Multiple equilibria in spatial economic transport interaction models

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Abstract

It is widely accepted that there is a two-way relationship between the spatial economic and the transport systems. The former affects transport, conditioning travel demand patterns. Conversely, the latter plays an important role in the spatial organization and the economy of an area (national, regional, urban), affecting activity location, production levels and trade patterns. The above mutual interactions are part of what we define as a Spatial Economic Transport Interaction (SETI) process.

Given that a SETI process concerns a strategic temporal scale, it may be related to two different spatial scales. At the national scale, attention is devoted to estimating the competitiveness of the different activities, defining production levels and location conveniences. As the economic component is dominant over the land use one, we define a National Economy Transport Interaction (NETI) process. At the urban scale, the focus is on effects of transport mobility on the spatial organization of an area (e.g. location of residential, service and production activities), with subsequent land use. As the spatial component (land use) is dominant over the economic one, we define a Land Use Transport Interaction (LUTI) process.

The paper presents the general formulation of a SETI model, which has two interacting modelling components: a transport model and a spatial economic model, relying on Multi-Regional-Input-Output (MRIO) framework. The SETI model simulates the transport and the spatial economic systems by means of market mechanisms, where demand and supply interact, providing simultaneously prices and quantities. In the transport model, users behaviour is simulated through demand models which estimate emission, mode, path choices. These choices are driven by utilities, which include transport costs provided by a congested network model. Demand-supply interaction is simulated through an assignment model, which estimates transport costs (prices) and flows (quantities) on network. If the available supply (transport facilities and services) is limited, congestion costs arise bringing the transport system to an equilibrium condition. The activity model is composed by a generation model which estimates demand (consumption) levels of activities and a location model which simulates where supply (production) is located across zones. Location choices are driven by utilities, composed by supply prices plus transport costs. Subsequently demand-supply interaction, supply prices and production quantities are estimated in each zone. Due to supply constrains, a rent could be generated bringing the spatial economic system to an equilibrium condition.

Both the transport and spatial economic models provide the mechanisms to bring the demand in line with the available supply, reaching a condition in which mutual interactions between spatial economic and transport systems achieve a balance (equilibrium condition).

The paper investigates the above mechanisms, describing several circular dependencies present in the SETI modelling framework, with ensure to reach an equilibrium condition inside and between the two interacting systems.

The transport model contains a circular dependence among transport demand, link flows and link costs, which is formalized through the assignment model. The generation-location model has a circular dependence involving trade coefficients, selling prices and acquisition costs, and another one which
arises when production capacity is limited. The generation model contains a circular dependence among selling prices and technical coefficients. Finally, the transport and the spatial economic models are mutually interacting: transport model provides transport utilities to location model; spatial economic model provides trade flows to demand model.

According to the authors knowledge, only the first two circular dependencies have been formalized and solved as a fixed point problem. The first one was object of extensive research starting from the enunciations of Wardrop's principles (Wardrop, 1952). Among the numerous studies, we recall the works of Dafermos (1980), Daganzo (1983) and Cantarella (1997). The second one was firstly implemented by de la Barra (1989), who introduced the explicit dependence of trade coefficients on selling prices. Zhao and Kochelman (2004) formalized it as a fixed point problem and defined the solution existence and uniqueness conditions. The other ones were implemented in a number of operational SETI models (de la Barra, 1989; Echenique, 2004), but no existence and uniqueness is demonstrated.

REFERENCES