Physica A 494 (2018) 76–86

Contents lists available at ScienceDirect

Physica A

journal homepage: www.elsevier.com/locate/physa

Economic agglomerations and spatio-temporal cycles in a spatial growth model with capital transport cost

J.P. Juchem Neto [a,*], J.C.R. Claeyssen [b], S.S. Pôrto Júnior [c]

[a] *Universidade Federal do Pampa, Campus Alegrete, Alegrete, RS, Brazil*
[b] *Universidade Federal do Rio Grande do Sul, Instituto de Matemática e Estatística, Porto Alegre, RS, Brazil*
[c] *Universidade Federal do Rio Grande do Sul, Faculdade de Ciências Econômicas, Porto Alegre, RS, Brazil*

HIGHLIGHTS

- Capital transport cost is introduced in a spatial Solow–Swan economic model.
- It is carried out a stability analysis of the spatially homogeneous equilibrium.
- The equilibrium is unstable if transport cost is smaller than a critical value.
- Numerical simulations confirm the stability analysis results.
- The model can produce economic agglomerations and spatio-temporal cycles.

ARTICLE INFO

Article history:
Received 4 July 2017
Received in revised form 3 November 2017
Available online 8 December 2017

Keywords:
Spatial economic growth model
Reaction–diffusion–advection system
Stability analysis
Pattern formation

ABSTRACT

In this paper we introduce capital transport cost in a unidimensional spatial Solow–Swan model of economic growth with capital-induced labor migration, considered in an unbounded domain. Proceeding with a stability analysis, we show that there is a critical value for the capital transport cost where the dynamic behavior of the economy changes, provided that the intensity of capital-induced labor migration is strong enough. On the one hand, if the capital transport cost is higher than this critical value, the spatially homogeneous equilibrium of coexistence of the model is stable, and the economy converges to this spatially homogeneous state in the long run; on the other hand, if transport cost is lower than this critical value, the equilibrium is unstable, and the economy may develop different spatio-temporal dynamics, including the formation of stable economic agglomerations and spatio-temporal economic cycles, depending on the other parameters in the model. Finally, numerical simulations support the results of the stability analysis, and illustrate the spatio-temporal dynamics generated by the model, suggesting that the economy as a whole benefits from the formation of economic agglomerations and cycles, with a higher capital transport cost reducing this gain.

1. Introduction

An evident empirical fact is that population and economic activity tend to agglomerate in certain regions of a territory, that is, they are not homogeneously distributed across the geographic space. Examples of such agglomerations, in different spatial scales, are countries in a continent, cities in a country, and industrial or commercial districts in a city [1].

* Corresponding author.
E-mail address: plinio@unipampa.edu.br (J.P. Juchem Neto).

https://doi.org/10.1016/j.physa.2017.12.036
0378-4371/

A macroeconomic approach in modeling economic agglomeration and its spatio-temporal dynamics, in the literature of Regional Science, can be found in [2–4], where a very general class of models was proposed, described mathematically by nonlinear systems of reactive–diffusive partial differential equations. These seminal spatio-temporal models were originally inspired by physical models of a moving fluid, and of electric current flowing through a transmission line. More recently, several articles have proposed a series of spatial economic growth models. Camacho and Zou [5] proposed a spatial version of the standard neoclassical model for economic growth, the Solow–Swan model [6,7], considering a constant labor force and diffusive capital flow; Brito [8] extended this spatial Solow–Swan model in order to include an exogenous exponentially increasing labor force; Engbers [9] and Capasso et al. [10] considered a nonstandard convex–concave production function in the model presented in [5], showing that the introduction of an exogenous Malthusian labor force with spatially non-homogeneous growing rates could reproduce the empirical phenomenon called poverty traps [11]; Brito [12] showed that a spatial version of the Ramsey model (which considers an endogenous interest rate) could endogenously produce economic agglomerations; Camacho et al. [13] also analyzed a spatial Ramsey model; and Boucekkine et al. [14] dealt with a spatial AK model.

A common characteristic of these recent models is that they only consider a diffusive spatial motion for both labor force and capital – i.e., workers and capital diffuse to regions where they are scarcer – and they do not take into account any kind of transport costs — with the exceptions of [2–4] in the latter case. More recently, and also disregarding transport costs, the authors [15] have proposed a spatial Solow–Swan model considering a logistic growth for the labor force and, besides considering its diffusive motion, introduced capital-induced labor migration. This kind of labor migration is characterized by a migratory behavior where workers move from regions with lower capital density to regions with higher capital density. With such a modification, they showed that this model can generate endogenous economic agglomeration and cycles, provided that the intensity of this migration is greater than some critical value, and that the geographic size of the economy is large enough. In [16] this model is modified in order to consider Caputo fractional time derivatives.

New Economic Geography (NEG), a field of Economics, is a more recent area of study to consider spatial structure in economic models. It began with Krugman [17] as an extension of his New Trade Theory [18], and was developed in great detail in [19–21,1], among others. The models proposed by NEG are different from those considered by Regional Science (RS) as cited above. While RS models are macroeconomic in essence – that is, they describe the evolution of aggregated economic variables, such as aggregated capital, labor, consumption, investment –, NEG models are microeconomic, i.e., they consider a market structure and individual economic agents that maximize some variables of interest, such profits (firms) and utility (consumers). The standard NEG model is called core–periphery model (see, for example, chapter 9 of [20]), and one of its main implications is that the combination of a lower transport cost, a mobile labor force, and the presence of increasing returns to scale can result in spatial agglomeration of economic activity.

In fact, transport cost is a key factor in explaining economic agglomerations. If it is too high, interregional shipments of goods tend to be absent, so each location has to produce everything: in this case the economic activity would be equally distributed across space. On the other hand, if transport cost decreases, interregional shipments of goods become viable, and spatial agglomeration of the economic activity is possible. This phenomenon was observed during the process of European industrialization (1800–1913), when a substantial decrease in transport costs was accompanied by the formation of economic agglomerations, and an increase in the overall European GDP *per capita* [22,23].

Given the importance of transport cost in economic geography, in this work we introduce physical capital transport cost in the model proposed by [15], following the macroeconomic Regional Science approach. Such a transport cost will be defined as a fraction, $\rho_K \in [0, 1)$, of the physical capital flow through a given location. This is similar to Samuelson's iceberg transport cost usually considered in the NGE literature [24,17], which states that a fraction of the good being transported melts away in transit [1]. One of the great advantages of this formalism is that it avoids the complications of modeling a separated transport sector. Since the Solow–Swan model uses a one-sector production technology, capital is considered in physical terms [25], then its transport cost is considered to "include all impediments caused by distance such as shipping costs per se, tariff and non-tariff barriers to trade, different product standards, difficulty of communication, and cultural differences"[20]. An account of the economic and geographic determinants of transport costs, and how they can be measured, can be found in [22].

The additional assumptions of the model, following the RS literature, are: the spatial structure of the economy is homogeneous and unidimensional, given by all real line [5,8]; capital accumulation follows a Cobb–Douglas production function and depreciates at a constant rate, a particular case usually assumed in the traditional Solow–Swan model [26,25]; labor grows following a logistic law, which implies an asymptotically bounded labor force [27–29]; both capital and labor diffuse to regions where they are scarcer, which models the neoclassical principle of diminishing marginal returns [5]; and capital-induced labor migration is present [15].

Mathematically, the model proposed here is described by a system of two reaction–diffusion–advection partial differential equations with given initial conditions and homogeneous Neumann boundary conditions at infinity. In order to analyze the model, we proceed with a stability analysis of the spatially homogeneous coexistence equilibrium points (or steady-states) of the system, following [30–32], and derive a critical value for the capital transport cost rate, which determines a change in the spatio-temporal dynamics of the model. Besides, numerical simulations using an explicit finite-difference method [33] are carried out to confirm the stability analysis results, and illustrate the types of spatio-temporal dynamics developed by the model.

This paper is organized as follows. In Section 2, we present the proposed spatial Solow–Swan model with capital transport cost; in Section 3, we present the results of the stability analysis; in Section 4, we show some numerical simulations illustrating the spatio-temporal dynamics of the model; and in the last section we summarize our results.