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Strengthening advanced manufacturing innovation ecosystems: The case of Massachusetts

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ABSTRACT

Recent years have brought a renewed focus on the importance of manufacturing to the health and future growth of nations and regions. Several studies have highlighted the need to maintain and build manufacturing capabilities to support economic growth and have linked a nation's as well as region's strength in manufacturing to its ability to innovate. In the U.S., where a manufacturing strategy has largely been absent for the past 25 years, advanced manufacturing capabilities are now seen as essential to the development of new products and processes across a range of industries. Against this backdrop, Massachusetts presents an interesting case since manufacturing in this U.S. state is integral to several of its most important industry clusters, yet it is a high wage, high costs state that must compete globally. This research examines the pathways and opportunities for building and fostering innovation capacity among Massachusetts manufacturers, with a particular focus on small and medium-sized enterprises (SMEs). We employ a systems approach to conduct analytic and empirical analyses that consider how knowledge and sources of innovation flow between key participants within the manufacturing innovation ecosystem. We find that the Massachusetts manufacturing innovation ecosystem is rich in terms of assets but relatively poor in terms of interconnectedness between those assets. In addition, rather than being focused on demand-driven innovation and technological upgrading for SMEs, non-market state-supported manufacturing intermediaries are primarily focused on supply-side, point solutions that work with individual firms rather than at a systems level.

1. Introduction

Recent years have brought a renewed focus on the importance of manufacturing to the health and future growth of the U.S. economy. Indeed, several studies and public-private initiatives have highlighted the need to maintain and build manufacturing capabilities to support economic growth, good jobs, and national security. Perhaps most importantly, they have linked the nation's manufacturing capabilities to its ability to innovate. Advanced manufacturing is essential for developing new products and processes across a range of industries, both established and emerging. As others have pointed out, the loss of these capabilities can shift an industry's center of gravity as higher value-added activities follow manufacturing abroad (Pisano and Shih, 2011).

In few states is the link between manufacturing and innovation more evident than in Massachusetts. The state, home to MIT and Harvard, is consistently ranked number one in terms of innovation capacity in the U.S. (Bloomberg Innovation Index, 2016). While manufacturing represents only 9% of employment in the Commonwealth (approximately 250,000 jobs), compared to 11% in the U.S. overall, it is integral to several of the state's most important industries, including aerospace/defense, semiconductors and computers, biopharmaceuticals, and medical devices. Massachusetts manufacturers compete globally on their innovation capacity, high skills, product quality, and rapid response.

Small and medium-sized enterprises (SMEs) play a critical role in maintaining and growing the manufacturing strengths of the U.S. and Massachusetts economies, and other advanced industrialized economies such as Germany. These companies are the “backbone” of the country's and the region's industrial capabilities and they exist in every community where manufacturing exists often supplying complex as well as commodity parts and components. SMEs supply both the large established firms (known as “original equipment manufacturers” or OEMs that regularly develop sophisticated products and systems as well as the entrepreneurial firms that engage in prototyping or pilot production to advance new products. The former are “firms that […] manufacture […] based on ‘original’ designs” (Sturgeon, 2001). OEMs either make

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products directly or act as a system integrator before selling directly to the customer. Throughout this paper, the term OEMs typically refers to large enterprises (with over 500 employees).

Today, because of the fierce global competition in manufacturing capabilities, most manufacturing that occurs in the U.S. fall into the category of "advanced manufacturing." In a broad sense the term refers to the use of next-generation technologies in manufacturing processes. More precisely, advanced manufacturing encompasses "a family of activities that depend on the use and coordination of information, automation, computation, software, sensing, and networking, and/or make use of cutting-edge materials and emerging capabilities enabled by the physical and biological sciences" (PCAST — President's Council of Advisors on Science and Technology, 2011). Advanced manufacturing can refer to improving current manufacturing practices of existing products as well as the manufacturing of new products using new advanced technologies.

As OEMs progressively look outside their operations toward their supply chains to improve their innovation capacity, key questions arise as to how to build this capacity among the SMEs that operate within global supply chains and support regional manufacturing capabilities.

This paper examines the question of how a highly innovative, high wage region like Massachusetts can improve its innovation ecosystem to support SMEs in their efforts to be globally competitive. Manufacturing capabilities are grounded in particular regions, where, historically, they have grown around key industries. Thus, manufacturing lends itself to regional approaches for increasing innovation capacity and upgrading firms' capabilities. Strengthening the regional innovation ecosystem as a whole will improve the "industrial commons" (Pisano and Shih, 2011) and leverage resources by helping all manufacturers in the state, not just a select few.

This is particularly important for SMEs. Recent research by MIT's Production in the Innovation Economy (PIE) project (Berger, 2013) concluded that SMEs often find themselves "home alone" when it comes to competing globally and driving innovation in their companies. The large, vertically-integrated corporations of the 1980s have become less vertically integrated over time as they have focused on their core competencies, outsourced much of their production and increasingly relied on smaller suppliers to drive innovation. This process has left "holes" in the industrial ecosystem in the U.S., cutting off many of the important investments and spillovers that used to flow from large corporations to smaller firms, for example, in training, technology adoption, and R & D investments. As a result, many SMEs have been left largely on their own to figure out how to find and train workers, adopt new technologies, and develop and scale new products and services, while shouldering the burden of funding this at the same time.

It is within this global and national context that small and medium-sized manufacturers need to innovate in order to remain competitive and participate in technological advances in manufacturing. The ecosystem within which they operate is critical to their ability to do this. The case of Massachusetts presents a dynamic model of how this occurs or could occur given gaps that exist in the manufacturing innovation ecosystem as it is presently organized.

This paper focuses on how one region is working to fill these holes as they relate to innovation. For this, an empirically grounded systems approach is used that considers how knowledge and sources of innovation flow between key actors within the manufacturing innovation ecosystem. Strengthening these links and expanding the flow of knowledge between key actors upgrades the system as a whole and enhances the region's competitiveness. As regions and countries around the world increase investment in manufacturing and incentives for manufacturing firms, it is increasingly important to understand what makes for a more effective regional innovation ecosystem.

2. Literature review

This literature review begins with defining "innovation," a term that is frequently used but often poorly specified. Innovation differs from invention in that the latter is the creation of something new and novel while innovation is the process of adding value to an invention such that it becomes useful in the marketplace (Schumpeter, 1934). There are generally considered four different dimensions to innovation; product, service, process, and organizational (Kirner et al., 2009). *Product* or *service innovation* is the first-time commercial utilization of a product or service that is new to the market, whereas *process innovation* is the implementation of methods that are new to the company, but not necessarily new in the market, and that change the way a company manufactures a product. Process improvement measures, like lean manufacturing, Six Sigma, etc., are often included in this category of innovation, though they may be less about true innovation and more about continuous improvement. *Organizational innovation* is the implementation of new organizational methods within a firm that change the firm's business practices, communication, and/or workplace organization (Uygun and Reynolds, 2016). The primary focus of this paper is on product and process innovation.

Innovations are often only realizable if embedded in a fruitful "ecosystem'. The term "innovation ecosystem" has gained popularity in recent years. The "ecosystem" metaphor draws from our understanding of natural and biological ecosystems. An ecosystem comprises all living organisms within a physical environment functioning together as a unit and seeking an equilibrium state with a stable set of conditions to keep a population at desirable levels. Equilibrium is sought through modeling the energy dynamics of the ecosystem operations where energy is a means by which living organisms' energy is transferred to the soil by dying and decomposing which then can be taken up by other organisms. Thus, ecosystems are a "complex set of relationships among the living resources, habitats, and residents of an area whose functional goal is to maintain an equilibrium sustaining state". Based on this idea, innovation ecosystems refer to the economic relationships between actors (university faculty and students, entrepreneurs, industry leaders, government officials) and entities (market and non-market organizations) whose functional goal is to enable innovation. Innovation ecosystems can be seen as "inter-organizational, political, economic, environmental, and technological systems through which a milieu conducive to business growth is catalyzed, sustained, and supported. A dynamic innovation ecosystem is characterized by a continual realignment of synergistic relationships of people, knowledge, and resources that promote harmonious growth of the system in agile responsiveness to changing internal and external forces" (Jackson, 2011).

The concept of an innovation ecosystem is rooted in the literature on systems of innovation that emerged approximately 25 years ago, building upon endogenous growth theory that emerged in the 1980s (Romer, 1986). New growth theory put knowledge creation at the center of economic growth models, though their antecedents can be traced back to Marshallian industrial districts described in the late 19th century. Systems of innovation thus describe the characteristics of environments that support knowledge creation and enhance greater innovation.

The systems of innovation literature began at the national level and then were later applied to the regional level. A national innovation system (NIS) is defined most succinctly as "the set of institutions [= organizations] whose interactions determine the innovative performance of national firms" (Nelson and Rosenberg, 1993). The NIS approach assumes homogeneity in a country with respect to national institutions such as legal and regulatory frameworks. There can be, however, significant regional differences within countries that impact the level of innovative activities (Asheim and Gertler, 2005). Regional innovation systems (RIS) stress the regional dimension of production and the exploitation of new knowledge to help explain regional differences in innovation capacity and economic strength where the focus is on the relationship between technology, innovation, and industrial location (D'Allura et al., 2012).

While the term innovation ecosystem can be used to refer to