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Spatial externalities and agglomeration in a competitive industry ☆

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ABSTRACT

We introduce spatial spillovers as an externality in the production function of competitive firms operating within a finite spatial domain under adjustment costs. Spillovers may attenuate with distance and the overall externality could contain positive and negative components with the overall effect being positive. We show that when the spatial externality is not internalized by firms, spatial agglomerations may emerge endogenously in a competitive equilibrium. The result does not require increasing returns at the private or the social level, increasing marginal productivity of private capital with respect to the externality, or location advantages. In fact agglomerations may emerge with decreasing returns to scale, declining marginal productivity of private capital with respect to the externality, and no location advantage. The result depends on the interactions between the structures of production technology and spatial effects as shown in the paper. No agglomerations emerge at the social optimum when spillovers are internalized and diminishing returns both from the private and the social point of view prevail. Numerical experiments with Cobb–Douglas and CES technologies and an isoelastic demand confirm our theoretical predictions.

1. Introduction

A central result in the investment theory of the firm (Scheinkman, 1978) states that in a perfect foresight competitive equilibrium where firms take the price function as given and face convex adjustment cost in net investment, each firm's capital stock converges to a unique steady state which is independent of initial conditions. When firms are identical, all firms will converge in the long run to the same stock of capital.

In this paper we examine whether in a perfect foresight equilibrium for a competitive industry operating in a finite spatial domain with spatial interactions among firms, identical firms will end up with the same capital stock in the long run, or whether agglomeration emerges. Spatial interactions among firms are expressed as a spatial externality which in general

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attenuates with distance. One way of interpreting spatial interactions is to consider them as knowledge spillover effects from one firm to another. Knowledge spillovers are regarded as a positive intra-industry Marshalian externality which is bounded in space, the main idea being that innovation and new productive knowledge flows more easily among agents which are located within the same area (e.g. Krugman, 1991; Feldman, 1999; Breschi and Lissoni, 2001). Thus proximity is important in characterizing spatial spillovers (Baldwin and Martin, 2004; Breinlich et al., 2013). We incorporate knowledge spillovers by interpreting the capital stock of each firm in a broad sense to include knowledge along with physical capital (e.g. Romer, 1986). Following Quah (2002) we assume that the effect of capital on each firm's output, at any given point in time, does not depend just on the accumulated stock by the firm up to this time, but on capital accumulated in nearby locations by other firms. Thus the spatial externality takes the form of a Romer (1986) externality where, by keeping all other factors in fixed supply, output is determined by own capital stock and by an appropriately defined aggregate of capital stocks of firms across the spatial domain. The capital stock aggregate is determined by a distance-response function[2] that measures the strength of the spatial spillover on the output of a firm in a certain location associated with the capital stock accumulated by a firm in another location.

A positive distance-response function that attenuates with distance can be interpreted as reflecting knowledge spillovers. A distance-response which is negative indicates a negative externality such as generalized congestion effects. Thus, by combining a distance-response function, centripetal and centrifugal responses can be introduced. These forces are localized in the sense that their strength – positive or negative – diminishes with distance.[3]

Our purpose is to study whether optimal investment policy by forward-looking competitive firms combined with localized spatial spillovers generated from accumulated investment induces endogenous agglomerations and spatial clustering of firms.

It is known that spatial clusters may appear with localized knowledge spillovers when there are increasing returns. In this case the increasing returns activity concentrates to one location (e.g. Grossman and Helpman, 1991). Actually increasing returns underlie the generation of centripetal forces that favor cumulative causation and thus spatial clustering (e.g. Nocco, 2005). In our model the production function of each firm exhibits diminishing marginal productivity with respect to own capital for any fixed value of the spatial externality. To put it differently, private returns to capital are diminishing. The production function is strictly concave with respect to own capital and the spatial externality. That is, there are diminishing returns with respect to the spatial externality, for fixed levels of own capital. However, increasing social returns, in the sense of Romer (1986), are possible.

Our main result indicates that when diminishing returns from both the private and the social point of view prevail, then endogenous agglomeration may emerge at a perfect foresight rational expectations competitive equilibrium (PF-RECE). This agglomeration result does not require increasing returns at the private or the social level, increasing marginal productivity of private capital with respect to the externality, or location advantages.[4] In fact agglomerations may emerge with decreasing returns to scale, declining marginal productivity of private capital with respect to the externality, and no location advantage. The result depends on the interactions between the structures of production technology and spatial effects. The emergence of agglomeration may lead to a long-run steady state for the competitive industry where the distribution of capital stocks and outputs across space is not uniform On the other hand, at a social optimum (SO) where a planner fully endogenizes spatial spillovers, agglomerations do not emerge and all firms converge to the same stock of capital irrespective of location. The possibility of a potential agglomeration at a PF-RECE is related to the incomplete internalization of the spatial externality by optimizing firms and the structures of the production technology and spatial interactions, while the “no agglomerations” result at the SO stems from the full internalization of the spatial externality by a social planner and the strict concavity of the production function.

Our contribution is twofold. First, we provide a conceptual framework that explains dynamic endogenous emergence of spatial clustering in a competitive industry with optimizing forward-looking agents that do not require increasing returns to scale. Our model includes only the spatial externality and not other features of economic geography models such as transport costs, product differentiation or forward/backward linkages. We believe that this is a reasonable trade-off for being able to study agglomeration emergence in a fully dynamic optimizing model. Second, we show how convexity arguments and spectral theory can be used to study PF-RECE problems and SO problems in infinite horizon spatiotemporal economies, by properly decomposing the spatial and the temporal behavior. We thus provide valuable insights regarding the endogenous emergence (or not) of optimal agglomerations at a PF-RECE and the SO of a competitive industry.

2. Spatial externalities and adjustment costs

We consider an industry consisting of a large number of small firms with each firm located at point x of a one-dimensional bounded spatial domain $\mathcal{X}=[-L,L]$.[5] We further assume that $\mathcal{X}$ is discretized, i.e., it is divided into N cells or

[2] See Papageorgiou and Smith (1983) for an early use of distance-response functions.

[3] This is consistent with Prager and Thisse's second law of geography that states that what happens close to us is more important than what happens far from us (Prager and Thisse, 2012).

[4] We assume that the spatial domain is a circle to avoid the creation of agglomeration by the boundary conditions at the edge of the domain.

[5] Most of our results can be extended to general domains of characteristics $\mathcal{X}\subset\mathbb{R}^d$, $d\geq 1$.