreasing the degrees of freedom which becomes pressing when the number of observations is relatively small and could also raise multicollinearity issues that could hamper inference.

Table 1
Institutions included in the dataset, number of affiliated academic entrepreneurs, number of affiliated firm births and firm-specific information.

Institution name (listed alphabetically)	Number of academic entrepreneurs associated with institution [1]	Number of firms associated with academic entrepreneur's from the institution [1]	Total amount of venture capital financing awarded to firms from each institution[2]	Average firm age for each firm affiliated with the institution[2]
Arizona State University	1	1	58,314,000	6
Beckman Research Institute of City of Hope	1	1	50,400,000	2
Boston University	3	2	49,159,000	1
Broad Institute Of MIT And Harvard	1	1	57,500,000	1
Brown University	2	1	500,000	7
California Institute Of Technology	9	6	186,215,000	3
California State University	1	1	107,657,000	4
Case Western Reserve University	1	1	33,813,000	1
City University Of New York	2	1	21,869,000	2
Colorado State University	2	2	75,220,000	3
Columbia University	5	5	54,940,000	8
Cornell University Medical School	2	2	4,500,000	3
Dartmouth College	1	1	25,747,000	1
Duke University	15	8	271,852,000	5
Emory University	2	1	45,067,000	3
Georgetown University	1	1	Undisclosed	5
Harvard University	4	6	432,607,000	5
Harvard University Medical School	22	19	958,692,000	4
Indiana University	1	1	9,635,000	2
Indiana University Purdue University Indianapolis	2	1	9,635,000	2
Institute Of Genomic Research	1	1	65,500,000	3
Johns Hopkins University	3	2	168,386,000	6
Louisiana State University	1	1	9,500,000	4
Massachusetts Institute Of Technology	15	17	754,087,000	4
Medical College Of Wisconsin	1	1	850,000	11
Medical University Of South Carolina	1	1	50,500,000	3
New York University	4	4	208,460,000	6
North Dakota State University	1	1	Undisclosed	5
Northwestern University-Evanston	4	3	225,491,000	6
Pennsylvania State University-University Park	3	2	12,553,000	5
Princeton University	1	1	20,000,000	4
Purdue University West Lafayette	1	1	26,090,000	5
Rockefeller University	1	1	156,117,000	8
Saint Louis University	1	1	21,869,000	2
Salk Institute For Biological Studies	5	4	145,700,000	3
Scripps Research Institute	8	9	346,264,000	5
Southern Research Institute-Birmingham	1	1	925,000	7
Stanford University	15	14	849,157,000	5
Temple University	1	1	52,432,000	10
Thomas Jefferson University	2	2	118,480,000	7
Torrey Pines Institute For Molecular Studies	1	1	38,234,000	14
Tufts University	4	4	75,767,000	5

[1] The total number of firms reported in this Table (239) does not equal the total number of firms in the dataset (187) because some firms were founded by academics from different institutions. In those cases, the focal firm is listed in all relevant institutions. The total number of academic entrepreneurs reported in this Table (282) does not equal the total number of academic entrepreneurs in the dataset (275) because few entrepreneurs founded firms when affiliated with different institutions. In those cases, the focal entrepreneur is listed in all relevant institutions.
[2] The ending point for performing the calculation is 2008 unless the firm had gone public, had merged or had been acquired before 2008. In these latter cases, the ending point for the calculation is the IPO, the merger or the acquisition date. For the two firms that are defunct, the ending point is the year that they ceased operations.

Institutions with larger numbers of academic entrepreneurs whose firms are in proximity to their institutions (on campus or within the institution's city limits) are represented with larger symbols on the map.

Close to 87% (seventy three of the eighty four) of the institutions in the dataset had up to five biopharmaceutical firms created by academic entrepreneurs in the period from 1983 to 2008. Most of these firms were located at a distance from these institutions. For example, Northwestern University at Evanston had four scientists who founded three firms from 1983 to 2008, with only one of the firms located in Evanston. The two remaining firms were founded at Boston, MA and at Gaithersburg, MD. In contrast, institutions with more than five firms created by academic entrepreneurs (Table 2) had a higher percentage of these firms located in close proximity.[15] For instance, Duke University had fifteen scientists who founded eight biopharmaceutical firms

[15] It is worth noting that all four institutions in our sample with more than eleven firm births had almost eighty percent of those firms located close by.

Table 1 *(continued)*

Institution name (listed alphabetically)	Number of academic entrepreneurs associated with institution [1]	Number of firms associated with academic entrepreneur's from the institution [1]	Total amount of venture capital financing awarded to firms from each institution[2]	Average firm age for each firm affiliated with the institution[2]
University Of Alabama Birmingham	1	1	925,000	7
University Of California Berkeley	3	3	236,314,000	5
University Of California Davis	3	3	100,003,000	6
University Of California Irvine	2	1	32,424,000	3
University Of California Los Angeles	2	2	187,490,000	12
University Of California San Diego	11	12	429,977,000	8
University Of California San Francisco	4	4	243,908,000	5
University Of Chicago	4	3	48,914,000	10
University Of Cincinnati	1	1	3,750,000	3
University Of Colorado at Boulder	3	3	44,607,000	3
University Of Colorado Denver/Hsc Aurora	8	6	354,283,000	5
University Of Florida	4	1	45,600,000	9
University Of Georgia	1	1	230,000	5
University Of Kansas	1	1	26,619,000	4
University Of Kentucky	4	3	38,629,000	5
University Of Louisville	1	1	727,000	3
University Of Maryland Baltimore	6	4	29,544,000	4
University Of Maryland Baltimore County	1	1	50,000	9
University Of Maryland College Park	1	1	225,000	3
University Of Michigan at Ann Arbor	11	7	277,696,000	12
University Of Minnesota	1	1	13,000,000	6
University Of North Carolina Chapel Hill	4	4	93,885,000	4
University Of Oklahoma	4	3	132,532,500	12
University Of Pennsylvania	2	2	46,191,000	3
University Of Pittsburgh at Pittsburgh	3	3	57,988,000	5
University Of Rochester	1	1	4,069,000	9
University Of South Alabama	1	1	500,000	1
University Of Southern California	1	1	24,646,000	1
University Of Tennessee Knoxville	1	1	500,000	2
University Of Tennessee Memphis	1	1	Undisclosed	5
University Of Texas Austin	5	2	138,500,000	5
University Of Texas Dallas	3	2	7,550,000	3
University Of Texas HSC at Houston	1	1	615,000	3
University Of Texas HSC at San Antonio	1	1	85,850,000	10
University Of Utah	2	2	32,574,000	9
University Of Virginia Charlottesville	2	2	22,117,000	8
University Of Washington	11	7	331,526,000	3
University Of Wisconsin Madison	5	3	41,645,000	6
Wake Forest University	1	1	350,000	7
Washington University	1	1	64,275,000	6
Yale University	5	4	69,068,000	8
Yeshiva University	1	1	15,000,000	2

from 1983 to 2008 with five of those firms located on Duke's campus. Likewise, out of the nineteen firms that originated from Harvard Medical School, fourteen were founded within the state limits with twelve of them in Cambridge. Interestingly, even after accounting for firm age, a significant degree of variability was observed among the total amount of venture capital funds raised by each of those firms. Taken together and without controlling for other contributing factors, these statistics would suggest that there may be an institution effect in firm location but the amount of finance received appears to be more firm-specific.

Table 3 presents descriptive statistics for the variables used in the fitted ordered logit model. Fifty-two percent of the observations correspond to firm locations within the city limits of the founder's institution (about 22% of them on campus) while close to 32% of the observations correspond to firms founded outside the state of the founder's institution. The nearly uniform distribution of “local” versus “distant” firm births suggests that a number of factors may influence firm location choices.

The explanatory variables with the least variability in the dataset were the academic entrepreneur's age and her number of years since her PhD at firm founding. The average age of the founders was 48 years old at firm birth with 22 years having elapsed between the year of the PhD and firm birth. The majority of the 275 entrepreneurs in the dataset did not own patents. 61 of the entrepreneurs had worked at a previous university, 111 were classified as eminent and 76 had started at least one firm before the firm birth in the data set. In 136 of the firms in our data set a co-founder was close to the location of the firm.

The variables that measure the agglomeration of VCFs close to entrepreneurs' institutions were left skewed but there still were observations with wide-ranging values. On average, about 39 VCFs were located within ten miles from the entrepreneur's institution, and the DBFs in the same radius had raised more than $142 million from Round 1 funds. Finally, the VCFs close to the founder's institution had invested, on average, $490 million in biotechnology firms and the closest VCF to a given firm averaged almost $790 million. Since these values reflect investments made over a lengthy period, they should be adjusted for inflation. Unfortunately in many cases we only had complete information on the total amount invested by each venture capital firm but not on the amounts invested on a per year basis. Thus, we could not accurately adjust these observations for inflation and retained their nominal values.

6. Estimation results

The ordered logit estimate and marginal effect (multiplied by 100 to represent change in probability) for each explanatory variable[16] (evaluated at the mean) are presented in Table 4. As explained at the end of Section 3, the *Age* and *SincePhD* variables are included separately in the empirical models. Model 1 includes *Age* and Model 2 includes *SincePhD*. (See Table 4.)

The Likelihood Ratio statistic for overall significance for both models (56 and 58.85) is significant at the 1% level, which indicates that the models presented in Table 4 have explanatory power. So does McFadden's pseudo-R^2 statistic which is 0.14 and 0.157 for Model 1 and Model 2 respectively. The condition number for the set of explanatory variables used is 41 and 39.23 for the two models and it is somewhat inflated indicating potential inference problems from multicollinearity.

We employed a number of tests to guide the specification of our empirical models and address the issue of multicollinearity. First, in order to identify the source of multicollinearity, we regressed each variable in the design matrix with the remaining variables. Based on this test we chose to exclude the density of other DBFs from the empirical models and used *Round1* to measure the impact of nearby biotech firms on location choice. Centering the variables did not offer a substantial advantage in reducing multicollinearity. Next, following Menard (2001), we estimated the final specification with OLS to measure the variance inflation factors (VIF) of each variable. As illustrated in Appendix Table 3, except *VCFs10* and *VCFs10s*, whose VIF is 43.61 and 29.95 respectively, the VIFs of the rest of the variables are well below the worrisome level of 10 ranging from 1.10 to 2.82. Prompted by the inflated VIFs of *VCFs10* and *VCFs10s* we subsequently constructed empirical specifications where we omitted *VCFs10s* from the analysis. The results of those models are qualitatively similar to those reported in Table 4 and we present them in Appendix Table 4. We also compared the R^2 of the model that included *VCFs10s* with the R^2 of the model that did not and we found them to be only slightly different, which could justify dropping the squared term from the analysis. However, because on theoretical grounds we saw the squared term as pertinent to our specification, we chose to use it as long as it did not cause inference problems. Appendix Tables 2 and 4 suggest that including the squared term of *VCFs10* does not come at a substantial inference cost, so we ultimately maintained the variable in the analysis. Finally, we estimated alternative versions of Models 1 and 2 with different subsets of explanatory variables where the multicollinearity index is significantly reduced and we present these in Appendix Table 2. The estimated parameters of these models exhibit only minimal differences with those presented in Table 4, which suggests that multicollinearity does not have a strong influence on the estimated results.

The χ^2 test for the parallel slopes assumption allows us to reject the null hypothesis that the explanatory variables shift the cumulative distribution to the right or to the left. In order to test the robustness of our estimates to the violation of that assumption for the ordered logit model we also estimated partial proportional odds models (Greene and Zhang, 2003) which yielded qualitatively similar results to those reported in Table 4. Finally, LR tests of joint significance across coefficients did not reveal any instances where statistically insignificant coefficients had strong explanatory power when considered in conjunction with other coefficients.

In all, the various tests performed suggest that our empirical models are stable to alternative specifications. Models 1 and 2 both fit the data well and yield similar inferences. The differences among the estimated coefficients of each model are relatively small but a comparison of the fit statistics reveals that Model 2 fits the data slightly better and as such we use it as the basis for the discussion of our empirical estimates.

The empirical results support H1 and indicate that a decrease in the distance between the funding VCF and the entrepreneur's institution increases the probability that the academic entrepreneur locates her firm either on campus or within the city limits. However, the magnitude of that effect is rather small, since a 1-mile decrease in the distance between the two locations increases the probability of on-campus location by only 0.0064%. When evaluated at the sample mean of 478 miles, this magnitude

[16] Marginal effects for interior cases are calculated as follows: $\frac{\partial Prob(y=j)}{\partial x_k} = \left[\phi\left(\mu_{j-1} - \sum_{k=1}^{K}\beta_k x_k\right) - \phi\left(\mu_j - \sum_{k=1}^{K}\beta_k x_k\right)\right]\beta_k, 0<j<J$ (Greene and Zhang, 2003). For the endpoints the marginal effects are calculated as follows: $\frac{\partial Prob(y=0)}{\partial x_k} = -\beta_k\phi\left(\mu_0 - \sum_{k=1}^{K}\beta_k x_k\right), \frac{\partial Prob(y=J)}{\partial x_k} = \beta_k\phi\left(\mu_J - \sum_{k=1}^{K}\beta_k x_k\right)$ (Wooldridge, 2009) where ϕ is the logistic probability distribution function and β_k are the estimated ordered logit coefficients. For dummy variables the marginal effect is approximated as the change in probability resulting from a change in the dummy variable's value from 0 to 1.

Table 2
Detailed information of the location, age and amount of venture capital raised for the firms that originated from the institutions with the most associated firms in our dataset.

Institution name (listed alphabetically)	Firm ID	Founding date of the firm	Firm city	Firm state	On campus firm location	Total amount of VC financing raised by the firm[1]
Duke University	1	6/1/2005	Bridgewater	NJ	No	$ 66,000,000
	2	3/1/2003	Durham	NC	Yes	$ 5,000,000
	3	10/1/2006	Raleigh	NC	Yes	$ 500,000
	4	6/5/2002	Morrisville	NC	Yes	$ 4,700,000
	5	1/1/2001	Durham	NC	Yes	$ 103,518,000
	6	1/1/2004	Malvern	PA	No	$ 20,000,000
	7	11/1/2007	Norristown	PA	No	$ 54,634,000
	8	1/1/1999	Morrisville	NC	Yes	$ 17,500,000
Harvard University	1	1/1/2005	Cambridge	MA	No	$ 57,250,000
	2	11/1/2005	Watertown	MA	Yes	$ 35,458,000
	3	5/1/2007	Cambridge	MA	No	$ 57,500,000
	4	1/1/1998	Montvale	NJ	No	$ 8,415,000
	5	7/1/1996	Boston	MA	Yes	$ 30,400,000
	6	6/1/1996	South San Francisco	CA	No	$ 243,584,000
Harvard University Medical School	1	6/20/2008	Cambridge	MA	Yes	$ 42,024,000
	2	1/1/2005	Cambridge	MA	No	$ 57,250,000
	3	1/1/2002	Cambridge	MA	Yes	$ 176,700,000
	4	12/1/2000	La Jolla	CA	No	$ 79,300,000
	5	11/1/2003	Cambridge	MA	Yes	$ 17,504,000
	6	7/10/2008	Boston	MA	Yes	$ 39,000,000
	7	1/1/2007	La Jolla	CA	No	$ 50,543,000
	8	5/1/2007	Cambridge	MA	No	$ 57,500,000
	9	2/4/1992	Cambridge	MA	No	$ 6,000,000
	10	1/1/2006	Cambridge	MA	Yes	$ 58,100,000
	11	5/1/2005	Los Altos	CA	No	$ 58,335,000
	12	2/1/2002	Cambridge	MA	No	$ 32,155,000
	13	8/1/2005	Chapel Hill	NC	No	$ 3,750,000
	14	1/1/2006	Lexington	MA	No	$ 36,153,000
	15	12/31/2007	East Watertown	MA	No	$ 32,600,000
	16	1/1/2006	Cambridge	MA	Yes	$ 36,095,000
	17	8/3/2000	Bedford	MA	No	$ 99,089,000
	18	2/4/2006	New York	NY	Yes	$ 21,869,000
	19	11/1/2005	Cambridge	MA	Yes	$ 54,725,000
Massachusetts Institute of Technology	1	5/1/2007	Lebanon	NH	Yes	$ 25,747,000
	2	9/1/2002	Waltham	MA	No	$ 70,410,000
	3	8/1/2001	Medford	MA	No	$ 6,500,000
	4	1/1/1987	Cambridge	MA	Yes	$ 12,870,000
	5	11/1/2005	Watertown	MA	Yes	$ 35,458,000
	6	10/1/2006	Cambridge	MA	Yes	$ 46,725,000
	7	1/1/2004	Cambridge	MA	Yes	$ 128,902,000
	8	6/1/1999	Cambridge	MA	No	$ 48,302,000
	9	7/10/2008	Boston	MA	Yes	$ 39,000,000
	10	1/1/2008	Cambridge	MA	No	$ 40,000,000
	11	8/21/2003	Cambridge	MA	No	$ 500,000
	12	1/1/1998	Montvale	NJ	No	$ 8,415,000
	13	5/18/2001	Cambridge	MA	Yes	$ 121,124,000
	14	7/1/1993	Cambridge	MA	Yes	$ 81,700,000
	15	12/31/2007	East Watertown	MA	No	$ 32,600,000
	16	1/1/2006	Cambridge	MA	Yes	$ 19,739,000
	17	1/1/2006	Cambridge	MA	Yes	$ 36,095,000
Stanford University	1	6/1/2005	San Carlos	CA	No	$ 49,569,000
	2	12/1/2001	Palo Alto	CA	No	$ 11,953,000
	3	1/4/2001	San Mateo	CA	No	$ 136,931,000
	4	7/10/2008	Boston	MA	Yes	$ 39,000,000
	5	1/1/2007	La Jolla	CA	No	$ 50,543,000
	6	4/1/2002	South San Francisco	CA	No	$ 92,147,000
	7	1/1/1995	Hayward	CA	No	$ 54,080,000
	8	5/28/1998	San Mateo	CA	No	$ 169,000,000
	9	11/1/2003	South San Francisco	CA	No	$ 20,541,000
	10	1/1/1988	Tarrytown	NY	No	$ 4,500,000
	11	1/1/2002	Newark	CA	No	$ 109,687,000
	12	8/1/1988	Palo Alto	CA	No	$ 31,000,000
	13	6/1/2003	South San Francisco	CA	No	$ 58,337,000
	14	2/4/2006	New York	NY	Yes	$ 21,869,000
University of California Berkeley	1	10/1/2007	Fremont	CA	No	$ 26,090,000
	2	8/4/2003	Pleasanton	CA	No	$ 3,000,000
	3	1/1/1998	South San Francisco	CA	No	$ 207,224,000

(continued on next page)

Table 2 (*continued*)

Institution name (listed alphabetically)	Firm ID	Founding date of the firm	Firm city	Firm state	On campus firm location	Total amount of VC financing raised by the firm[1]
University of California Davis	1	1/1/2003	South San Francisco	CA	No	$ 26,090,000
	2	8/1/2002	San Mateo	CA	No	$ 70,163,000
	3	8/1/2005	Chapel Hill	NC	No	$ 3,750,000
University of California Irvine	1	7/20/2005	Laguna Hills	CA	No	$ 32,424,000
University of California Los Angeles	1	1/1/1997	Thousand Oaks	CA	No	$ 172,800,000
	2	5/1/1995	Alameda	CA	No	$ 14,690,000
University of California San Diego	1	1/1/2002	La Jolla	CA	No	$ 5,500,000
	2	1/1/2001	San Diego	CA	Yes	$ 68,670,000
	3	1/1/1997	San Diego	CA	No	$ 36,120,000
	4	8/1/1996	Berkeley	CA	No	$ 117,949,000
	5	1/1/1999	Monmouth Junction	NJ	No	$ 2,000,000
	6	7/1/2000	San Diego	CA	No	$ 80,399,000
	7	4/1/2003	San Diego	CA	No	Undisclosed
	8	1/1/1994	San Diego	CA	No	$ 21,025,000
	9	1/1/1998	San Diego	CA	No	$ 2,000,000
	10	5/1/1992	San Diego	CA	No	$ 58,314,000
	11	8/1/1988	Palo Alto	CA	No	$ 31,000,000
	12	1/1/2006	La Jolla	CA	No	$ 7,000,000
University of California San Francisco	1	1/1/2003	South San Francisco	CA	No	$ 82,155,000
	2	6/1/1999	Cambridge	MA	No	$ 48,302,000
	3	1/1/2007	La Jolla	CA	No	$ 2,900,000
	4	11/1/2003	San Francisco	CA	No	$ 110,551,000
University of Colorado Denver/Hsc Aurora	1	1/1/2006	Aurora	CO	No	$ 25,000,000
	2	1/1/2005	Broomfield	CO	No	$ 3,500,000
	3	1/1/1996	Broomfield	CO	No	$ 191,453,000
	4	1/1/1996	Louisville	CO	No	$ 500,000
	5	8/10/2005	Aurora	CO	No	$ 90,224,000
	6	3/1/2004	Cambridge	MA	No	$ 43,606,000
University of Michigan at Ann Arbor	1	9/1/2003	Malvern	PA	No	Undisclosed
	2	6/1/1998	Plymouth	MI	No	$ 15,485,000
	3	9/1/2005	Ann Arbor	MI	No	$ 8,125,000
	4	1/1/2003	Ann Arbor	MI	No	Undisclosed
	5	8/1/2004	Redwood City	CA	No	$ 186,772,000
	6	5/1/1992	San Diego	CA	No	$ 58,314,000
	7	1/1/1995	Houston	TX	No	$ 9,000,000
University of Washington	1	1/1/2000	Seattle	WA	No	$ 10,000,000
	2	1/1/2007	La Jolla	CA	No	$ 50,543,000
	3	7/1/2007	Seattle	WA	No	$ 36,289,000
	4	2/1/2008	Seattle	WA	No	$ 24,646,000
	5	2/1/2003	Burlingame	CA	No	$ 38,931,000
	6	8/14/2000	Rockville	MD	No	$ 156,117,000
	7	3/1/2006	Seattle	WA	No	$ 15,000,000

[1] The ending point for performing the calculation is 2008 unless the firm had gone public, had merged or had been acquired before 2008. In these latter cases, the ending point for the calculation is the IPO, the merger or the acquisition date. For the two firms that are defunct, the ending point is the year that they ceased operations.

suggests that proximity to the funding VCF has a moderate impact on the firm location choice of the academic entrepreneur. Nevertheless, because of the general bimodal structure of this variable, the sample mean is not representative of its central tendency (the median is only 63 miles) and the impact of the specific variable evaluated at the mean is somewhat overstated. Therefore our results suggest that, while statistically significant, the distance between the venture capitalist and the entrepreneur's academic institution has only a modest impact on the firm's location.

The relatively modest effect of proximity to venture capital on the location choice of academic entrepreneurs is reinforced by the insignificance of the agglomeration of VCFs in proximity to the entrepreneur's institution and the insignificance of the variable that measures their size (used here as indicator of the VCF quality). Parameter estimates that could indicate the potential of non-linearities in the relationship between agglomerations or size of VCFs and firm location choice were also statistically insignificant. Hence, these results suggest that academic entrepreneurs may not be strongly attracted to regions that host many large venture capital firms. Overall, our results appear in line with some previous work that has documented limited impact of agglomerations of VCFs on attracting small firms (Zucker et al., 1998) and in particular university spinoffs (Di Gregorio and Shane, 2003) but inconsistent with recent work that has found the opposite (Samila and Sorenson, 2010, 2011). Because our work, and that of Di Gregorio and Shane (2003), focuses on university spinoffs while the work of Samila and Sorenson (2010, 2011) does not, the difference in results may indicate that the anchoring effect of venture capital is less pronounced in the case of firms spawned from universities and started by academic entrepreneurs.

With respect to our second measure of the regional environment as discussed in *H2*, the results are in line with our theoretical expectations. We find that the amount of Round 1 funds raised by biotechnology firms in proximity (used here as indicator of the

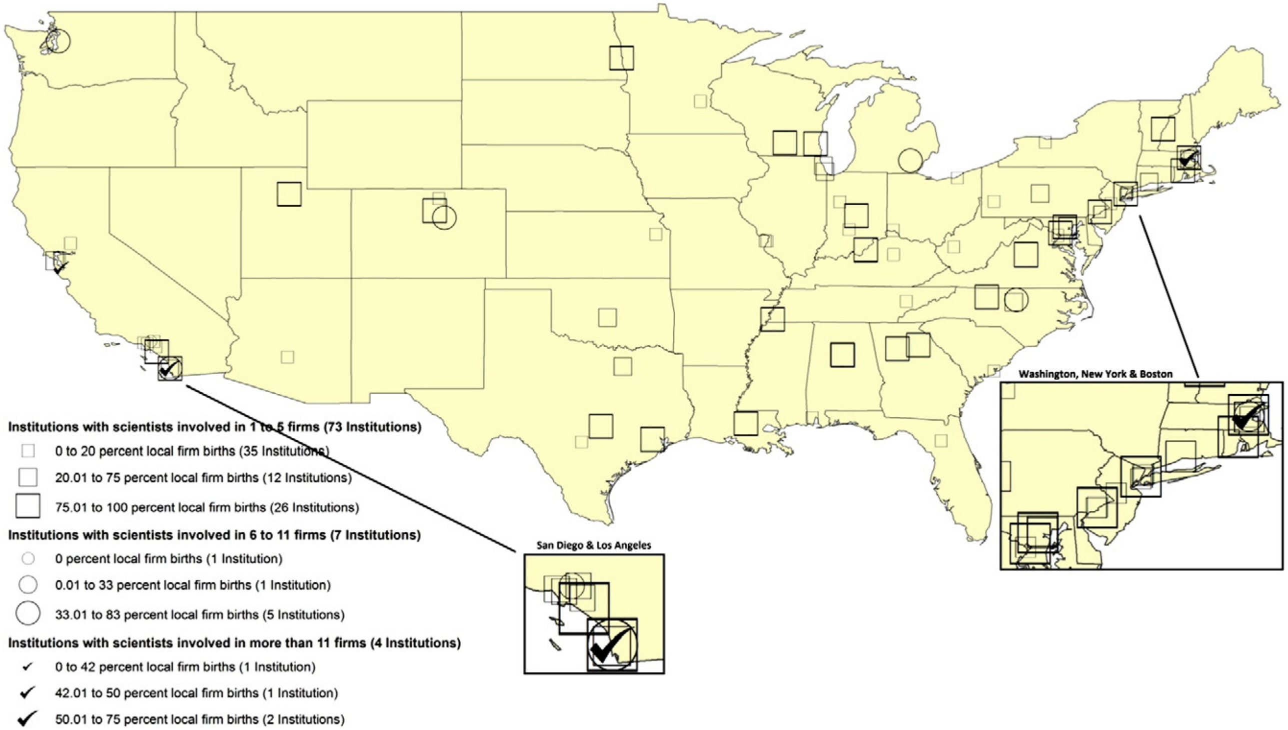

Fig. 1. Firm births in proximity and distance to the founder's institution.

Table 3
Descriptive statistics of the variables used in the empirical models.

	Variable	Number of observations[a]	Mean	Median	Mode	Standard deviation
Continuous variables	Distance to closest funding venture capital firm (miles)	257	477.71	63.42	0.73	750.13
	Number of venture capital firms in 10 miles from institution	301	38.99	12.00	0.00	47.84
	Round1 funds raised by biotechnology firms in 10 miles from institution	287	142.56	20.79	0.00	199.88
	Average number of startups at the entrepreneur's institution 5 years proceeding firm birth	223	5.57	3.33	2.00	5.70
	Entrepreneur's age at firm birth	292	47.74	47.00	47.00	10.42
	Years since PhD at firm birth	272	22.10	21.00	11.00	10.63
	Total number of patents awarded to entrepreneur before firm birth	287	9.67	2.00	0.00	25.90
	Size of closest funding venture capital firm	243	788.81	361.44	1522.17	1767.59
	Size of venture capital firms in 10 miles from institution	273	488.76	339.88	725.77	518.40
	Year trend	301	7.04	7.00	8.00	1.61
Dichotomous variables	Medical	225				
	Eminence	111				
	Serial entrepreneur	76				
	Previouswork	61				
	Co-founder	136				
Dependent variable			Category 1: Observations[b] Corresponding to firms started on academic founder's campus	Category 2: Observations[b] Corresponding to firms started outside academic founder's campus but within academic founder's city	Category 3: Observations[b] Corresponding to firms started outside academic founder's city but within academic founder's state	Category 4: Observations[b] Corresponding to firms started outside academic founder's state
Number of observations in each category			65	92	49	95

[a] For dichotomous variables, the figures measure the number of observations that have the value of 1.
[b] An observation is defined as a firm founding - academic founder match. The total number of observations in the database is 301, which can be broken down in two ways. First, 253 academic entrepreneurs were involved with one firm (253 observations), 20 academic entrepreneurs with 2 firms (40 observations), 1 academic entrepreneur with 3 firms (3 observations) and 1 academic entrepreneur with 5 firms (5 observations). Equivalently, we have 187 firms in the database; 114 firms had one academic founder (114 observations), 49 firms had 2 academic founders (98 observations), 13 firms had 3 academic founders (39 observations), 5 firms had 4 academic founders (20 observations) and 6 firms had 5 academic founders (30 observations).

quality of nearby biotech firms) is a significant factor in explaining the location preferences of academic entrepreneurs. In particular, the probability of on-campus firm birth increases by 0.0747 for every additional million dollars raised by proximate firms in Round 1. Evaluated at the mean value of *Round1* (Table 2), this result suggests that academic entrepreneurs are approximately 10.6%[17] more likely to start their firm on campus if the institution is located in proximity to DBFs that have attracted (the average) $142 million of Round 1 funds in the previous five years. Hence, the firm location choice of academic entrepreneurs appears to be influenced (positively) by the presence of other successful nearby biotechnology firms, perhaps because of gains that arise from the agglomeration of like firms.

[17] 0.0747*142.56 = 10.6.

Table 4
Model 1 (specification with *Age* variable). Marginal effects[1] and logit estimates of variables affecting firm location choice. The dependent variable is the location of the firm.

Variable	Change in probability of on campus firm location	Change in probability of in city firm location	Change in probability of outside city firm location	Change in probability of outside state firm location	Logit estimate
Distance to closest funding venture capital firm	−0.0067 *	−0.0032 *	0.0023 *	0.0076 *	−0.0004 *
Size of closest funding venture capital firm	−0.0007	−0.0003	0.0002	0.0008	0.0000
Number of venture capital firms in 10 miles from institution	−0.1395	−0.0666	0.0477	0.1584	−0.0090
(Number of venture capital firms in 10 miles from institution)^2	−0.0005	−0.0003	0.0002	0.0006	0.0000
Size of venture capital firms in 10 miles from institution	−0.0014	−0.0007	0.0005	0.0016	−0.0001
Round 1 funds raised by biotechnology firms in 10 miles from institution	0.0737 ***	0.0352 ***	−0.0252 ***	−0.0837 ***	0.0047 ***
Average number of PhD graduates in biosciences at the institution 5 years preceding firm birth	−0.1799 **	−0.0858 **	0.0615 **	0.2043 **	−0.0115 **
Medical school on campus	11.8036 **	8.7869 **	−3.6948 **	−16.8956 **	0.8636 **
Average number of startups at the entrepreneur's institution 5 years proceeding firm birth	0.2178	0.1039	−0.0744	−0.2473	0.0140
Entrepreneur's age at firm birth	−0.7825 ***	−0.3733 ***	0.2673 ***	0.8885 ***	−0.0502 ***
Eminence dummy	1.6190	0.7553	−0.5526	−1.8218	0.1034
Total number of patents awarded to entrepreneur before firm birth	0.1258	0.0600	−0.0430	−0.1428	0.0081
Serial entrepreneur dummy	5.3180	1.9940	−1.7933	−5.5188	0.3257
Previouswork dummy	−4.3779	−2.5651	1.4832	5.4598	−0.2957
1 if a cofounder is within 10 miles from the location of the firm and from campus	14.6206 ***	7.2552 ***	−4.7108 ***	−17.1650 ***	0.9557 ***
Year trend	−5.2096 *	−2.4852 *	1.7797 *	5.9151 *	−0.3343 *
μ_1					2.7924
μ_2					4.8013
μ_3					5.4324
Observations					153
McFadden's Pseudo R^2					0.140
Likelihood ratio of all variables = 0					56.000 ***
Log likelihood					−172.506
Multicollinearity condition number					41.008
Proportionality assumption χ^2					67.300 ***
Model 2 (specification with SincePhD variable). Marginal effects[1] and logit estimates of variables affecting firm location choice. The dependent variable is the location of the firm.					
Distance to closest funding venture capital firm	−0.0064 *	−0.0043 *	0.0027 *	0.0079 *	−0.0005 *
Size of closest funding venture capital firm	−0.0007	−0.0005	0.0003	0.0009	−0.0001
Number of venture capital firms in 10 miles from institution	−0.0458	−0.0306	0.0192	0.0573	−0.0033
(Number of venture capital firms in 10 miles from institution)^2	−0.0011	−0.0007	0.0004	0.0013	−0.0001
Size of venture capital firms in 10 miles from institution	−0.0056	−0.0037	0.0023	0.0070	−0.0004
Round 1 funds raised by biotechnology firms in 10 miles from institution	0.0747 ***	0.0499 ***	−0.0313 ***	−0.0933 ***	0.0054 ***
Average number of PhD graduates in biosciences at the institution 5 years preceding firm birth	−0.1331	−0.0889	0.0557	0.1662	−0.0096
Medical school on campus	10.6199 **	10.6189 **	−4.0715 **	−17.1673 **	0.8849 **
Average number of startups at the entrepreneur's institution 5 years proceeding firm birth	0.1785	0.1192	−0.0748	−0.2230	0.0128
Years since PhD at firm birth	−0.4801 **	−0.3207 **	0.2011 **	0.5996 **	−0.0345 **
Eminence dummy	−0.0257	−0.0171	0.0108	0.0321	−0.0018
	0.1446 *	0.0966 *	−0.0606 *	−0.1806*	0.0104 *

(continued on next page)

Table 4 (*continued*)

Variable	Change in probability of on campus firm location	Change in probability of in city firm location	Change in probability of outside city firm location	Change in probability of outside state firm location	Logit estimate
Total number of patents awarded to entrepreneur before firm birth					
Serial entrepreneur dummy	−0.7282	−0.5021	0.3053	0.9250	−0.0528
Previouswork dummy	−3.8495	−3.0262	1.6057	5.2700	−0.2910
1 if a cofounder is within 10 miles from the location of the firm and from campus	17.0801 ***	12.0389 ***	−6.4103 ***	−22.7087 ***	1.2679 ***
Year trend	−6.3233 **	−4.2238 **	2.6487 **	7.8984 **	−0.4543 **
μ_1					1.7441
μ_2					3.8983
μ_3					4.5927
Observations					143
McFadden's Pseudo R^2					0.157
Likelihood ratio of all variables = 0					58.850 ***
Log likelihood					−158.820
Multicollinearity condition number					39.232
Proportionality assumption χ^2					51.020 **

*** .01 significance, ** .05 significance, * .10 significance.
[1] For continuous variables the marginal effects are approximated with the variable magnitudes held at their mean value. For dichotomous variables the marginal effects are approximated as the change in the probability resulting after the variables' value changes from 0 to 1.

The variables that test the effect of the institution's biotechnology research activity level and infrastructure on the academic entrepreneur's firm location choice provide some support for *H3*. In particular, our empirical results suggest that entrepreneurs employed at institutions with a medical school are almost 11% more likely to start their firm on campus or in the institution's city. This result supports the expectation that increased research capacity and infrastructure encourage localization of new firms started by academic entrepreneurs. In contrast, an increase in the number of bioscience PhDs in the entrepreneur's institution does not have a statistically significant effect on the academic entrepreneur's firm location choice. Similarly, controlling for the overall startup rate of a university does not seem to have a significant effect on the empirical results. Taken together, these results imply that certain characteristics of the entrepreneur's university may have a more significant influence on the firm location choice than others. These results may therefore qualify Varga's (1998) proposition that, overall, there is no agreement in the literature about the role of universities on firm location choice.

In line with *H4* and the results of our theoretical model, we find that the age and the stage of the professional career of academic entrepreneur significantly shape her location preferences. In particular, we find that academic entrepreneurs at later stages of their career are considerably more likely to start their firm outside their city compared to those at earlier stages.[18] One additional year of professional experience decreases the probability of on-campus firm location by approximately 0.48 and increases the probability of locating outside the state where the entrepreneur's institution is located by approximately 0.60. The magnitude of these estimates suggests that the professional experience/age of the academic entrepreneur is the most important determinant of her firm location choice in our sample. Consistent with our theoretical results then, we find that academic entrepreneurs that are younger or at earlier stages of their academic careers maybe hesitant to locate their firm at a distance from their campus and that such cohort effects may overwhelm other factors in the firm location decision.[19] Controlling for the level of professional eminence does not change this basic result as the *Eminence* dummy variable is statistically insignificant.

With respect to remaining factors that can explain the location choice of academic entrepreneurs, we find the impact of firm co-founder(s) particularly interesting. Specifically, we find that there is a 17% higher chance for the firm to be located on campus whenever a co-founder is in proximity to the firm. The magnitude of the variable suggests that the proximate presence of co-founder(s), when they exist, is a significant factor in explaining the location choice of academic entrepreneurs.[20]

[18] In unreported results, we included the years since PhD variable and the age variable in quadratic form in order to check for potential nonlinearities in the relationship between years of experience and firm location choice. The quadratic variable was statistically insignificant, which suggests that the effect of founder's age on location choice is not nonlinear. Given their statistical insignificance the variables were not included in the analysis presented here.

[19] We note here that we explored the possibility that interaction effects among entrepreneur-specific and location-specific variables could be important (e.g. Age*Distance to VCF, Age * Average number of PhD graduates in Biosciences) but found no empirical evidence to support them. Furthermore, in order to test whether observations from biotech/venture capital hubs drove our empirical results, we re-estimated Models 1 and 2 while we progressively excluded observations from a. Stanford, b. Harvard University, Harvard medical school, MIT, and c. Salk Institute, Scripps Research Institute and University of California-San Diego. In all these models the results were qualitatively similar to the baseline estimates presented above and as such our conclusions that personal entrepreneur characteristics are prime drivers of firm location remained intact.

[20] It is possible that the location of co-founders is affected by the presence of a medical school on campus. If this was true, the impact of the co-founders and that of the presence of medical school on the firm location choice of the academic entrepreneur could overlap. To test the robustness of our results against this possibility, the models in Appendix Table 2 include specifications where the medical school dummy is included separately from the co-founder dummy. In these models the magnitude, sign and statistical significance of the medical school dummy is very similar to the corresponding figures in Table 4 (for instance the logit estimate of the medical school dummy of the full model in Table 4 is 0.88 and the logit estimates of the subset models in Appendix 2 are between 0.94 and 0.96). Accordingly, we expect our estimates to measure separate effects of medical school and co-founder on location choice.

Controlling for other personal characteristic that may affect the mobility of the academic entrepreneur has limited influence on her location choice in our sample. Serial academic entrepreneurs as well as those with previous work experience at other institutions are not found to make materially different location choices. In contrast, academic entrepreneurs with more patents are found to be more likely to start their firms locally. For each additional patent owned by the academic entrepreneur, the probability of on-campus firm location increases by 0.14 and the probability of out-of state firm location decreases by more than 0.18. These results seem to support findings reported in previous literature (e.g. Zucker et al., 1998) where entrepreneurs with an established record of research with commercial potential are able to attract the necessary resources to form firms and start them locally.

Finally, we find that over the period of our analysis the tendency of academic entrepreneurs to start their firms at a distance from their academic institution increased. This trend may reflect the increase in the size and reach of research collaborations and networks as communication costs have declined over time (Johnson and Lybecker, 2012).

7. Summary and conclusions

Partially prompted by the limited treatment in the academic entrepreneurship literature, we developed a theoretical model to examine the location choice of the academic entrepreneur within the standard utility maximization theory. The academic entrepreneur is assumed to maximize her utility by allocating her effort between academic and entrepreneurial pursuits which, in turn, determines her future streams of income and end-period wealth. Our theoretical model showed that the optimal allocation is a function of both personal and environmental factors that condition the relevant payoffs of entrepreneurial efforts, and that such factors can be empirically observed. Guided by our theoretical model and prior literature we then specified and measured a set of factors that could have influenced the firm location choice of 187 venture-capital backed biopharmaceutical firms started by 275 academic entrepreneurs in the US. We then showed that using an ordered logit model to examine these choices is both theoretically consistent and empirically relevant. Based on this model, we drew some important conclusions.

First, there are location-specific factors that have a significant impact on the location choice of the academic entrepreneur. The distance from the nearest funding venture capital firm has a statistically significant effect on the location choice, although the magnitude of this impact is relatively modest. The distance to other successful biotech firms also has a significant impact. The location of the firms co-founder(s) has, similarly, a significant influence on the firm location choice. Finally, the presence of a medical school at the academic entrepreneur's institution has a significant and large impact on the firm location choice. This seems to confirm the relevance of medical schools and similar infrastructure for biotech research and firm spawning, as reported in various case studies in the literature.

Second, there are entrepreneur-specific factors that have a significant impact on the location choice of the academic entrepreneur. The age/professional experience of the entrepreneur is strongly significant and has a substantial influence on the entrepreneur's choice of firm location. Other factors being equal, younger/less experienced entrepreneurs are more likely to locate their new firms closer to their current institution. Academic entrepreneurs that own patents are similarly more likely to locate their firms closer to their institutions.

Third, of equal interest are the location- and entrepreneur-specific factors that do not have a significant impact on the location choice of the firms in our sample. Proximity to local agglomerations of venture capital firms or local pools of graduates in biophysical sciences is not found to have a significant impact. Similarly, such personal characteristics as professional eminence, evidence of previous mobility, or serial entrepreneurship also do not have a significant impact on location choice of the firms in our sample.

From a policy perspective, our empirical results suggest that a deeper understanding of the location choice of firms spawned by universities may require more research and increased attention to the characteristics and incentives of the academic entrepreneurs that establish them. Therefore, our findings may be relevant to the ongoing debate about policies designed to create “entrepreneurial” local environments. While broad capital investments in local research infrastructure may help to attract new firms, our results suggest that the personal characteristics of academic entrepreneurs as well as the various incentives they face may be equally important for the creation of local firms. As a case in point we refer to the BioRegio contest that was launched in 1995 by the German government in order to strengthen the biotechnology industry of that country, partly via the creation of local biotechnology firms. Briefly, under this contest different regions competed for a common pool of funds and, as explained in detail in Dohse (2000), the criteria for picking the winners focused solely on the institutional infrastructure of each region. Notably, the characteristics of potential (academic) entrepreneurs were not taken into account when selecting the winning regions, which might have hampered the efficacy of the program to promote sustainable high growth startups (Champenois, 2012). Indeed, our results indicate that policies that target the responsive cohort of academic professionals may have high payoffs by increasing the regional rate of new firm creation.

It is also worth noting that our fitted ordered logit model leaves unexplained a significant portion of the variation in the observed firm location outcomes in our sample. Our theoretical model clarifies why such unexplained variation should be expected. Entrepreneurial scientists are likely to make lifetime decisions not only on the basis of financial rewards alone but also on a host of other important factors. These might include academic achievement and non-monetary rewards (e.g. honors, awards, reputation); quality of life and lifestyle considerations (e.g. leisure, proximity to recreation, proximity and time availability for friends and family); other personal and family considerations and the like. Such factors are difficult to measure through secondary data and as such they are not accounted for in our empirical analysis. Further, the theoretical model clarifies that the inherent heterogeneity in the individual preferences of academic entrepreneurs should also be expected to increase the unexplained variation in our sample. Primary data that emphasize such considerations and their impact on the firm location choice of the academic entrepreneur could therefore offer additional and useful insights.

We conclude with the boundaries of our study. First, as part of the research design we focused on firms that received funds from venture capitalists in order to be able to measure the effects of external finance on location choice. By extension, our results may not generalize to firms that do not receive funds of this kind. Also as part of our research design, we included academic institutions in our sample that had as few as one firm birth and as many as nineteen. More than half of the institutions had only one firm birth and only a handful had more than five. Consequently, this inherent data structure did not allow us to control for unobserved heterogeneity across academic institutions via panel data methods. Testing and evaluating the potential impact of such effects could be a useful contribution of future studies.

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Appendix A

Appendix Table 1
Description of variables and data sources.

Variable name	Variable description	Associated hypothesis	Data sources
Location	Variable that takes the value of: 1 if the firm of the academic entrepreneur is located on or around campus, 2 if located in their institution's city, 3 in their state and 4 if located out of state at a distant location	Dependent variable	SDC Platinum Database, Zoominfo Database, Moneytree report, InKnowVation Inc.
VCF_Distance	Distance between the closest venture capital firm that provided funds to the biotechnology firm and the entrepreneur's academic institution (miles)	H1	SDC Platinum Database
VCFs10	Number of venture capital firms located within a 10 miles radius of the entrepreneur's academic institution	H2	SDC Platinum Database
Round1	Total amount of Round 1 venture capital funds raised by biotechnology firms in a 10 miles radius of the entrepreneur's academic institution (million $)	H2	SDC Platinum Database
Funding_VCF_Size	Total amount invested by the closest funding venture capital firm to remaining biotechnology firms over time (million $)	H2	SDC Platinum Database
BioGraduates $_{t-1\ to\ t-5}$	Average number of PhD graduates in biosciences at the entrepreneur's institution in the 5 years preceding firm birth	H3	National Science Foundation
Medical	Dummy variable that equals 1 if the entrepreneur's institution has a medical school on campus (and 0 otherwise)	H3	Licensing Survey of the Association of University Technology Managers, Google Earth®
Startups $_{t-1\ to\ t-5}$	Number of startup firms associated with the founder's institution in the 5 years preceding firm birth	H3	Licensing Survey of the Association of University Technology Managers
Age	Entrepreneur's age at firm founding	H4	Marquis Who's Who, Women and Men of Science, Academic entrepreneurs' biographies provided at their personal websites
SincePhD	Number of years that have elapsed between the year that the entrepreneur received his PhD and the year of firm founding	H4	Marquis Who's Who, Women and Men of Science, Academic entrepreneurs' biographies provided at their personal websites
Eminence	Dummy variable that equals 1 if the entrepreneur had an endowed chair, was a member of the academy of science, had a named professorship, had won a nobel price or had a distinguished title before firm birth (and 0 otherwise)	H4	Marquis Who's Who, Women and Men of Science, Academic entrepreneurs' biographies provided at their personal websites
Serial entrepreneur	Dummy variable that equals 1 if the academic entrepreneur had founded at least one firm before firm birth (and 0 otherwise)	–	Marquis Who's Who, Women and Men of Science, Academic entrepreneurs' biographies provided at their personal websites
Patents	Total number of patents awarded before firm birth where the academic entrepreneur is listed as a (co)inventor	–	United States Patent and Trademark Office
Previouswork	Dummy variable that equals 1 if the entrepreneur worked at another academic institution before the one he was affiliated with at firm birth and 0 otherwise	–	Marquis Who's Who, Women and Men of Science, Academic entrepreneurs' biographies provided at their personal websites

Appendix Table 1 (*continued*)

Variable name	Variable description	Associated hypothesis	Data sources
VCFs10s	The VCFs10 variable in quadratic form	–	SDC Platinum Database
10M_VCFs_size	The average value of the Funding_VCF_Size variable for venture capital firms located in a 10 miles radius from the academic entrepreneur's institution	–	SDC Platinum Database
Co-founder	Dummy variable that equals 1 if at least one of the academic co-founders is located within 10 miles of the location of the firm and from campus (and 0 otherwise)	–	Marquis Who's Who, Women and Men of Science, Academic entrepreneurs' biographies provided at their personal websites
Year_trend	Variable that takes the value of 1 if the firm was founded between 83 to 85 (including those years), takes the value of 2 if the firm was founded between 86 to 88 and so on	–	SDC Platinum Database

Appendix Table 2

Model 1. Logit estimates of models with subsets of regressors.

	Logit estimates of subset models								Logit estimates of full Model 1
Variable	1	2	3	4	5	6	7	8	
Distance to closest funding venture capital firm	−0.0005***	−0.0005***	−0.0005***	−0.0005***	−0.0006***	−0.0005**	−0.0004*	−0.0005*	−0.0004*
Size of closest funding venture capital firm	−0.0001	−0.0001	−0.0001	−0.0001*	−0.0001	−0.0001	−0.0001	0.0000	0.0000
Number of venture capital firms in 10 miles from institution		0.0011	0.0154	0.0154	0.0212	0.0065	0.0008	−0.0023	−0.0090
(Number of venture capital firms in 10 miles from institution)^2			−0.0001	−0.0001	−0.0002	−0.0001	−0.0001	−0.0001	0.0000
Size of venture capital firms in 10 miles from institution				−0.0008**	−0.0006	−0.0004	0.0001	0.0001	−0.0001
Round 1 funds raised by biotechnology firms in 10 miles from institution					0.0022**	0.0029**	0.0034**	0.0039***	0.0047***
Average number of PhD graduates in biosciences at the institution 5 years preceding firm birth						−0.0076	−0.0084	−0.0114**	−0.0115**
Medical school on campus						0.9477**	0.9264**	0.9326**	0.8636**
Average number of startups at the entrepreneur's institution 5 years proceeding firm birth						0.0229	0.0120	0.0080	0.0140
Entrepreneur's age at firm birth							−0.0516***	−0.0567***	−0.0502***
Eminence dummy							0.1447	0.1540	0.1034
Total number of patents awarded to entrepreneur before firm birth							0.0098*	0.0081	0.0081
Serial entrepreneur dummy							0.1761	0.2312	0.3257
Previouswork dummy							−0.4440	−0.2749	−0.2957
1 if a cofounder is within 10 miles from the location of the firm and from campus								0.8438**	0.9557***
Year trend									−0.3343*
μ_1	−0.8521	−0.9016	−1.0569	−0.7479	−0.9534	−1.4491	0.7569	0.6677	2.7924
μ_2	0.4064	0.3569	0.2082	0.5738	0.4519	0.3300	2.6528	2.6294	4.8013
μ_3	1.0790	1.0285	0.8901	1.2615	1.1867	0.8785	3.2572	3.2436	5.4324
Observations	243	243	243	228	220	157	153	153	153
McFadden's Pseudo R^2	0.021	0.021	0.024	0.029	0.056	0.080	0.115	0.131	0.140
Likelihood ratio of all variables = 0	13.85***	14.05***	16.01***	17.8***	33.61***	32.85***	46.16***	52.56***	56***

(*continued on next page*)

Appendix Table 2 (*continued*)

Variable	Logit estimates of subset models								Logit estimates of full Model 1
	1	2	3	4	5	6	7	8	
Log likelihood	−321.433	−321.333	−320.355	−299.677	−281.137	−188.77	−177.427	−174.225	−172.506
Multicollinearity condition number	2.078	2.881	13.081	13.746	20.395	25.336	30.097	31.257	41.008
Proportionality assumption χ^2	14.150***	23.360***	31.610***	30.700***	23.360**	49.440***	57.150***	61.120***	67.300***
Model 2. Logit estimates of models with subsets of regressors.									
Distance to closest funding venture capital firm	−0.0005***	−0.0005***	−0.0005***	−0.0005***	−0.0006***	−0.0005**	−0.0005*	−0.0006**	−0.0005*
Size of closest funding venture capital firm	−0.0001	−0.0001	−0.0001	−0.0001*	−0.0001	−0.0001	−0.0001	0.0000	−0.0001
Number of venture capital firms in 10 miles from institution		0.0011	0.0154	0.0154	0.0212	0.0065	0.0076	0.0055	−0.0033
(Number of venture capital firms in 10 miles from institution)^2			−0.0001	−0.0001	−0.0002	−0.0001	−0.0002	−0.0001	−0.0001
Size of venture capital firms in 10 miles from institution				−0.0008**	−0.0006	−0.0004	−0.0001	−0.0002	−0.0004
Round 1 funds raised by biotechnology firms in 10 miles from institution					0.0022**	0.0029**	0.0034**	0.0041***	0.0054***
Average number of PhD graduates in biosciences at the institution 5 years preceding firm birth						−0.0076	−0.0055	−0.0092	−0.0096
Medical school on campus						0.9477**	0.9473**	0.9659**	0.8849**
Average number of startups at the entrepreneur's institution 5 years proceeding firm birth						0.0229	0.0093	0.0033	0.0128
Years since PhD at firm birth							−0.0363**	−0.0410**	−0.0345**
Eminence dummy							0.0503	0.0649	−0.0018
Total number of patents awarded to entrepreneur before firm birth							0.0124**	0.0107*	0.0104*
Serial Entrepreneur dummy							−0.1718	−0.1908	−0.0528
Previouswork dummy							−0.4745	−0.2493	−0.2910
1 if a cofounder is within 10 miles from the location of the firm and from campus								1.1124***	1.2679***
Year trend									−0.4543**
μ_1	−0.8521	−0.9016	−1.0569	−0.7479	−0.9534	−1.4491	−0.9929	−1.3745	1.7441
μ_2	0.4064	0.3569	0.2082	0.5738	0.4519	0.3300	0.9589	0.6923	3.8983
μ_3	1.0790	1.0285	0.8901	1.2615	1.1867	0.8785	1.5983	1.3558	4.5927
Observations	243	243	243	228	220	157	143	143	143
McFadden's Pseudo R^2	0.021	0.021	0.024	0.029	0.056	0.080	0.113	0.140	0.157
Likelihood ratio of all variables = 0	13.85***	14.05***	16.01***	17.8***	33.61***	32.85***	42.53***	52.68***	58.85***
Log likelihood	−321.433	−321.333	−320.355	−299.677	−281.137	−188.77	−166.445	−161.369	−158.820
Multicollinearity condition number	2.078	2.881	13.081	13.746	20.395	25.336	29.631	30.731	39.232
Proportionality assumption χ^2	14.150***	23.360***	31.610***	30.700***	23.360**	49.440***	61.180***	61.750***	51.020**

*** .01 significance, ** .05 significance, * .10 significance.

[1] For continuous variables the marginal effects are approximated with the variable magnitudes held at their mean value. For dichotomous variables the marginal effects are approximated as the change in the probability resulting after the variables' value changes from 0 to 1.

Appendix Table 3
Variance inflation factors of variables in models 1 and 2.

Variable	VIFs in Model 1	VIFs in Model 2
Distance to closest funding venture capital firm	1.2	1.19

Appendix Table 3 (*continued*)

Variable	VIFs in Model 1	VIFs in Model 2
Size of closest funding venture capital firm	1.08	1.1
Number of venture capital firms in 10 miles from institution	42.98	43.61
(Number of venture capital firms in 10 miles from institution)^2	29.53	29.95
Size of venture capital firms in 10 miles from institution	2.88	2.82
Round 1 funds raised by biotechnology firms in 10 miles from institution	2.55	2.45
Average number of PhD graduates in biosciences at the institution 5 years preceding firm birth	1.18	1.21
Medical school on campus	1.15	1.19
Average number of startups at the entrepreneur's institution 5 years proceeding firm birth	2.07	2.11
Entrepreneur's age at firm birth/years since PhD at firm birth	1.39	1.49
Eminence dummy	1.43	1.58
Total number of patents awarded to entrepreneur before firm birth	1.47	1.59
Serial entrepreneur dummy	1.33	1.4
Previouswork dummy	1.25	1.28
1 if a cofounder is within 10 miles from the location of the firm and from campus	1.2	1.2
Year trend	1.33	1.31

Appendix Table 4
Logit estimates of Models 1 and 2 with the VCF square term omitted.

Variable	Logit estimates of Model 1	Logit estimates of Model 1 without VCF square term	Logit estimates of Model 2	Logit estimates of Model 2 without VCF square term
Distance to closest funding venture capital firm	−0.0004*	−0.0004*	−0.0005*	−0.0005*
Size of closest funding venture capital firm	0.0000	0.0000	−0.0001	−0.0001
Number of venture capital firms in 10 miles from institution	−0.0090	−0.0137*	−0.0033	−0.0138*
(Number of venture capital firms in 10 miles from institution)^2	0.0000		−0.0001	
Size of venture capital firms in 10 miles from institution	−0.0001	−0.0001	−0.0004	−0.0003
Round 1 funds raised by biotechnology firms in 10 miles from institution	0.0047***	0.0049***	0.0054***	0.0057***
Average number of PhD graduates in biosciences at the institution 5 years preceding firm birth	−0.0115**	−0.0115**	−0.0096	−0.0094
Medical school on campus	0.8636**	0.8559**	0.8849**	0.8756**
Average number of startups at the entrepreneur's institution 5 years proceeding firm birth	0.0140	0.0160	0.0128	0.0169
Entrepreneur's age at firm birth	−0.0502***	−0.0504***		
Years since PhD at firm birth			−0.0345**	−0.0351**
Eminence dummy	0.1034	0.1023	−0.0018	−0.0015
Total number of patents awarded to entrepreneur before firm birth	0.0081	0.0080	0.0104*	0.0101*
Serial entrepreneur dummy	0.3257	0.3226	−0.0528	−0.0526
Previouswork dummy	−0.2957	−0.2927	−0.2910	−0.2866
1 if a cofounder is within 10 miles from the location of the firm and from campus	0.9557***	0.9631***	1.2679***	1.2794***
Year trend	−0.3343*	−0.3406*	−0.4543**	−0.4649***
μ_1	2.7924	2.8677	1.7441	1.8731
μ_2	4.8013	4.8796	3.8983	4.0336
μ_3	5.4324	5.5099	4.5927	4.7265
Observations	153	153	143	143
McFadden's Pseudo R^2	0.140	0.140	0.157	0.156
Likelihood ratio of all variables = 0	56***	55.95***	58.85***	58.68***
Log likelihood	−172.506	−172.528	−158.820	−158.368
Multicollinearity condition number	41.008	36.823	39.232	35.7663
Proportionality assumption χ^2	67.300***	66.750***	51.020**	69.600***

*** .01 significance, ** .05 significance, * .10 significance.

[1] For continuous variables the marginal effects are approximated with the variable magnitudes held at their mean value. For dichotomous variables the marginal effects are approximated as the change in the probability resulting after the variables' value changes from 0 to 1.

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