Growing Silicon Valley on a landscape: an agent-based approach to high-tech industrial clusters*

Junfu Zhang

Public Policy Institute of California, 500 Washington Street, San Francisco, CA 94111, USA
(e-mail: zhang@ppic.org)

Abstract. We propose a Nelson-Winter model with an explicitly defined landscape to study the formation of high-tech industrial clusters such as those in Silicon Valley. The existing literature treats clusters as the result of location choices and focuses on how firms may benefit from locating in a cluster. We deviate from this tradition by emphasizing that high-tech industrial clusters are characterized by concentrated entrepreneurship. We argue that the emergence of clusters can be explained by the social effect through which the appearance of one or a few entrepreneurs inspire many followers locally. Agent-based simulation is employed to show the dynamics of the model. Data from the simulation and the properties of the model are discussed in light of empirical regularities. Variations of the model are simulated to study policies that are favorable to the high-tech economy.

Keywords: Silicon Valley – Agent-based simulation – Industiral clusters

JEL Classification: L11, R12

> *Do not regard Silicon Valley as some sort of economic machine, where various raw materials are poured in at one end and firms such as Apple and Cisco roll out at the other, but rather as a form of ecosystem that breeds companies: without the right soil and the right climate, nothing will grow.*
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> – The Economist, March 29, 1997

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1 Introduction

Silicon Valley is the most salient example of high-tech industrial clusters. Public policy makers throughout the world would like to learn the secrets of Silicon Valley in order to build their own high-tech economies. The existing literature on industrial clusters, which traces back to Marshall (1920), focuses on the way in which firms benefit from locating in a cluster; it suggests that once a cluster comes into existence, it tends to reinforce itself by attracting more firms. However, a more important question is how to reach this critical mass in the first place. In contrast to the literature, evidence suggests that entrepreneurs rarely move when they establish high-tech start-ups (Cooper and Folta, 2000). This contradicts the notion that location choice analyses lead entrepreneurs to a high-tech cluster.

A high-tech industrial cluster such as Silicon Valley is characterized by concentrated entrepreneurship. Following Schumpeter, we emphasize the fact that "the appearance of one or a few entrepreneurs facilitates the appearance of others" (Schumpeter, 1934). We propose an agent-based computational model to show how high-tech industrial clusters could emerge in a landscape in which no firms existed originally. The model is essentially a spatial version of the Nelson-Winter model: Boundedly rational agents are scattered over an explicitly defined landscape. Each agent is endowed with some technology, which determines his firm's productivity (if he has one). During each period of time, an agent with no firm would make a decision as to whether he wants to start one. This decision is mostly affected by the behavior of his social contacts, who are all his neighbors. If an agent's neighbors are successful in their entrepreneurial activities, the agent is more likely to found a firm himself. An entrepreneur makes business decisions according to some rules of thumb. When an agent does start a firm and begin to make a profit, he spends part of his profit on R&D in order to improve his productivity, part on imitating other firms' technology, and the rest on capital accumulation. Entrepreneurs who lag behind in the Schumpeterian competition lose money and eventually fail; however, it is possible that they learn from their failures and try again.

We use an agent-based simulation to show that Silicon Valley-type industrial clusters will emerge spontaneously on the landscape. In addition, the model exhibits the following properties: 1) First mover's advantage: the first firm has a better chance to survive and grow; a region in which firms enter the market early tends to capture a large piece of the industry. 2) Path dependence: the more firms a region has, the more it tends to have; once a cluster is formed, it can hardly be toppled. 3) Clustering of entrepreneurship: firms are continuously forming and dying within clusters. 4) Clustering of innovations: the productivity in clusters is much higher than elsewhere because of the collective learning within clusters through innovation and imitation.

Data from the simulation and the properties of the model are discussed in light of empirical regularities. We also explore variations of the model in order to study the factors that determine the location of emerging clusters. We learn two lessons from the model. First, the conventional knowledge-spillover literature may only tell part of the story; the contagion of entrepreneurship through peer effects seems to be an important mechanism through which high-tech industrial clusters emerge