Small Bus Econ (2015) 44:475–484
DOI 10.1007/s11187-014-9606-0

Toward a theory of the entrepreneurial process

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Accepted: 14 August 2014 / Published online: 5 September 2014

Abstract This paper models the entrepreneurial process as both creation and discovery composed of an iterative two-step process where entrepreneurs create social networks based on subjective expectations about the future effectiveness of those networks, and then choose the innovation to pursue and map a search process to discover how to bring the innovation to fruition. Critical to this process is the mix of strong ties and weak ties that make up social networks and the ability to carry forward the social capital embodied in such networks. The tendency of long-existing entrepreneurs to be less innovative can be explained using this model.

Keywords Entrepreneurship · Social networks · Innovation · Technology · Creation and discovery

JEL Classifications L26 · O31 · O33 · M13

1 Introduction

While the study of entrepreneurship has a long history (Hébert and Link 2006a, b), it has been hampered by the lack of a theory about, and a conceptual framework for, understanding the entrepreneurial process (Shane and Venkataraman 2000; Shane 2013). In this paper, we extend the framework of Leyden et al. (2014) to model the entrepreneurial process as one of both creation and discovery composed of an iterative two-step process in which entrepreneurs create social networks based on subjective expectations about the future effectiveness of those networks, then choose an innovation to pursue and map out a search process to discover how to bring that innovation to fruition.

Our model's treatment of the creation of the entrepreneur's social network is based on Burt's (2005) work on brokerage and closure; our treatment of the exploitation of that network is based in part on Alvarez and Barney's (2007) characterization of entrepreneurial creation and search theories. However, unlike Alvarez and Barney who present entrepreneurial creation and search theories as components of a long debate about whether entrepreneurial activity is essentially a process of discovery (an argument perhaps most notably associated with Kirzner (1985)) or a process of creation (perhaps most notably associated with Schumpeter (1934)), our view is that the discovery/creation choice is a false one; in reality both discovery and creation are present in the entrepreneurial process.[1] We characterize the entrepreneurial

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[1] de Jong and Marsili (2014) present important empirical evidence that the realization of opportunities exhibits both Schumpeterian and Kirznerian characteristics.

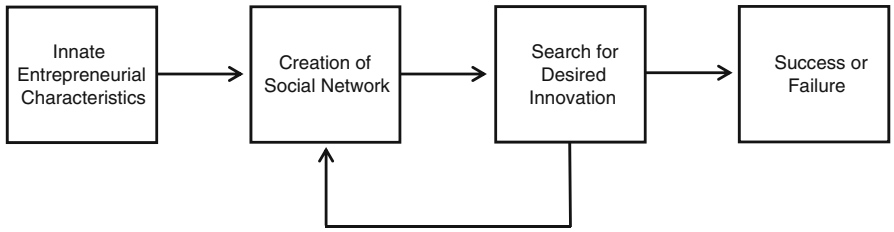

Fig. 1 The entrepreneurial process

process as one in which the entrepreneur, given an endogenous social network innovates within the context of an uncertain environment.

Our model of the entrepreneurial process is illustrated in Fig. 1. The process is an iterative one in which the entrepreneur repeatedly sequences through the creation of a social network and the search for a defined innovation. The social network creation process is inherently and irremediably an uncertain one (Knight 1921; Shackle 1979). The search for a defined innovation is also an uncertain one. To the extent that the search has dimensions of being an engineering problem, it has the potential for being converted, at least in part, into one of risk or certainty; that is, it is in terms of Alvarez and Barney (2007) a process of discovery. This complicates the overall entrepreneurial process because the choices made in the first creation phase having implications for the environment in which the entrepreneur searches, and the results of the search process (successful or failing) having implications for the process of revising the knowledge network. An important implication is that there is generally no optimal social network structure. Instead, that structure, which is the result of some mix of brokerage and closure activities, will depend on circumstances particular to the entrepreneur.

The remainder of the paper is organized as follows. In the following section we examine the second step of the entrepreneurial process—the search for an innovation given a knowledge network in place and the goal already decided. Then, we turn back to an examination of the first step of the entrepreneurial process—the creation of the entrepreneur's social network, and we explore some implications of this model with particular emphasis on its ability to provide insight on the differential behavior of entrepreneurs. The arguments in these sections are derived from an extension of Leyden et al. (2014) in several dimensions. First, uncertainty is formally introduced into the entrepreneur's process of creating a social network and searching over it for an innovation. Second, the social network, following Granovetter (1973) and Burt (2005), can now be characterized as a mix of strong and weak ties with others. And third, our extended model allows us to offer an explanation as to why entrepreneurs differ (e.g., nascent versus incumbent entrepreneurs; serial versus one-time entrepreneurs), thus leading to testable hypotheses.

Finally, the paper concludes with summary remarks and a statement about the policy implications of our model. The technical elements of our model are described in mathematical terms in the Appendix.

2 The search for an innovation

The conceptualization of the innovation process begins with an entrepreneur who has a social network in place and has decided on which innovation to pursue. As mentioned, this decision has engineering-like dimensions and, following Alvarez and Barney (2007), it can be characterized in the context of discovery. However, we extend Alvarez and Barney and allow for the possibility of uncertainty in this discovery process, although if that uncertainty can be resolved to a matter of probabilistic certainty, the discovery process ultimately will then be characterized by risk.

The entrepreneur's search for an innovation is a costly one that develops over time against the backdrop of the entrepreneur's resource constraints and social network. That search process can be conceived as an exploration of various combinations of inputs—knowledge, actions, and resources—that will generate the desired innovation. Imposed on this process is the entrepreneur's subjective assessment of the likelihood of finding a successful combination of inputs that will ensure success in the search for the desired innovation.

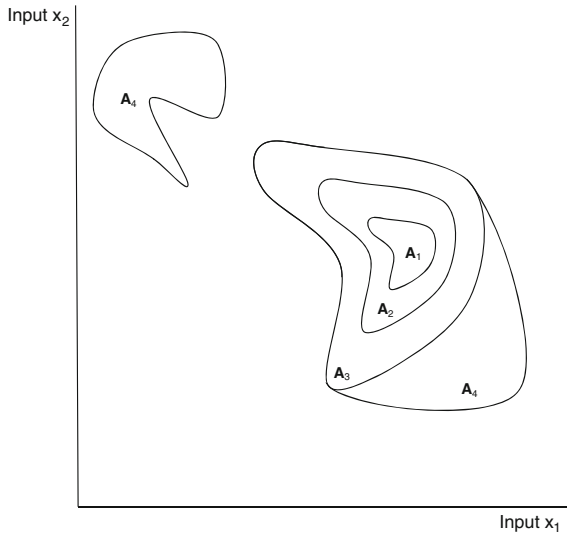

Fig. 2 Regions of entrepreneurial search among knowledge, actions, and resources

The entrepreneur begins by exploring input combinations that are in the entrepreneur's subjective view most likely to yield success. If success is not achieved initially, the entrepreneur then widens the range of input combinations, again guided by a subjective assessment of the likelihood of finding a successful input combination given the lack of success to that point in time. This sequence of increasing search areas is illustrated in Fig. 2 for the case of two inputs, x_1 and x_2. Initially, the entrepreneur begins with a relatively small search region $\mathbf{A}_1$ chosen because of the entrepreneur's subjective belief that the likelihood of finding a successful input combination is greatest within that region. If not successful, the entrepreneur expands to a larger region $\mathbf{A}_2$, and continues to search over ever widening regions until an innovation is found or until it is no longer desirable to search.

There is no reason to believe that the search regions $\mathbf{A}_i$ are convex, or even connected. Thus, for example, Fig. 2 includes the case of an entrepreneur who, after failing to find a successful input combination in regions $\mathbf{A}_1$, $\mathbf{A}_2$, and $\mathbf{A}_3$, is of two minds about what combinations of inputs might be successful and concludes that input combination most likely to be successful will either be an input combination with a very high level of input x_1 and a very low level of input x_2, or an input combination with a very low level of input x_1 and a very high level of input x_2. Hence, the entrepreneur's next search region $\mathbf{A}_4$ is a disconnected set.

Searching is a costly process with the expected cost of searching increasing as the size of the search region increases. Search costs are assumed to be a negative function of the effectiveness of the entrepreneur's social network, with effectiveness tied to the heterogeneity of that social network (which is commensurate with the number of weak ties which we define below) and the cohesion of that same social network (which is defined by the number of strong ties, again defined below). Thus, the cost of search can be represented by the function $c^S(A, \gamma)$, with increases in A, which represents the size of the region $\mathbf{A}$, resulting in greater cost, but with increases in the effectiveness of the entrepreneur's social network, represented by γ, resulting in lower cost.

Because the search process is costly, the entrepreneur's choice of where to search is determined by his/her subjective estimates of the likelihood of finding an input combination that succeeds in achieving the desired innovation. For a given search region of size A, the entrepreneur will choose the boundaries of that search region so as to maximize the subjective likelihood $L(A|\gamma)$ of successfully finding an input combination that results in successfully achieving the desired innovation. Note that this subjective likelihood function, in addition to being a function of the size of the search region, will also be a function of the effectiveness of the entrepreneur's social network with the greater the effectiveness of this social network, the greater the entrepreneur's subjective assessment of the likelihood of success.[2]

2.1 The entrepreneur's resource constraint

We assume that the entrepreneur seeks funding from a capital market (Link et al. 2014), and that the entrepreneur's access to financial capital is constrained by the expectation (^{e}) that the suppliers of capital hold regarding the value of the entrepreneur's innovation project, V^e. Because the innovation process is an uncertain one, the expected value of the project that the capital market holds will be subjective. Moreover, because there is no guarantee of success, this expected value can be defined as the subjectively determined value, V, of the innovation were it to be

[2] This point is emphasized by Schott and Sedaghat (2014) under the implicit assumption that the size of the network and its effectiveness are positively related.

successfully achieved times the subjective probability of success $P(A|\mathbf{K})$, where $\mathbf{K}$ is the capital market's knowledge base. It is important to note the different perspective of the capital market regarding the chance that the entrepreneur will succeed. For the entrepreneur, the focus is on finding a combination of inputs that will yield success. Because there is likely to be more than one input combination associated with success, and because the entrepreneur knows that he/she does not know the entire universe of possibilities, one cannot speak in terms of probabilities, which in terms of formal theory must sum to one across all possibilities. Thus, the entrepreneur thinks in terms of the less constrained notion of likelihoods. For the capital market, in contrast, the focus is not on possible input combinations that might be successful. Instead, it is on the entrepreneur and whether that entrepreneur will be successful. The universe of possibilities is then the set of all entrepreneurs who come to the capital market for financial support. That set is known empirically, and so through the analysis of past successes and failures of entrepreneurs using statistical models and portfolio theory, the capital market constructs a probability of success.

The assessment of the probability of success by the capital market will be a function of the size of the entrepreneur's search region, A, because that information can be easily conveyed to the capital market; indeed, it is likely to be part of the entrepreneur's funding proposal (Schott and Sedaghat, 2014).[3] However, the effectiveness of the entrepreneur's social network, γ, is not included because of the amorphous nature of this variable would be difficult to convey to the capital market. In essence, γ is private information. As a result, the capital market will base its subjective assessment of the probability of success on its own knowledge base, $\mathbf{K}$, comprising methods for estimating the end value, V, of the innovation were it to be achieved and for estimating the chances of success using portfolio theory. Because this estimation of success does not include knowledge of the effectiveness of the entrepreneur's social network, the subjective probability of success, $P(A|\mathbf{K})$, held by the owners of private equity may not be the same as the subjective likelihood of success, $L(A|\gamma)$, held by the entrepreneur. The entrepreneur in choosing to engage in the uncertain innovation process will be constrained by the requirement that the cost of the project, $c^S(A, \gamma)$, not exceed the expected value V^e of the project held by the owners of private equity.

[3] To the extent that size of the network is positively related to the size of the firm and to the technological maturity of the firm, then Link's (1980) finding—formulated as a test of the Schumpeterian hypothesis—that the returns to R&D investments at the firm level is a function of the size of the firm might have policy implications regarding public support of R&D and related innovative activity in small versus large firms.

2.2 The optimal search region

While profits are clearly part of what motivates the entrepreneur, we assume that the motivation of the entrepreneur is better modeled as seeking to maximize the likelihood of success than simply to maximize profits. This assumption thus blends aspects of the teleological theories of human action described by Alvarez and Barney (2007): assumptions about the nature of human objectives and about the nature of individuals. Given this motivation, the entrepreneur's problem is one of choosing a region of size A^* that will maximize the entrepreneur's subjective likelihood of successfully identifying an input combination that achieves the desired innovation, $L(A|\gamma)$, subject to the resource constraint that the expected cost to the entrepreneur, $c^S(A, \gamma)$, not exceed the expected value V^e of the project as assessed by the owners of private equity. Moreover, because increasing the size of a search region will always increase the entrepreneur's subjective assessment of the likelihood of success, the resource constraint will always hold as an equality, that is, $c^S(A, \gamma) = V^e$. As a result, the condition that the expected cost, $c^S(A, \gamma)$, equals the expected value, V^e, of the project is equivalent to the condition that the expected average cost of the project per unit of area searched equals the expected average value of the project per unit of area searched, that is, $c^S(A, \gamma)/A = V^e/A$.

Given this structure, the entrepreneur's problem and its solution can be represented by Fig. 3. Given that the effectiveness of the entrepreneur's social network is some γ_1, the solution to the entrepreneur's problem will be at point E_1 in Fig. 3 where the expected average value line, V^e/A, intersects the average cost curve, $c^S(A, \gamma_1)/A$, and hence the size of optimal search region will be A_1^*.

Note that this solution depends on the effectiveness of the entrepreneur's social network, γ. Because greater social network effectiveness reduces the cost

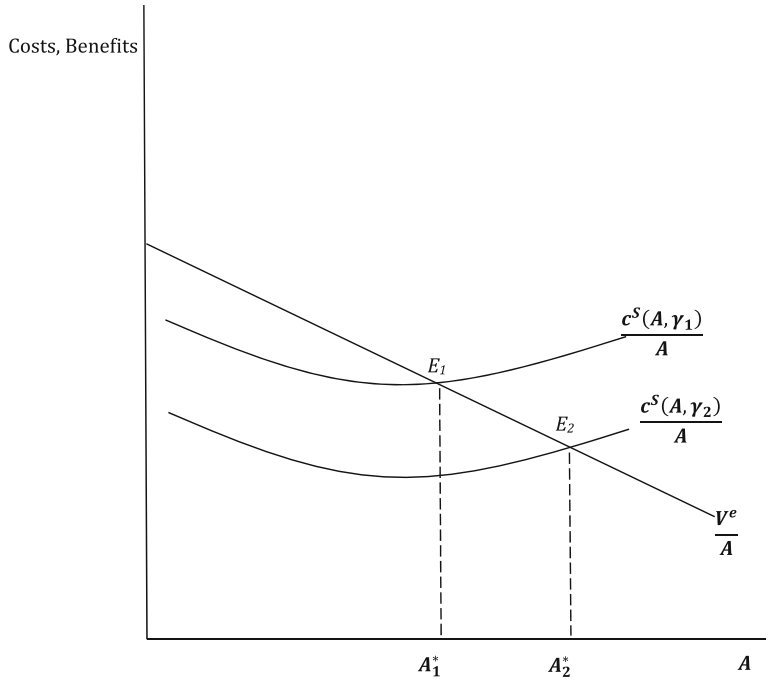

Fig. 3 Optimal solution to the entrepreneur's innovation search problem

of searching, all else held constant, an increase in the effectiveness of the entrepreneur's network reduce the entrepreneur's cost of searching. Figure 3 illustrates such a case with an increase in network effectiveness from γ_1 to γ_2 resulting in the size of the optimal search region increasing to A_2*.

2.3 The creation of a social network

As demonstrated above, the entrepreneur's social network is crucial to the entrepreneur's project. It likely plays a role in the identification of the entrepreneur's desired innovation and is clearly critical in determining the search regions over which the entrepreneur searches and therefore the success of the entrepreneur. The more effective is the entrepreneur's social network, the greater will be the size of the optimal search region and therefore the greater will be the chance of successfully discovering an input combination that results in achieving the desired innovation. The question therefore becomes what determines the effectiveness of the entrepreneur's social network and to what extent does the entrepreneur have control of that effectiveness.

Following Granovetter (1973, p. 1361), the entrepreneur's social network can be characterized as a mix of strong and weak ties with others, the distinction between those ties depending on 'the amount of time, the emotional intensity, the intimacy (mutual confiding), and the reciprocal services which characterize the tie.' As Burt (2005) notes, strong ties are associated with a shared body of knowledge, group cohesion, and entrepreneurial control; weak ties by contrast are associated with less group cohesion and entrepreneurial control but have the virtue of providing access to a heterogeneous set of knowledge and perspectives. In essence, then, weak ties are about creativity and new ideas, strong ties are about organizational integrity, and both ties are conducive to the effectiveness of the social network. Evidence presented by Burt suggests that weak and strong ties have synergistic effects on the effectiveness of the social network. As a result, we can visually represent the relationship between strong ties, β, and weak ties, α, by an iso-effectiveness map such as the set of curves labeled as $\gamma_1 < \gamma_2 < \gamma_3$ in Fig. 4.

The entrepreneur assembles a social network through what Burt (2005) calls brokerage (i.e., the creation of weak ties) and closure (that is, the creation of strong ties). Such actions require resources. However, unlike the search process, the entrepreneur cannot turn to capital markets for funding because

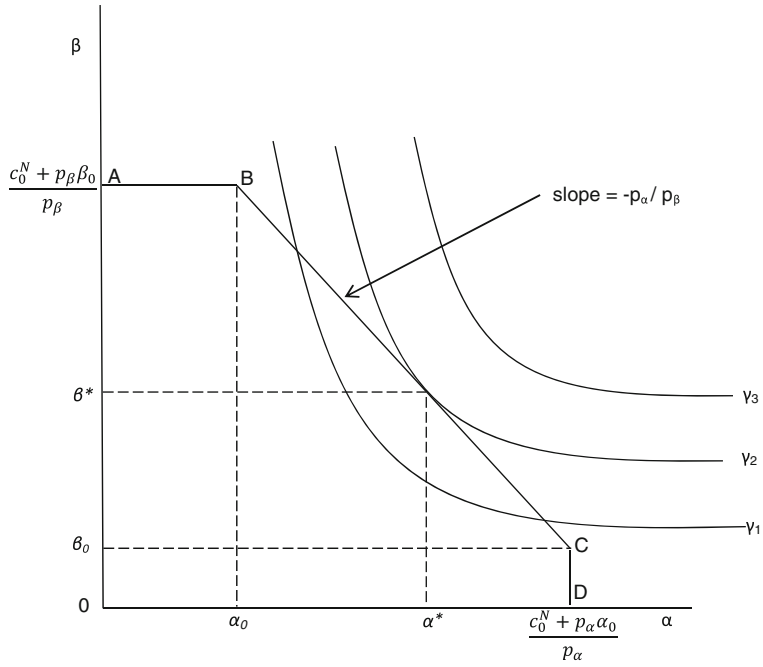

Fig. 4 Optimal social network effectiveness

the desired innovation may not yet be determined and because of the amorphous nature of social networks. Moreover, the nature of the project and the probability of its success from the perspective of capital markets are predicated on the existence of the entrepreneur's social network and therefore cannot be evaluated before the social network has been created. As a result, the entrepreneur must rely on internal resources to fund the network creation process. Those internal resources, or endowments, come in two forms. The first is a monetary endowment that can be used to create strong and weak ties; the second is an in-kind endowment in the form of a pre-existing social network. Thus, if the entrepreneur's monetary endowment is some c_0^N dollars, and its network endowment is composed of β_0 amount of strong ties and α_0 amount of weak ties, the entrepreneur's production possibilities frontier can be represented by the line ABCD in Fig. 4. Note that this production possibilities frontier assumes a constant marginal cost of creating strong ties and a constant marginal cost of creating weak ties (see the Appendix for details). In Fig. 4, those marginal costs are labeled p_α (for the marginal cost of acquiring weak ties) and p_β (for the marginal cost of acquiring strong ties). Following Burt's (2005) characterization of the problems of echo and rigidity that arise from closure, we assume that the marginal cost of weak ties increases with the size of the strong tie endowment, β_0.

The solution to the entrepreneur's network problem is that mix of strong and weak ties that maximizes the effectiveness of the created network. Given the convex production possibilities frontier and the concave iso-effectiveness curves, that solution will be where the production possibilities frontier is just tangent to the highest possible iso-effectiveness curve that intersects the production possibilities frontier. In Fig. 4, that solution is noted by the pair (α^*, β^*).

2.4 Why do entrepreneurs differ?

Our theoretical model explains a variety of entrepreneurial behaviors. For example, consider the behavior of nascent versus incumbent entrepreneurs (Acs and Audretsch 1988). It has often been observed that nascent entrepreneurs are more creative than incumbent entrepreneurs. Recognizing that over time an entrepreneur will cycle through the process of network creation and innovation search many times (recall Fig. 1), the difference in creativity between the two entrepreneurs can be explained by the growing network endowment for the incumbent entrepreneur. With time, the incumbent entrepreneur will have a

greater and greater endowment of strong ties. While that results in a more effectively run organization, it also increases the marginal cost of acquiring weak ties that are the source of creativity. (In terms of Fig. 4, it results in a steeper production possibilities frontier.) The increase in the cost of weak ties will generally result in less of an effort to create weak ties and more of an effort to create strong ties (i.e., tighten up the structure of the organization), reducing still further the focus on creativity. Note, however, that such behavior is rational, for to do otherwise would be to generate a less than optimally effective social network and therefore a reduced subjective likelihood of successfully locating an innovation. However, to the extent such bias is broader so that there is also a rejection of existing weak ties as Burt (2005) suggests, the result can be an entrepreneur with reduced ability to innovate.

Another noted difference between entrepreneurs is with respect to the higher success rate among some serial entrepreneurs. Within the context of our model, the key to understanding this phenomenon is again the cycling process illustrated in Fig. 1 and the growing network endowment for the serial entrepreneur. It may be harder, though not impossible, for a serial entrepreneur to maintain strong ties with each new venture. But weak ties are easier to maintain, and to the extent that the network endowment of the serial entrepreneur maintains those weak ties, over time the serial entrepreneur's endowment of weak ties will grow. (In terms of Fig. 4, the production possibilities frontier will shift further to the right with each new venture.) With such growth comes an increasing ability to establish an effective social network with an emphasis on creativity.

3 Conclusions

The literature on entrepreneurship contains a debate over whether entrepreneurial behavior is essentially one of discovery or creation. We argue that this is a false choice and that in fact entrepreneurial behavior in general includes both. We model that inclusion through an iterative two-step process in which the entrepreneur creates a social network based on subjective expectations about the future effectiveness of that network, chooses the innovation to pursue, and then maps out a search process using that social network to discover how to bring the desired innovation to fruition.

Critical to this process of creation and discovery is the mix of strong ties and weak ties that make up the entrepreneur's social network and the ability to carry forward the social capital embodied in that social network. This implies that there is no ideal template for an entrepreneur to follow in terms of creating a social network. Instead, each entrepreneur must construct a network that maximizes its expected likelihood of success based on the particulars of that entrepreneur. Thus, long-existing entrepreneurs have a tendency to become less innovative as the social network becomes more and more internally focused on the creation and maintenance of strong ties, and serial entrepreneurs, by being able to jettison older strong ties but maintain weak ties, are able to become increasingly creative and effective in the innovation process.

We have not explored the public policy implications of this model, but can sketch in rough terms what such policy should be. In brief, because there is a general tendency toward the creation of strong ties over time, public policy should focus on the creation of weak ties and on creating the ability to keep strong ties from overwhelming the innovation process. The creation of weak ties can come both by reducing the cost of interactions and by increasing the number of potential points of interaction through a vibrant education system. To keep strong ties under control, it suggests increased flexibility in the ability of entrepreneurs to start up new organizations and shut down old ones. Note, however, that this should not be interpreted as a dismissal of strong ties in general. Like weak ties, they serve an important function in the innovation process.

Appendix: Derivation of toward a theory of the entrepreneurial process

The search for an innovation

Given a desired innovation and a social network, the entrepreneur's efforts focus on exploring various combinations of knowledge, actions, and resources (hereafter inputs) thought to have a reasonable chance of producing the innovation. Let N be the total number

of possible inputs so that input sets can be represented by $N \times 1$ vectors $\mathbf{x} \in R^n$ (some entries in the vectors perhaps being zero).

The search for a combination of inputs $\mathbf{x}$ that will generate the desired outcome is assumed to take place sequentially over time. Letting $\mathbf{A}_t \in R^n$ represent the region of the input space explored in time t, the entrepreneur searches over increasing larger regions. Thus:

$$\mathbf{A}_0 \subset \mathbf{A}_1 \subset \mathbf{A}_2 \subset \ldots \tag{1}$$

Searching is a costly process. Assume that the cost of searching is a positive function of the size of the region explored and the degree to which the entrepreneur has the ability to engage in creative cognition, and assume that the ability to engage in creative cognition is a positive function of the effectiveness, γ, of the entrepreneur's social network. Thus, let A_t be the Lebesgue measure (that is, the size) of region $\mathbf{A}_t$:

$$A_t = A(\mathbf{A}_t) = \int_{\mathbf{x} \in \mathbf{A}} \mathbf{x}\, \mathbf{dx}. \tag{2}$$

We can thus define the cost of searching as:

$$c_t^S = c^S(A_t, \gamma). \tag{3}$$

Assume that the costs of searching increase at a (weakly) increasing rate with the size of the search region:

$$\partial c^S / \partial A_t > 0,\ \partial^2 c^S / \partial A_t^2 \geq 0, \tag{4}$$

and decrease at a decreasing rate with the effectiveness of the entrepreneur's social network:

$$\partial c^S / \partial \gamma < 0,\ \partial^2 c^S / \partial \gamma^2 < 0. \tag{5}$$

The average cost of searching can then be defined as:

$$\bar{c}^S = c^S(A_t, \gamma)/A_t. \tag{6}$$

Assume also that the average cost, $\bar{c}^S$, is convex with respect to A_t

$$A_t(\partial^2 c^S / \partial A_t^2) - 2\,(\partial c^S / \partial A_t) + 2\,c^S / A_t > 0. \tag{7}$$

Because the entrepreneurial process is an uncertain one, the likelihood of finding a successful input combination in a given region $\mathbf{A}_t$ is objectively unknown. As a result, the entrepreneur is guided by subjective estimates of the likelihood of success. Let the entrepreneur's subjective likelihood of success in region $\mathbf{A}_t$ be defined by the function $\Lambda(\mathbf{A}_t|\gamma)$, and note that this likelihood function is a function of the entrepreneur's social network. Given the pattern of search regions described by Eq. (1), this subjective likelihood function will increase as the entrepreneur widens the search region. Thus:

$$\Lambda(\mathbf{A}_t|\,\gamma) \ni 0 \leq \Lambda(\mathbf{A}_t|\,\gamma) \text{ and } \Lambda(\mathbf{A}_t|\,\gamma) < \Lambda(\mathbf{A}_{t+1}|\,\gamma). \tag{8}$$

Note that because the cost of searching increases with the size of the search region, the entrepreneur has an incentive given any region $\mathbf{A}_t$ to define the boundaries of $\mathbf{A}_t$ so as to maximize $\Lambda(\mathbf{A}_t|\gamma)$. As a result the $\mathbf{A}_t$ is uniquely associated with $\Lambda(\mathbf{A}_t|\gamma)$, and we can redefine this subjective likelihood function in terms of the size $\mathrm{A_t}$ of the region $\mathbf{A}_t$:

$$L(A_t|\,\gamma) \ni 0 \leq L(A_t|\,\gamma) \text{ and } L(A_t|\,\gamma) < L(A_{t+1}|\,\gamma). \tag{9}$$

To fund the innovation process, assume that the entrepreneur uses capital markets. As a result, the entrepreneur's access to capital is constrained by the capital market's expected value, V^{e}, of the project. That expected value can be defined as the product of the ultimate expected value V of the project were it to succeed and the (subjective) probability of success $P(A_t|\mathbf{K})$, where $\mathbf{K}$ represents the capital market's M-dimensional knowledge set ($\mathbf{K} \in R^M$):

$$V^{\mathrm{e}}(V, A_t|\mathbf{K}) = V \cdot P(A_t|\mathbf{K}). \tag{10}$$

Thus, the entrepreneur's resource constraint will be:

$$c^S(A_t, \gamma) \leq V^{\mathrm{e}}(V, A_t|\mathbf{K}). \tag{11}$$

The solution to the entrepreneur's problems depends on the objective of the entrepreneur. We assume that the objective of the entrepreneur is to maximize the likelihood of successfully innovating. Thus, the entrepreneur's objective is to choose a region of size A^* that will maximize the likelihood $L(A_t|\gamma)$ of success in achieving the desired entrepreneurial outcome subject to the budget constraint (11). Because increasing the size, A_t, of a search region will always increase the likelihood of success (recall Eq. (9)), the resource constraint (11) will always hold as an equality:

$$c^S(A_t, \gamma) = V^e(V, A_t|\mathbf{K}) \tag{12}$$

which is equivalent to the condition that average cost is equal to the average value of searching:

$$c^S(A_t, \gamma) / A_t = V^e(V, A_t|\mathbf{K}) / A_t. \tag{13}$$

Figure 3 provides an illustration of this problem and its solution. Note that the outcomes noted above are *ex ante*. In practice, the entrepreneur engages in a sequential process of exploration. If he or she finds success before the search area reaches A^*, he/she will stop searching, and profits *ex post* will be higher than expected. If he/she does not find success after having searched the region A^*, he/she will stop searching, and profits *ex post* will be lower than expected, and in fact will be negative.

Entrepreneurial network creation

Social networks are created by entrepreneurs to aid in deciding which innovation to pursue and in searching for that innovation. The determination of the various search regions, A_t, and the costs associated with searching them, depends on the effectiveness, γ, of the social network. Because the process of innovation search described in the text can only take place after a social network is in place, the process of creating the social network must take place before, and independent of the later innovation search process.

Social networks are composed of bonds between individuals and/or organizations with varying types of knowledge. The effectiveness of an entrepreneur's social network is determined by the degree of heterogeneity in the set of knowledge embodied in the social network, and by the degree of closure, that is, the degree to which the individuals/organizations, in the network are bound closely into an integral whole. We assume that the degree of heterogeneity and of closure can be represented, respectively, by the non-negative variables α and β.

The effectiveness, γ, of a given network is inherently and irremediably uncertain. It is therefore a matter of subjective conjecture by the entrepreneur. Nonetheless, we assume that entrepreneurs believe that α and β are both valuable components of any network and that there is to some degree or other a trade-off between the two, that is, that a reduction in one can to some extent be compensated by an increase in the other. Assume then that the entrepreneur's subjective estimation of the effectiveness of a social network is a positive, strict quasi-concave function of α and β:

$$\gamma = \gamma(\alpha, \beta) \ni \frac{\partial \gamma}{\partial \alpha} > 0, \frac{\partial \gamma}{\partial \beta} > 0, \text{and } 2\frac{\partial^2 \gamma}{\partial \alpha \partial \beta}\frac{\partial \gamma}{\partial \alpha}\frac{\partial \gamma}{\partial \beta} - \frac{\partial^2 \gamma}{\partial \alpha^2}\left(\frac{\partial \gamma}{\partial \beta}\right)^2 - \frac{\partial^2 \gamma}{\partial \beta^2}\left(\frac{\partial \gamma}{\partial \alpha}\right)^2 > 0. \tag{14}$$

As a result, we can represent the relationship between γ and the various values of α and β by an iso-effectiveness diagram similar to the iso-quant diagram used in the standard microeconomic theory of the firm. Figure 4 represents such a diagram with $\gamma_1 < \gamma_2 < \gamma_3$.

The cost of assembling a social network is assumed to be a positive, linear function of α and β:

$$c^N = p_\alpha \alpha + p_\beta \beta \tag{15}$$

where p_α and p_β are the marginal costs of α and β. In addition, based on Burt's (2005) characterization of the problems of echo and rigidity that arise from closure, assume that the marginal cost of α is an increasing function of the entrepreneur's endowment, β_0 (see below for the characterization of the entrepreneur's endowment):

$$p_\alpha = p_\alpha(\beta_0) \ni \frac{\partial p_\alpha}{\partial \beta_0} > 0. \tag{16}$$

In choosing the optimal mix of α and β, the entrepreneur cannot access funding from capital markets. Those funds are provided on the basis of the capital market's estimation of the value of the entrepreneur's project and the probability of success. But the nature of the project and the probability of its success are predicated on the existence of an entrepreneurial social network and therefore cannot be evaluated before the social network has been created. Therefore, the entrepreneur must rely on internal resources to fund the network creation process.

Assume that the entrepreneur has access to two sources of internal resources. The first source is a pre-existing social network that the entrepreneur has already created. That pre-existing social network essentially means that the entrepreneur will have an endowment of $\alpha = \alpha_0$ and an endowment of $\beta = \beta_0$. The second source is a general monetary endowment c_0^N that can be used to acquire α and β. Thus, the entrepreneur's production possibilities frontier can be

derived by setting $c^N = c_0^N$ in Eq. (15) and accounting for the endowments (see Fig. 4):

$$c^N = p_\alpha(\alpha - \alpha_0) + p_\beta(\beta - \beta_0) \ni \alpha \geq \alpha_0 \text{ and } \beta \geq \beta_0. \tag{17}$$

The solution to this network creation problem is to choose that mix of α and β that achieves the greatest expected value of the network, that is, that mix such that the marginal rate of substitution is equal to the marginal rate of transformation (see Fig. 4):

$$\frac{\frac{\partial \gamma}{\partial \alpha}}{\frac{\partial \gamma}{\partial \beta}} = \frac{p_\alpha}{P_\beta}. \tag{18}$$

The effect on the eventual levels of α and β of different marginal cost and endowments will depend on the specific structure of the entrepreneur's subjective iso-effectiveness of the social network map. However, for a given social network map, we can note the following observations:

- A higher marginal cost of α, p_α, will mean a steeper budget line and hence a desire for relatively more β and less α.
- A higher marginal cost of β, p_β, will mean a flatter budget line and hence a desire for relatively less β and more α.
- A higher resource endowment, c_0^N, will mean a budget line further to the northwest. The effect on α and β will depend on the nature of the iso-effectiveness map.
- A higher endowment of α will mean the budget line will be further to the right but with the same slope. Hence, the effect will be similar to that associated with a higher resource endowment except that the minimum amount of α will be higher.
- A higher endowment of β will mean the budget line will be vertically higher and steeper. As a result, the effect will be a combination of the effect of a higher endowment and a higher marginal cost of α, with the added restriction that the minimum amount of β will be higher.

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