An Agent-Based Study on the Regional Impact of Business Incubation in Innovation Ecosystems

Ivan Garibay, Christopher D. Hollander, Ozlem Ozmen, Thomas O'Neal

University of Central Florida

Extended Abstract

1 Introduction

Business incubators are organizations that provide business education, access to business support services (e.g. marketing, accounting, financial management, production assistance and product development) and shared equipment, access to a network of contacts, access to capital, and a vast array of other services [7] to entrepreneurs and their companies. Incubator programs are designed to help startups become financially viable companies with the potential to create jobs and commercialize new technologies [7]. The success of a business incubator is often measured by number of companies that "graduate" (i.e. no longer require the incubator's resources). The regional impact of a business incubator is typically measured by the employment contribution (in jobs) of the companies that graduate [8, 9]. We suggest that an alternative way to measure the regional impact of a business incubator is to consider the network effects that result from the survival of its companies (i.e. the trickle down and indirect benefits to non-incubated companies). In particular, show that when a subpopulation of firms are incubated, new companies entering the economy become successful by adopting production processes that complement (or compete with) the incubated companies. This behavior increases the technological diversity of the population, as reflected by an increase in the density of the technology space of the regional economy. An increase in technological diversity is desirable because Hollander and Garibay [5] have previously shown that technological diversity positively correlates with economic performance (as measured by GDP). Furthermore, we show that the permanency of this increased diversity depends on the type of support being given.

2 Resource and Technology Space

The goal of our research is to better understand how business incubation affects the structure of an economy's technology space, H.

The resource space of an economy [5] is the set of resources used for production and consumption. These resources can be natural (e.g. trees), manufactured (e.g. tables), or intangible (e.g. labor). The technology space of an economy is

a directed hypergraph, $H = (V, E)$, such that V is the resource space and E is a set of "hyper" edges [4] that connect all resources used in a production process (i.e. each edge encodes a production process available to the population). If every production process consumes a single resource to produce a single resource, then H is a simple directed graph. Each edge of H is associated with a weight, $w_e > 0$, that denotes the number of companies capable of the associated production process. For example, if the resources of an economy are labeled with integer values and there is a hyper-edge that connects resources 1 and 2 to resource 3 and that edge has a weight of 5, then there are 5 companies in the economy capable of consuming resources 1 and 2 to produce resource 3. As companies enter and leave the economy, the weights associated with the edges of H will change. Edges with a weight of 0 are removed from E and added back when their weight becomes greater than 0. In reality, the technology space will rarely form a complete network due to Schumpeterian "creative destruction" – the idea that technologies overtake and replace one another [2, 6].

3 A Generative Innovation Ecosystem

To explore the impact of business incubation, we use an agent-based model of innovation ecosystems [1, 5] that incorporates principles and ideas from the resource-based view of the firm [10], Schumpeterian creative destruction, and generative systems [3]. Agents are bounded rational entities that exist in a spatial environment (i.e. agents live on a 2D grid with a finite sensory range of radius r) and possess a production process that transforms a single resource of one type to a single resource of another type. All agents with the same production process form a sector. The population of agents evolves to maximize economic performance, as measured by a fitness function that accounts for trade activity and personal wealth. Evolutionary advances that introduce technologies novel to the population are interpreted as innovations (i.e. they may create in new edges within the technology space). The dynamics of the model and its associated performance measures center around the flow of resources between individual agents at the micro level.

Within the population, agents form a dynamic interaction network with the spatially local neighbors and compete with each other for finite resources. A generalized notion of money is used to facilitate trade among agents. Agents leave the economy if their combined money and resources ever reaches zero; new agents have the potential to enter the economy at each time step though a "copy-with-error" mechanism that is intended to represent the idea of successful economic sectors growing larger (e.g. if everyone wants bread, more bakeries appear). At each simulated time step, every economically successful agent (i.e. agents with a combined resource and money level above a parameterized threshold) is duplicated with a constant non-zero, parameterized, probability that the production process will be copied incorrectly (e.g. an agent with the rule {input = 1, output = 2} might be copied as {input = 1, output = 3}); all other agent

characteristics are guaranteed to be unmodified; errors in agent duplication may lead to changes in the topology of the technology space.

Resources are generated exogenously at fixed locations in the environment, enter the economy once they are discovered by roaming agents, and then traded away or transformed by those agents. As agents alter their location in space, the interaction network necessarily changes to reflect the new local neighborhoods of each agent.

4 Experiments

We expect that 1) certain methods of business incubation create stable, long-lived, and successful companies that provide a foundation for the production process of new entries into the economy; and 2) other methods of business incubation do not. We justify our expectations with the following scenario: while a company is being incubated, it is producing goods that may be desired by others in the economy. If the incubated company is economically successful, then new companies entering the economy will be likely to compete with the incubated company because the associated sector is profitable. Likewise, if companies that use the products of incubated companies are successful, then new companies entering the economy will be likely to copy them as well, as will other companies linked by the edges of the technological space. If the technology being used by the chain of companies linked to the incubator forms a cycle (in the technology space), then all associated companies will form a self-reinforcing niche. This niche persists as other companies leave the economy. Over time, the structure of the technological space is fundamentally changed as a result of incubation. Ideally, the altered structure of the technology space also results in a higher level of economic performance than the original structure.

For this extended abstract, we hypothesize that incubation can increase the density of an economy's technology space. We conduct a preliminary test of our hypothesis by running a series of simulated experiments in our innovation ecosystem (using Netlogo [11] to implement our agent-based model). Each experiment generates data for the technology space of an artificial economy before, during, and after incubation. As the method of incubation, agents are given either money, which they can use to buy resources used by their production process and pay upkeep costs, or they are given resources specific to their production process, which they can then sell or transform. The agents selected for incubation are drawn from either the "youngest" agents or the "oldest" agents, as determined by ranking their age (in simulation time), or uniformly at random. In total, we conduct 7 simulation experiments ($\{money, resources\} \times \{young, old, random\} \cup \{baseline\}$) at 21 replications each (to ensure a level of generality). Each replication is based off a specific random seed that is duplicated across experiments. This approach (known as common random numbers) is used to ensure that the same agents are chosen for incubation across each experiment, thereby allowing us to control for the influence of incubation method and selection type.

5 Results

The resource space for the experimental economy consists of $n = 10$ resources, with one of those resources being "natural" (i.e. the environment produces it at a constant rate and in a specific spatial location). We focus our attention on the density of the technology space both before and after incubation. A plot of the density at each simulated time step, broken down by experimental configuration with comparisons to the baseline behavior of no incubation, is given in figure 1.

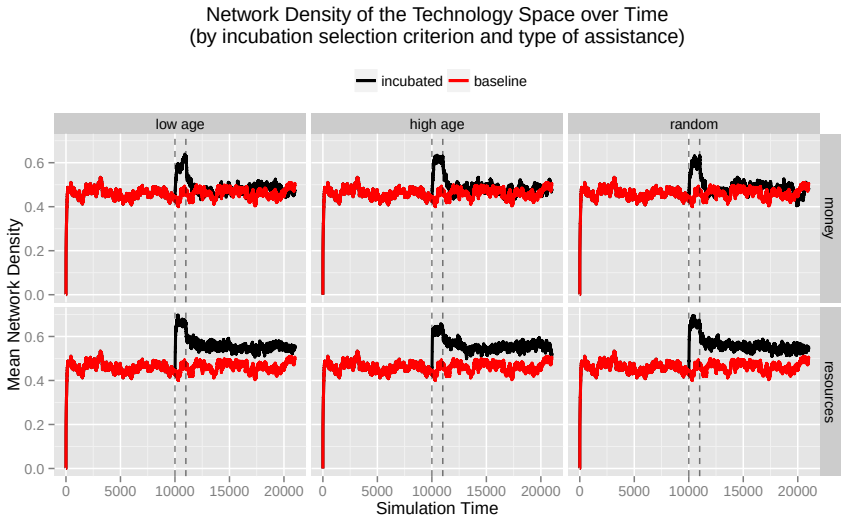

Fig. 1. The density of the technology space over time, broken down by incubation selection criterion and type with comparisons to the baseline behavior of no incubation. The dashed vertical lines denote the incubation period.

Figure 1 shows that that the type of incubation matters: giving either resources, as required by the production process of a company, or money yields a different pattern in the change of density of the technology space as compared to the baseline case without any incubation. Furthermore, if the economy is not operating at its full capacity, incubating with resources results in a permanent increase to the density of the technology space, providing money does not appear to have this benefit. This finding was confirmed by conducting a t-test for the equality of means between the incubated density and baseline density for each post-incubation step in each experiment ($p < 0.05$ for resource cases). These preliminary results support our general hypothesis, but with the constraint that incubation be resource-based. No evidence was observed to support the notion that money-based incubation increases the density of an economy's technology space; however, further experimentation is required to validate these findings.

6 Conclusion

The process of business incubation and the best practices for its use are still being developed. Part of the difficulty in fully understanding the effectiveness of business incubation is the lack of available economic data for appropriate comparisons of incubated versus non-incubated companies [8, 9] – jobs are the most widely cited measure of success because employment data is easy to acquire. We propose another means by which to measure the impact of business incubation: by examining the network effects that percolate out from the incubated companies. In this paper, we use an idea model to explore how business incubation can impact the technology space of an innovation ecosystem. Our early results suggest that not only does incubation affect the technology space of an innovation ecosystem, but certain types of incubation produce a permanent increase in the technological diversity, which may also lead to an increase in overall economic performance.

References

1. Adner, R., Kapoor, R.: Value creation in innovation ecosystems: how the structure of technological interdependence affects firm performance in new technology generations. Strategic Management Journal 31(3), 306–333 (2010)
2. Dosi, G., Fagiolo, G., Roventini, A.: Schumpeter meeting Keynes: A policy-friendly model of endogenous growth and business cycles. Journal of Economic Dynamics and Control 34(9), 1748–1767 (Sep 2010)
3. Epstein, J.M., Axtell, R.L.: Growing Artificial Societies: Social Science from the Bottom Up. The MIT Press, first edn. (Nov 1996)
4. Gallo, G., Longo, G., Pallottino, S., Nguyen, S.: Directed hypergraphs and applications. Discrete Applied Mathematics 42(2-3), 177–201 (Apr 1993)
5. Hollander, C.D., Garibay, I., ONeal, T.: Transformation networks: A study of how technological complexity impacts economic performance. In: Teglio, A., Alfarano, S., Camacho-Cuena, E., Gins-Vilar, M. (eds.) Managing Market Complexity, Lecture Notes in Economics and Mathematical Systems, vol. 662, pp. 15–26. Springer Berlin Heidelberg (2013)
6. Klimek, P., Hausmann, R., Thurner, S.: Empirical confirmation of creative destruction from world trade data. PLoS ONE 7(6) (06 2012)
7. Lewis, D.A., Harper-Anderson, E., Molnar, L.A.: Incubating Success: Incubation Best Practices that Lead to Successful New Ventures. Tech. rep., University of Michigan (2011)
8. O'Neal, T., Ford, C., Lasrado, V., Sivo, S.: The effect of regional characteristics on the relationship between university resources and knowledge-based startups performance. Technology Transfer in a Global Economy p. 233 (2012)
9. O'Neal, T., Lasrado, V.: The role of university of central florida in regional economic development. Technology Transfer in a Global Economy p. 117 (2012)
10. Wernerfelt, B.: A Resource-Based View of the Firm. Strategic Management Journal 5(2), 171–180 (Jan 1984)
11. Wilensky, U.: NetLogo (1999), http://ccl.northwestern.edu/netlogo/