The Rise (and Fall) of Tech Clusters

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Motivation

Tech clusters play a growing role in knowledge-based economies by accommodating high-tech firms and providing an environment that fosters location-dependent knowledge spillovers and promotes R&D investments by firms. Yet, not much is known about the economic conditions under which such entities may form in equilibrium without government interventions. This paper develops a spatial equilibrium model with a competitive final sector and a monopolistically competitive intermediate sector, which allows us to determine necessary and sufficient conditions for a tech cluster to emerge as an equilibrium outcome.

The concept of tech clusters has gained favor of many analysts and policy-makers[1]. Even though the idea of industrial district has been around for a long time[2], it was not until the 1990s that the related concept of a tech cluster has been developed[3,4]. Although there is a rich variety of tech clusters[5,6], they do share some common features. In particular, a tech cluster (i) accommodates knowledge-intensive firms, (ii) encourages R&D investments by firms, while researchers and high-skilled workers can be drawn from nearby universities/research institutes, and (iii) provides an environment that fosters location-dependent knowledge spillovers.

Main objective

First, we develop a model that captures the following basic features: (i) a composite consumption good is produced by using an endogenous range of specialized inputs provided by intermediate firms whose combination generates coordination problems that require the hiring of production-line designers; (ii) high-skilled and specialized workers are hired to produce intermediate goods or to conduct R&D in the intermediate sector; (iii) the productivity of an intermediate firm depends on its level of R&D investments and inter-firm spillovers, the intensity of which depends on how intermediate firms are distributed across space; and, (iv) both workers and intermediate firms are spatially mobile and use land.

The novelty of our approach lies in an agglomeration force that combines firms' R&D investments and the existence of localized knowledge spillovers. On the other hand, the dispersion force, which is generated by both intermediate firms' and workers' demand for land and costly commuting, is common to most models of city formation. As usual, the equilibrium distribution of firms and workers is determined as the balance between these two opposite forces.

The main tenet of this paper is that the emergence and efficiency of a tech cluster is intimately related to the spatial structure of the area that hosts it. To show this, we view a tech cluster as a city formed by firms involved in R&D activities and which interact to determine endogenously knowledge spillovers. The clustering of firms thus works with other agglomeration economies, such as a large pool of high-skilled and specialized workers and the provision of knowledge-intensive and technology-sophisticated production processes, to further enhance firms' productivity.[7,8]

Model

The economy consists of a featureless one-dimensional space Z and a continuum H of high-skilled workers. A unit mass of firms are able to produce the final good with the basket of intermediate goods, which is priced under perfect competition. Intermediate firms and workers choose their location within the urban area and consume a fixed amount of land. The final sector is located at the city center and do not consume land which allows us to focus on symmetric distributions of intermediate firms and workers. Production of intermediate goods requires land. Apart from land, workers consume the final good and are endowed with one unit of labor each. Commuting between the residence and workplace requires t units of the numéraire per unit of space.

The total demand for land is equal to N+H where N is the mass of intermediate firms that will be endogenously determined in equilibrium. Therefore, the city size is also endogenous. We focus on a high-tech city where all firms are clustered around city center, which is flanked by two residential areas. In this case, the intermediate producers are uniformly distributed within a tech cluster whose spatial extend is given [-N/2,N/2].

Sectors and workers

The **intermediate sector** produces a differentiated intermediate good under monopolistic competition using land and labor with endogenous R&D that enhances firm productivity. A firm located at z produces the quantity $x(z)$ by using one unit of land, $R(z)$ units of labor for R&D, and $L(z)$ units of labor:

$$x(z) = A(z) \cdot L(z)^{\beta} l^{1-\beta},$$

with $\beta \in (0,1)$. The total factor productivity (TFP) $A(z)$ is given by a Cobb-Douglas aggregator of the firm's R&D employment $R(z)$ and a *spatial externality* that combines a Romer-Lucas external effect weighted by a distance-decay function $S(z)$:

$$A(z) = R(z)^{\theta} \cdot (\bar{R}S(z))^{1-\theta},$$

where $\bar{R}$ is the total mass of workers involved in R&D activities, $S(z)$ is a measure of firms' spatial concentration around z, and $\theta \in (0,1)$. The distance-decay effect is given by a negative exponential:

$$S(z) \equiv \int_{-N/2}^{N/2} \exp(-\gamma |z-y|) \mathrm{d}y = \frac{1}{\gamma} \left[2 - \mathrm{e}^{-\gamma N/2} \left(\mathrm{e}^{-\gamma z} + \mathrm{e}^{\gamma z} \right) \right].$$

The **final sector** produces the numéraire according to the following production function:

$$Y = \int_{Z^F} x(z)^{\frac{\sigma-1}{\sigma}} \mathrm{d}z,$$

where $\sigma > 1$. Furthermore, designing the production line gives rise to an expenditure $w(0)\phi N$ that has the nature of an endogenous fixed cost for the final sector, where $\phi > 0$ is the labor requirement needed to use one additional intermediate input.

Each **worker** is endowed with an increasing in the quantity of the final good utility function and chooses her residential site y and workplace z. Since workers' utility is increasing in the final good consumption, maximizing consumption amounts to maximizing her net income given by

$$\max_{y,z} I(y,z) = w(z) - t|y-z| - r(y).$$

Key results

First, we establish necessary and sufficient conditions for a high-tech cluster to emerge as a spatial equilibrium outcome which uncover the reasons explaining why high-tech clusters may or may not be formed. More specifically, we identify three key rationales for firms to have incentives for gathering in a high-tech cluster: (i) highly localized knowledge spillovers, (ii) relatively inexpensive commuting costs, and (iii) abundance of high-skilled labor. These are all typical features of new high-tech industries that make a cluster which accommodates more intermediate firms and fosters research activities more likely to emerge. This may explain why knowledge-intensive firms form a high-tech cluster such as the Silicon Valley, the Hsinchu Science-Based Industrial Park in Taiwan or the Cambridge Science Park in the U.K. and why in the absence of localized knowledge spillovers, simple cluster policies are not sufficient for a high-tech city or a local innovative system to develop[9].

Second, abundant availability of high-skilled labor fosters a tech cluster if one emerges, whereas highly localized spillovers lead to a smaller tech cluster but make it more likely to arise in equilibrium. By contrast, continual improvements in infrastructure and communication technology that lowers coordination costs may lead to the fragmentation of tech clusters as observed in the case of Silicon Valley.

Third, tech clusters are more likely to be sustainable in urban environments that do not have too large of a population because commuting may become too costly. This may explain why most successful tech clusters or science parks do not emerge in megacities. For example, Silicon Valley is over 30 miles south of San Francisco, the Cambridge Science Park in the U.K. more than 60 miles north of London, and Hsinchu Science-Based Industrial Park in Taiwan 50 plus miles away from Taipei.

Due to endogenous determination of the size of a high-tech city, our setting has the nature of an "open" city model: despite a given population of workers, the physical size of the urban space is endogenous. In this context, a full welfare analysis is not obvious. To gain insights, we undertake a "quasi-counterfactual" approach by considering an urban configuration in which activities are assumed to be evenly dispersed across locations. We find that a high-tech city hosts more intermediate firms and more researchers than a flat city. What is more, the final sector is more productive while wages and land rents are higher in a high-tech city. Last, despite paying higher rent and incurring higher commuting costs, workers are better-off in a high-tech city than in a flat city. All of this shows why high-tech cities have a lot of appeal.

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