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Moving beyond the iceberg model: The role of trade relations in endogenizing transportation costs in computable general equilibrium models

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ABSTRACT

Modeling trade and transportation costs is an essential part of multiregional or spatial computable general equilibrium models where interregional trade plays an important rolein shaping economic activity. The majority of such models use the iceberg trade cost approach where part of the produced output (representing the material costs of transportation) is assumed to melt away during transportation. There are a few models which employ a more refined approach with an explicit transportation sector providing transportation services which are then used to ship goods between locations. In this paper we show that this approach, although much more convenient than the iceberg approach, still lacks full usability due to the fact that markets, hence prices are defined at the regional level and as a result, transportation costs can not be endogenous at the trade relation level. Moreover, under regional level market clearing the iceberg and the more detailed approach are equivalent. We propose to refine the definition of market equilibrium and move it to the trade relation level. Using this approach we can gain full advantage of the explicit transport sector in the model with respect to trade cost evolution. We show through simulations that refining the way trade costs are modelled indeed gains new insights, and that moving the market definition to the trade relational level leads to qualitative changes in the effect of labor supply shocks on main model variables. The paper also presents a method to estimate a SAM by reallocating data from standard industries to a transportation sector which is then consistent with the model setup. This SAM can be used to calibrate the refined model with a detailed transportation sector.

1. Introduction

Spatial economic models raise the challenge to incorporate trade and transportation costs into economic models as an inherent part of economic activity, regional development and resource allocation. In recent decades a wave of spatial general equilibrium models has attempted to handle geographical diversity in economic models. This literature has gained a lot from the revival of the emphasis on geography in economics (Krugman, 1991; Fujita et al., 1999), by redirecting attention to externalities and spatial concentration. On the other hand, spatial concentration may reallocate demand on transportation routes which is then reflected by changes in the price of transportation services and the costs of using specific routes.

In addition to the role of trade relations emphasized by the former studies, there is another vein of literature which builds on the tradition of modelling location choices by firms (Hotelling, 1929) and emphasize that firms may differentiate their activities with respect to the destination where they supply their output. Some studies focus on differentiation of quantities (Greenhut and Greenhut, 1975; Anderson and Neven, 1991; Hamilton et al., 1989; Shimizu, 2002), whereas others emphasize differentiation in prices (Lederer and Hurter, 1986; MacLeod et al., 1988). There is more recent evidence that firms indeed employ spatial price discrimination, i.e. they treat supplies to different locations differently and they are willing to charge higher prices for more remote destinations (see e.g. Greenhut, 1981; Manova and Zhang, 2012; Martin, 2012). This means that once we try to account for interregional trade, not only purchaser (CIF) prices differ due to the different transportation costs between locations, but also the mill (FOB) prices are different due to price discrimination. As a result of these findings, one feels that trade relations are not only important from the viewpoint of transportation costs and agglomeration, but also for the supply and pricing decisions of firms.

All these findings drive us to consider trade at the level of trade relations, i.e. origin-destination pairs. On this level, the differentiating

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role of transportation costs to and from more concentrated regions can be taken into account and also the direct interplay between supply and demand on these trade relations can be taken into account. Accounting for these effects is extremely important in long run studies, where the trade infrastructure and its cost structure resulting from over- or under-utilization can not be treated as exogenous.

Once we look at the modeling strategy of trade and transportation costs in spatial equilibrium models, we see a picture which only partly covers these challenges. In the previous decades many attempts have been recorded to refine the mechanisms of trade and transportation in spatial models. Trade theory heavily builds on the Armingtonian approach which treats commodities from different countries or regions as imperfect substitutes (Armington, 1969). In contrast to early interregional input-output models, which inherited fixed coefficients of trade between regions from standard input-output analysis, this approach allows agents to choose between commodities from different regions on the basis of their price differentials.

On the other hand, interregional price differentials are driven by transportation costs in addition to the different producer prices of commodities from different regions. Thus, capturing these transportation costs in a meaningful way is important in modeling spatial economic interactions. The literature in this field has developed basically two approaches in this respect.[1] First, the iceberg model of Samuelson (1954) is used by many applied spatial economic models, such as the CGEurope (Bröcker et al., 2002, 2004), the GMR (Varga et al., 2013, 2015), the RAEM (Tavasszy et al., 2002), or the RHOMOLO (Brandsma et al., 2013, 2015) models. In this approach the cost of transportation is modelled as a given fraction of the transported commodity “melting away” during the transportation process. This modelling principle allows for taking into account geographical distance and other trade barriers as a determinant of CIF prices on a region-region basis. However, there are several shortcomings known of this type of models, as emphasized by Oosterhaven and Knapp (2003) and Tavasszy et al. (2002). First, under the iceberg assumption one implicitly assumes that the transportation service is produced by the same technology as the transported product itself and second, it mixes up volume and price effects because only an exogenous trade-markup is employed between the FOB and CIF prices. In the paper we are going to refer to this solution to model transportation costs as the ‘iceberg approach’.

The other approach separates the transportation sector and lets it to produce some transportation service which is then used to transport commodities between regions. Users eventually buy a composite good which contains the “raw” commodities from different origin regions and the corresponding transportation services. Transportation services are merged with raw commodities in a fixed coefficient technology. The PINGO (Vold and Jean-Hansen, 2007; Ivanova, 2003) and SUSTRUS (Heyndricks et al., 2011) models employ this approach in an attempt to carefully model interregional economic interactions, but similar solutions can be found in Latorre et al. (2009) or Ueda et al. (2005). This approach takes into account that transportation markups may change in an endogenous manner as a response to cost driven changes and also a demand-supply interaction can be modelled on the market for transportation services. On the other hand, a main shortcoming of these models is that the market for transportation services is handled at an aggregate level. In the PINGO model trade service coefficients are independent of the region pairs, thus it is not possible to handle distance with them. In the SUSTRUS model there is an aggregate transportation sector also, and only an aggregate price for transportation service is endogenous, region-region transportation cost are still determined by fixed coefficients. In the paper we are going to refer to this solution to model transportation costs as the ‘composite approach’.

This paper contributes to the existing literature in two ways. First, we show that the iceberg approach to model transportation costs is equivalent to the composite approach (despite of the seemingly more detailed construction of the latter) if the equilibrium conditions are defined at the regional level, attaching one producer price for one region. Although the composite approach to model transportation costs seems more detailed by adding an explicit transportation service, it yields quantitatively the same results as the iceberg approach. Second, we propose a model setting in which market clearing is defined at the relational level (i.e. for every origin-destination pair), which allows for two things: (i) combined these relational market clearing conditions with the composite transportation cost approach we get a model setting which is qualitatively different from the iceberg model, with truly endogenous transportation markups which reflect changes in supply and demand on specific trade relations; (ii) by explicitly taking into account firms’ supply decisions on the specific destinations they are willing to sell at, it incorporates insights from the literature on spatial price discrimination and the role of destinations in firms supply decisions. In relation to this second contribution, we also present a method which estimates a Social Accounting Matrix consistent with the decentralized (relational) model setting on the basis of generally available data. This estimated SAM can easily be used to calibrate the decentralized model setting.

The paper is structured as follows. In the second section we set out a common framework in which the iceberg and composite approaches can be compared. This is a partial equilibrium model, focusing on interregional trade, transportation costs and market equilibrium. In the third section we use this framework (i) to prove that the iceberg and the composite approaches are equivalent if the market equilibrium is defined on the regional level, (ii) to show that moving the market clearing condition down to the relational level yields a departure from the iceberg approach and (iii) to show that the level at which transportation service providers differentiate among destinations is crucial in the level of endogeneity of transportation costs in the model. In the four section we extend the partial model to a general equilibrium setting and illustrate with the help of this model our points in the previous settings by providing an explanation how and why the mechanisms differ between the regional and the relational market clearing conditions. The fifth section then proposes an estimation method of the model-consistent SAM which allows for the calibration of the decentralized model. Finally, some concluding remarks close the paper.

2. A common framework for the iceberg and composite approaches

In this section we present a partial equilibrium model where the most important relationships of the two approaches for modeling trade costs are expressed. A fully specified model is presented in Appendix A. In order to keep the discussion tractable, only two sectors are differentiated: one producing the transportation services and one producing all other commodities or services – the latter is going to be labelled as ‘raw’ commodities, or simply as industries in what follows.

Let the output of region r be X_r. The specific technology through which this output is produced is not relevant in our discussion, but one example is given in Appendix A for a fully specified model. The price index of the output of this region is going to be PX_r, which is interpreted as the FOB price of the commodities produced in different regions. Separated from the production of these raw commodities, the output of the transportation sector residing in region r is denoted by XT_r, which has also a specific production technology not specified here. For the time being, we assume a single, aggregate market for transportation services, so the transportation sectors’ output is sold at the same price everywhere which is labelled by PQT.

[1] We should note that some models do not consider transportation costs, or price differentials between CIF and FOB prices. In these models trade is assumed to be costless (see e.g. Kim and Kim, 2002; Böhringer and Welsch, 2004; Roeger et al., 2008).