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Trade relations and endogenous transportation costs in computable general equilibrium models.

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Abstract

Modeling transportation and trade costs is an essential part of regional CGE and SCGE models where interregional trade plays an important role. 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 transport sector providing transport 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, transport costs can not be endogenous at the trade relation level. 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 way to calibrate such a refined model by reallocating data on standard industries to a transport sector which is the consistent with the model setup.

Keywords: CGE, SCGE, interregional trade, transportation cost, simulation, iceberg trade cost

JEL: C63 C68 R13 R15 R40

1. Introduction

Spatial economic models raise the challenge to incorporate trade and trade costs into economic models as an inherent part of economic activity, regional development and resource allocation. 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 transport costs in addition to the different producer prices of commodities from different regions. Thus, capturing these transport 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.

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.

The other approach separates the transport 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 transport services. Transport 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. This approach takes into account that transport 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 transport 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 transport sector also, and only an aggregate price for transport service is endogenous, region-region transport cost are still determined by fixed coefficients.

In this paper we ask the question whether it is possible to utilize the advantages of the refined transportation cost approach without further disaggregating the models and establishing market clearing on the relational level, i.e. for each region-region pair. In the attempt to answer this question we propose a further refined way of handling transportation costs and the transportation market which allows for a truly endogenous determination of transportation costs at the region-region relations. We show that the shortcomings of the previously mentioned approaches with explicit transport sectors come from the generally employed technique in regional models: markets for commodities are placed at the regional level: the total supply of a region must equal the total demand for the commodities produced in that region. Using this approach, however, it is not possible to handle transport costs which are endogenous on every single region-region pair. In contrast, we propose establishing markets at the transportation relation levels, i.e. for each region-region pair. This way we have a separate price for each region-region pair enabling this framework to accommodate endogenous transport costs with trade coefficients on each region-region pair. The simulation results presented in this paper show that in order to allow for really endogenous trade costs one needs to disaggregate the models to the relational level.

The paper is structured as follows. In the second section we set out the problem of endougenous trade costs in detail and describe our approach to solve this problem together with a possible typology of the approaches used in handling trade costs in SCGE models. The third section then sets out a simplified model under the refined approach and describes its difference form the alternative formulations. The fourth section presents some simulation results with regards to the effect of shocks under different transport cost specifications. Given the higher complexity in the refined approach, it requires more data for calibration as simpler specifications. In the fifth section we show how the model can be calibrated using SAM-based techniques. Finally, some concluding remarks close the paper.

2. What it makes endogenizing trade costs?

2.1. Setting out the problem of partly endogenous trade costs

As discussed in the Introduction, the literature uses essentially three ways to handle interregional (or international) trade costs in CGE or SCGE models. The first, less relevant way is disregarding trade costs. This means that some models do not take into consideration the fact that there is a cost to transport goods from one place to another. Of course, this solution has its merits by being easy to handle and requiring a conveniently small amount of data for calibration. On the other hand, although these models handle the role of price in interregional trade by using Armington composites, the price which is observed by users and on which demand decisions are established are determined solely by the cost of production in the origin region where the goods are produced. Putting this in a different angle, the transport markup is zero in these models which means that the user price (CIF price) of a good in the destination region is the same as the producer price (FOB) price of the good in the origin region.

The second, widely used method around trade costs is to apply the iceberg approach originating from Samuelson (1954). This method assumes that $(1 + \tau)$ unit of the good is required to be sent from the origin in order for 1 unit to arrive at the destination. Here, τ is the transportation markup, so the difference between FOB and CIF prices is τ as expressed in percentage of the FOB price. On the other hand, these models treat τ as a given parameter, so although the price markup is non-zero in these models, it is exogenous, it can not change in response to the endogenous variables, e.g. the demand for different goods, production costs and reshaping of the spatial structure of the economy. However, τ can be specified separately for all region-pairs, so (although in an exogenous way), this approach is able to handle the spatial structure of the economy. It is also important to note that this approach implicitly assumes that the production technology of transportation services is the same as that of the transported goods which is problematic in a multisector environment. In addition, one must explicitly take into account that some quantities 'disappear' during transportation which is not a fully satisfying solution.

In response to the limitations of the iceberg approach, the third solution builds an explicit transportation sector into the models. This sector then supplies transportation services which are used to transport the goods from the origin to the destination. The general solution used by these kinds of models is to put a new, special level of nesting on the economy's production structure. This level of nesting takes 'raw' products produced by a standard nested production technology and combines it with the transportation services, also produced according to the standard nested production technology. In the iceberg approach, users in the destination region consume physically the same goods as produced in the origin destination. In this alternative approach users consume a composite good which contains the raw product and the transportation services. This composite good is assumed to be produced under a Leontief technology, so in order to have one unit of the consumer composite, one must have a fixed proportion of raw goods and transportation services inside. This method provides at least two advantages compared to the iceberg approach. First, there is an explicit production side behind transportation services, which means that the transportation markup does not disappear, but it is linked to some value added and incomes generated in the economy. Second, the price of the consumer good (the user or CIF price) evolves in response to changes in the price of the raw product (producer or FOB price) and the price of the transportation services, both endogenous in the model. So although the unit real transportation cost is fixed in the sense that the coefficient with which transportation services and raw products are combined does not change, the price composition is exposed to changes, so transport costs can change endogenously with other variables of the model. In this approach, which is going to be referred to as the composite trade cost approach throughout this paper, the transportation markup (the difference between FOB and CIF prices) exists and is endogenous.

The composite trade cost approach seems to provide a satisfying solution to the problems of the iceberg trade cost and a realistic description of the real economies with respect to the determination of the trade costs. However, the models which apply this solution generally use a *regional* market definition, or in other terms the level where these models establish market equilibrium does not allow for a full utilization of the possibilities embedded in the composite approach. Putting it differently, the standard way of establishing market equilibrium is to impose the equity of supply of the producer (origin) region) with the demand of all destination regions with respect to goods from the origin region. Formally, if X_r is the amount of goods produced in region r, whereas the demand of region q for goods produced in region r is $D_{r,q}$ then this market definition requires the equilibrium condition as $X_r = \sum_q D_{r,q}$. This is what we call the 'regional market' approach: market equilibrium is defined at the regional level. In another angle, one can look at this solution how prices are determined. In general, one market clearing condition sets one price. If the market is defined at the regional level, there is going to be one endogenous price of the produced goods by region. If the market for goods was defined at the national level, there would be only one price of the good.

With respect to the transportation costs, this means that although there is a difference between producer and user prices, this can be endogenous only at the regional level. The price of the goods is set for each region endogenously – this is then composed of the price of the raw product and the transportation services, but due to the regional prices, the latter can also be determined only on the regional level. This means that transportation costs are endogenous up to the regional scale and not to the transport relational scale. So, one of the strengths of the composite trade cost approach is half-legged under the regional market solution. This means that although the composite trade cost approach is able to accommodate endogenous trade costs, if markets are established on the regional level, i.e. there is one endogenous price per region, trade costs will be endogenous also at the regional level. In other words, the transportation markup is endogenous, but we will have an endogenous transportation markup for all regions separately, although the price markup should be determined at the origin-destination pair level, so for all region-pairs. This approach can be justified on the basis of a threshold-effect where there is a cost to moving goods in general and the additional cost of moving the goods specifically between the origin and destination is less relevant. However, there is clearly something missing from a refined picture of trade costs in these models. Our argument here is that a model can not exhaust the refined view of composite trade costs unless it redefines also the way how markets are defined. In the following point we suggest a possible solution for this problem.

2.2. A possible solution: the relational market approach

As set out in the previous subsection, although the composite trade cost approach seems to be a satisfying endpoint of handling transportation costs in CGE and SCGE models, the environment in which it is applied, namely the regional market definition does not allows for a full utilization of its merits. However, it follows clearly from the discussion above that refining the market definition yields a model in which trade costs can be fully endogenous in the sense that a different endogenous trade cost applies for all origin-destination pairs.

Our proposal for refining the trade cost structure and making advantage of the detailed picture of transportation under the composite trade cost approach is the 'relational market' approach. Under relational market approach we mean that market equilibrium is established at the level of region-region pairs instead of the regions. Formally this means that the X_r production level of region r must be split between different destinations. If we denote by $Q_{r,q}$ the amount of goods produced in region r and supplied to users in region q, the relational market approach establishes market equilibrium as $Q_{r,q} = D_{r,q}$, where $D_{r,q}$ is the demand of region q for goods produced in region r. Under this approach equilibrium sets a price for goods at the level of each region-region pair (transport relation, hence the name of the approach). As a result, this solution allows for an endogenous transport cost determination for each region-region (origin-destination) pair separately taking into account relation-specific determining forces: the production costs of the transportation services at different location, the demand and supply of transportation services for different transportation relations, etc.

In addition to the standard regional market approach, the relational market approach requires that producers make an explicit decision on where to supply the goods. Under the regional market approach producers produce the goods and let the users buy them from different destinations. Under the relational market approach producers decide where to supply the goods, depending on the price structure. This can easily be fit in the logic of CGE models where it is a typical solution to use constant elasticity of transformation functions to split domestic production between domestic supply and exports. This solution is brought down to the regional level in our relational approach and the producers dependence on prices in the decision of supplying to different destinations makes it possible to establish equilibrium prices at the relational level, i.e. for each origin-destination pair.

Our proposed refinement of the modeling strategy fits in a reasonable direction for disaggregating CGE models. At the top level one may refer to non-regional or a-spatial, country-level CGE models as the starting point. In these models market equilibrium is established at the national level, that is, all produced goods, regardless of the point of production, goes to the national good market (or good markets in a multisector sense). At this market all users are present with their demand regardless of the point of use. As a result, there is one national price level which is determined by market equilibrium. Regional or spatial models can be referred as a step towards a reasonable disaggregation of economic activity in space: markets are established at the regional level, with one price per region. This setting is able to capture spatial and regional disparities, trade flows and so on which is impossible in the national approach. Our refined relational approach is another step in the direction of spatial disaggregation where economic agents (which are the regions in these settings) engage in trade in a more direct way. In contrast to the national level markets, at the other extreme of the scale we may find a model where agents are much more disaggregated (in principle we may end up with an individual/firm level detail) and they get into economic interaction directly. Of course, although they yield a refined picture of economic activity, these disaggregation come with more complex model structures and heavier data requirements.

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3. A stylized model with relational markets and explicit transport sector

In this section we provide a brief description of a baseline model where we focus on the composite trade cost and the relational market approaches. All other parts of the model are simplified. We assume only two sectors, one which contains all standard industries while the other is the transportation sector. As the transportation sector plays a distinguished role in this model, it has separate notation and not merged into the standard indexing. However, the model can be conveniently extended for a multisector environment. This model setting focuses on the production side of the economy, the demand side is very simple, containing only consumption demand in addition to the intermediate demand of the two sectors. The production side is modelled as follows. Labor and capital, in each region, produces a composite production factor or value added according to a CES technology. This composite factor is then used in combination with a composite intermediate good coming from different regions. Intermediate goods from different regions are merged according to a CES technology (Armington composites) while the composite intermediate and the composite factor is combined with a Leontief technology (fixed coefficients). The combination of composite intermediates and composite factors yield the regional output. Regional output is then split between supplies to different regions according to a CET technology. This is the point where transportation comes into the picture.

The transportation sector is treated separately from other industries. However, the basic structure is the same. The transportation sector is defined separately for each region, it uses labor and capital from that region to produce value added (composite factor) and this is combined with composite intermediates (form other regions). The regional output (or activity) of the transportation sector is the combined with industry output in the following way. Industry output in a region is split between supplies to different regions (according to a CET function). Thus industry output is allocated into region-region relations. The services (output or activity) of the transportation sector are also allocated between region-region relations using a CET function. On the other hand, industry outputs and transportation services are merged with a Leontief technology using the assumption that transporting a given amount of goods from one region to the other requires a fixed amount of transportation service. This way, a composite good is attached to each region-region relation combining raw product (produced by industries) and transportation services (produced by the transportation sector). This composite good is then used for final consumption (in this model we have only consumption as final demand) and intermediate use by the industries.

Goods market equilibrium is defined at the region-region relation level. In addition to this, there must be equilibrium in the transportation sector, so the transportation services provided by the regional transportation sectors must equal the demand generated by the transfer of industry outputs between regions.

Figure 1 below shows the schematic production structure of the model. We also show the types of aggregators used in each step and the corresponding price variables.

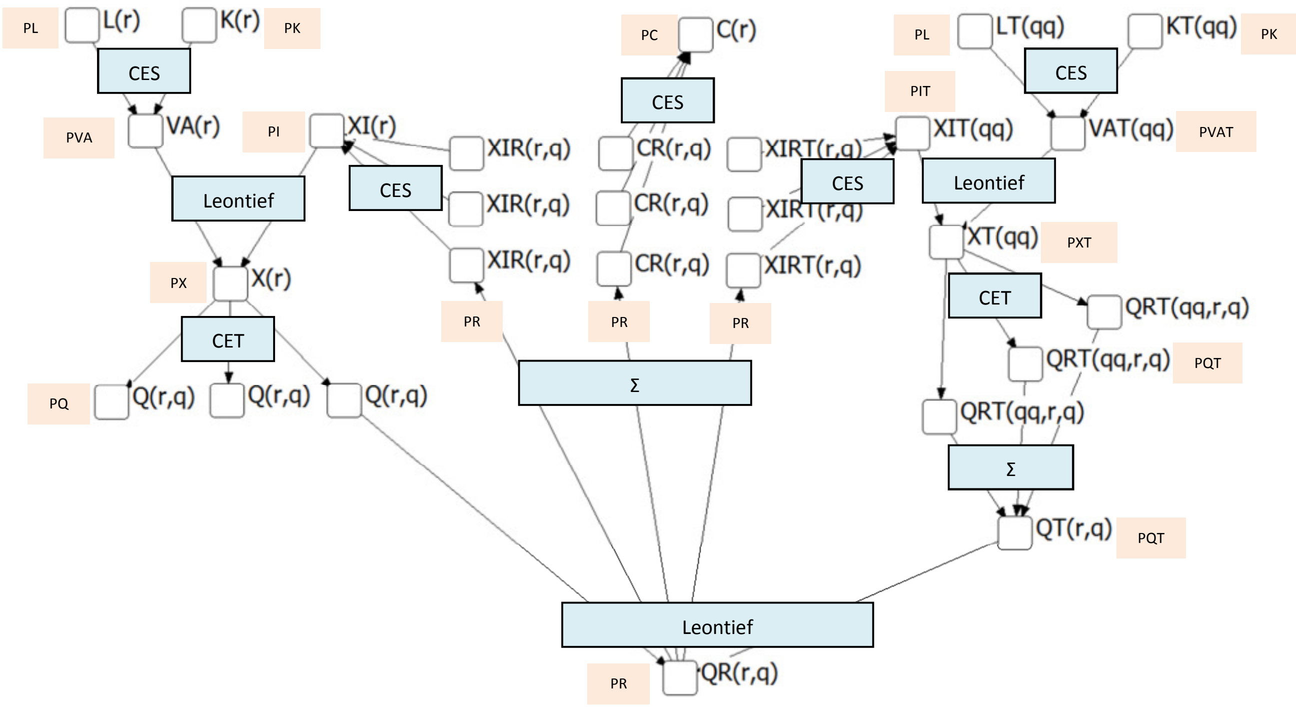


Figure 1 – The schematic production structure of the baseline model

In what follows we provide the formal description of the model. Throughout the description below we use the following notation. Upper case letters are used to denote endogenous variables and lower case letters for parameters. The indices r and q are used to refer to regions, with typically r denoting the origin and q denoting the destination region. Within the equation numbering we use the brackets to denote the dimension of the equations.

3.1. The production structure

The first step of the production combines labor and capital (both specific to the regions) into a composite production factor or value added:

$$VA_r = d_r^{VA} \cdot \left[b_r^L \cdot (L_r)^{\rho_r^{VA}} + b_r^K \cdot (K_r)^{\rho_r^{VA}} \right]^{\frac{1}{\rho_r^{VA}}}$$

where VA_r is the composite factor, L_r is the labor use and K_r is the capital use. b_r^L and b_r^K are the share parameters of factors d_r^{VA} is the TFP while ρ_r^{VA} is the substitution parameter. From this production function, profit maximization yields the following demand functions for labor and capital:

$$L_r = \left(\frac{PVA_r}{PL_r} \right)^{\sigma_r^{VA}} \cdot (d_r^{VA})^{\sigma_r^{VA}-1} \cdot (b_r^L)^{\sigma_r^{VA}} \cdot VA_r$$

(EQ1 [r])

$$K_r = \left(\frac{PVA_r}{PK_r}\right)^{\sigma_r^{VA}} \cdot (d_r^{VA})^{\sigma_r^{VA}-1} \cdot (b_r^K)^{\sigma_r^{VA}} \cdot VA_r$$

(EQ2 [r])

where PVA_r is the price index of the composite factor, PL_r and PK_r is the price of the labor and capital respectively σ_r^{VA} is the elasticity of substitution which is linked to the substitution parameter: $\rho_r^{VA} = (\sigma_r^{VA} - 1)/\sigma_r^{VA}$. The price index of the value added is defined by the following equation:

$$PVA_r \cdot VA_r = PL_r \cdot L_r + PK_r \cdot K_r$$

(EQ3 [r])

The composite factor is merged with intermediates using a Leontief technology. At the first level, we use a composite intermediate combining the intermediates from different regions (and possibly of different industries if we had multiple industries):

$$X_r = min\left(\frac{1}{v_r^{VA}} \cdot VA_r, \frac{1}{v_r^{XI}} \cdot XI_r\right)$$

where X_r is the output of the regional industry and XI_r is the use of composite intermediates. v_r^{VA} and v_r^{XI} are the coefficients defining the requirement of composite factors and composite intermediates in order to produce one unit of output. The demand functions for composites factors and intermediates are as follows:

$$VA_r = v_r^{VA} \cdot X_r$$

(EQ4 [r])

$$XI_r = v_r^{XI} \cdot X_r$$

(EQ5 [r])

The price index of the regional output is defined by the following equation:

$$PX_r \cdot X_r = PVA_r \cdot VA_r + PI_r \cdot XI_r$$

(EQ6 [r])

where PI_r is the price index of the composite intermediate good (to be defined later).

Once the output is produced, we assume a CET technology to split the output between supplies to each region:

$$X_r = d_r^X \cdot \left[\sum\nolimits_q b_{r,q}^Q \cdot \left(Q_{r,q}\right)^{\rho_r^X}\right]^{\frac{1}{\rho_r^X}}$$

where $Q_{r,q}$ is the industry output produced in region r and shipped to region q, $b_{r,q}^{Q}$ are the respective share parameters, d_r^X is a shift parameter and ρ_r^X is a transformation parameter. From this CET function the following supply functions can be derived:

$$Q_{r,q} = \left(\frac{PQ_{r,q}}{PX_r}\right)^{\sigma_r^X} \cdot (d_r^X)^{-\sigma_r^X - 1} \cdot \left(b_{r,q}^{Q}\right)^{-\sigma_r^X} \cdot X_r$$

(EQ7 [r])

where $PQ_{r,q}$ is the FOB price of a good shipped from region r to region q and σ_r^X is the elasticity of transformation, determined by the transformation parameter: $\sigma_r^X = 1/(\rho_r^X - 1)$. The zero profit condition of the production requires that the value of production in a region be equal to the sum of (FOB) value of the products sold in different industries:

$$PX_r \cdot X_r = \sum\nolimits_q PQ_{r,q} \cdot Q_{r,q}$$

(EQ8 [r])

The structure of the transportation sector is the same as that of industries. In the first step, labor and capital is used to produce a composite production factor using a CES technology:

$$VAT_r = d_r^{VAT} \cdot \left[b_r^{LT} \cdot (LT_r)^{\rho_r^{VAT}} + b_r^{KT} \cdot (KT_r)^{\rho_r^{VAT}}\right]^{\frac{1}{\rho_r^{VAT}}}$$

where VAT_r is the composite factor of the transportation sector, LT_r and KT_r are the labor and capital use in the sector. The interpretation of d_r^{VAT}, b_r^{LT}, b_r^{KT} and ρ_r^{VAT} is analogous to the parameters in industrial production. The previous production function gives rise to the following factor demand functions:

$$LT_r = \left(\frac{PVAT_r}{PL_r}\right)^{\sigma_r^{VAT}} \cdot (d_r^{VAT})^{\sigma_r^{VAT} - 1} \cdot (b_r^{LT})^{\sigma_r^{VAT}} \cdot VAT_r$$

(EQ9 [r])

$$KT_r = \left(\frac{PVAT_r}{PK_r}\right)^{\sigma_r^{VAT}} \cdot (d_r^{VAT})^{\sigma_r^{VAT} - 1} \cdot (b_r^{KT})^{\sigma_r^{VAT}} \cdot VAT_r$$

(EQ10 [r])

where $PVAT_r$ is the price index of the value added in the transportation sector, σ_r^{VAT} is the elasticity of substitution which is linked to the substitution parameter: $\rho_r^{VAT} = (\sigma_r^{VAT} - 1)/\sigma_r^{VAT}$. The price index of the value added is defined by the following equation:

$$PVAT_r \cdot VAT_r = PL_r \cdot LT_r + PK_r \cdot KT_r$$

(EQ11 [r])

Note, that there is an integrated regional labor market, so industries and the transportation sector hire labor from the same pool. At the regional level, the activity of the transportation sector is a function of composite intermediate use and composite production factor use, according to a Leontief technology:

$$XT_r = min\left(\frac{1}{v_r^{VAT}} \cdot VAT_r, \frac{1}{v_r^{XIT}} \cdot XIT_r\right)$$

where XT_r is the activity level (output) of the transportation sector and XIT_r is the composite intermediate consumption. The interpretation of the parameters v_r^{VAT} and v_r^{XIT} is analogous to those of the industrial production. The demand functions for composites factors and intermediates are as follows:

$$VAT_r = v_r^{VAT} \cdot XT_r$$

(EQ12 [r])

$$XIT_r = v_r^{XIT} \cdot XT_r$$

(EQ13 [r])

The price index of the regional transportation activity is defined by the following equation:

$$PXT_r \cdot XT_r = PVAT_r \cdot VAT_r + PIT_r \cdot XIT_r$$

(EQ14 [r])

where PIT_r is the price index of the composite intermediate good (to be defined later). The total activity of the transport sector in a given region can be split between transportation services among any two region pairs. Using qq as an index for regions, we can write the following CET function:

$$XT_r = d_r^{XT} \cdot \left[\sum_q \sum_{qq} b_{r,q,qq}^{QRT} \cdot \left(QRT_{r,q,qq}\right)^{\rho_r^{XT}}\right]^{\frac{1}{\rho_r^{XT}}}$$

where $QRT_{r,q,qq}$ is the transportation activity produced by transportation firms in region r used in transporting industry output from region q to region qq. $b_{r,q,qq}^{QRT}$ are the respective share parameters, d_r^{XT} is the shift parameter while ρ_r^{XT} is the transformation parameter. From this CET function the following supply functions can be derived:

$$QRT_{r,q,qq} = \left(\frac{PQT_{q,qq}}{PXT_r}\right)^{\sigma_r^{XT}} \cdot (d_r^{XT})^{-\sigma_r^{XT}-1} \cdot \left(b_{r,q,qq}^{QRT}\right)^{-\sigma_r^{XT}} \cdot XT_r$$

(EQ15 [r])

where $PQT_{q,qq}$ is the price index of the transportation activity from region q to region qq and σ_r^{XT} is the elasticity of transformation, determined by the transformation parameter: $\sigma_r^{XT} = 1/(\rho_r^{XT} - 1)$. Zero profit condition of the transportation sector requires that the value of produced transportation activity be equal to the value of transportation activities in all relations:

$$PXT_r \cdot XT_r = \sum_q \sum_{qq} PQT_{q,qq} \cdot QRT_{r,q,qq}$$

(EQ16 [r])

3.2. Interregional trade and transportation

The industry outputs and transportation activities are merged in a Leontief-type production function. Production of industries are allocated for region-to-region relations denoted by $Q_{r,q}$ while production of transportation activities are also allocated for region-to-region relations denoted by $QT_{r,q}$. Consumers will buy a composite good, composed of raw output $Q_{r,q}$ and transportation services $QT_{r,q}$. This composite is defined according to the following Leontief technology:

$$QR_{r,q} = min\left(\frac{1}{q_{r,q}^{Q}} \cdot Q_{r,q}, \frac{1}{q_{r,q}^{QT}} \cdot QT_{r,q}\right)$$

where $QR_{r,q}$ is the composite good going from region r to region q. Assuming a fixed coefficient technology means that we have a fixed real cost of transporting one unit of industry output from region r to region q. The technology above results in the following demand functions for industry output and transportation services:

$$Q_{r,q} = q_{r,q}^{Q} \cdot QR_{r,q}$$

(EQ17 [r,r])

$$QT_{r,q} = q_{r,q}^{QT} \cdot QR_{r,q}$$

(EQ18 [r,r])

We define the (CIF) price index of the composite good as

$$PR_{r,q} \cdot QR_{r,q} = PQ_{r,q} \cdot Q_{r,q} + PQT_{r,q} \cdot QT_{r,q}$$

(EQ19 [r,r])

This is the final step of production and these products are used for consumption (final and intermediate).

3.3. The demand structure

In the model we have two distinct branches of production which use intermediates goods to produce output: industries and the transportation sector. As described before, industries use XI_r composite intermediate goods, while the transportation sector uses XIT_r composite intermediate goods. In a multi-industry version of the model these composites may be a Leontief aggregate of intermediates from different industries, in the present setting, however, this composite intermediate is a composite from different regions. In order to allow for an active role of transportation costs, we use a CES aggregator for the composite intermediate between intermediates from different regions. For the industries we can write:

$$XI_r = d_r^{XI} \cdot \left[\sum\nolimits_q b_{q,r}^{XIR} \cdot \left(XIR_{q,r}\right)^{\rho_r^{XI}}\right]^{\frac{1}{\rho_r^{XI}}}$$

where $XIR_{r,q}$ is the intermediate demand of industries in region r coming from region q. $b_{q,r}^{XIR}$ are the respective share parameters, d_r^{XI} is the shift parameter and ρ_r^{XI} is the parameter of substitution. This aggregator gives rise to the following demand for regions-specific intermediate demands in industries:

$$XIR_{q,r} = \left(\frac{PI_r}{PR_{q,r}}\right)^{\sigma_r^{XI}} \cdot (d_r^{XI})^{\sigma_r^{XI}-1} \cdot \left(b_{q,r}^{XIR}\right)^{\sigma_r^{XI}} \cdot XI_r$$

(EQ20 [r,r])

where σ_r^{XI} is the elasticity of substitution, linked to the substitution parameter: $\rho_r^{XI} = (\sigma_r^{XI} - 1)/\sigma_r^{XI}$

Analogous functions describe the intermediate demand of the transportation sector. The aggregator is:

$$XIT_r = d_r^{XIT} \cdot \left[\sum\nolimits_q b_{q,r}^{XIRT} \cdot \left(XIRT_{q,r}\right)^{\rho_r^{XIT}}\right]^{\frac{1}{\rho_r^{XIT}}}$$

And the intermediate demand functions:

$$XIRT_{q,r} = \left(\frac{PIT_r}{PR_{q,r}}\right)^{\sigma_r^{XIT}} \cdot (d_r^{XIT})^{\sigma_r^{XIT}-1} \cdot \left(b_{q,r}^{XIRT}\right)^{\sigma_r^{XIT}} \cdot XIT_r$$

(EQ21 [r,r])

where σ_r^{XIT} is the elasticity of substitution, linked to the substitution parameter: $\rho_r^{XIT} = (\sigma_r^{XIT} - 1)/\sigma_r^{XIT}$. $XIRT_{q,r}$ is the intermediate demand of the transportation sector in region r, for industry outputs produced in region q.

The price indices of the composite intermediates for the industries and the transportation sector are defined by the following two equations respectively:

$$PI_r \cdot XI_r = \sum\nolimits_q PR_{q,r} \cdot XIR_{q,r}$$

(EQ22 [r])

$$PIT_r \cdot XIT_r = \sum\nolimits_q PR_{q,r} \cdot XIRT_{q,r}$$

(EQ23 [r])

Turning to the final consumption demand of households, income is defined on the regional level. Total income of the regional households is made up of labor and capital incomes generated in the regional industries and transportation sectors:

$$YH_r = PL_r \cdot L_r + PK_r \cdot K_r + PL_r \cdot LT_r + PK_r \cdot KT_r$$

(EQ24 [r])

where YH_r is the total income of the households. Household saving is assumed to be zero in this model, so household budget (BH_r) is defined simply as:

$$BH_r = YH_r$$

(EQ25 [r])

On the first level, households consume a composite consumption good, the price level of which is defined by the following equation:

$$PC_r \cdot C_r = BH_r$$

(EQ26 [r])

where C_r is the composite (real) consumption of households and PC_r is its price index. Composite consumption, on the other hand, is composed of outputs of industries from different regions according to a CES technology:

$$C_r = d_r^C \cdot \left[\sum\nolimits_q b_{q,r}^{CR} \cdot \left(CR_{q,r}\right)^{\rho_r^C}\right]^{\frac{1}{\rho_r^C}}$$

where $CR_{q,r}$ is the consumption of households in region r coming from region q. $b_{q,r}^{CR}$ are the share parameters, d_r^C is the shift parameter and ρ_r^C is the substitution parameter. The consumption demand functions from this aggregator are as follows:

$$CR_{q,r} = \left(\frac{PC_r}{PR_{q,r}}\right)^{\sigma_r^C} \cdot (d_r^C)^{\sigma_r^C - 1} \cdot \left(b_{q,r}^{CR}\right)^{\sigma_r^C} \cdot C_r$$

(EQ27 [r,r])

where σ_r^C is the substitution elasticity, linked to the substitution parameter: $\rho_r^C = (\sigma_r^C - 1)/\sigma_r^C$.

The consumption is closed by the following value equation:

$$PC_r \cdot C_r = \sum\nolimits_q PR_{q,r} \cdot CR_{q,r}$$

(EQ28 [r])

3.4. Equilibrium conditions

First, equilibrium on the goods market is established on a region-region specific basis:

$$CR_{r,q} + XIR_{r,q} + XIRT_{r,q} = QR_{r,q}$$

(EQ29 [r,r])

Equilibrium on the transportation market requires that the demand for transportation services be equal to the supply. The supply is determined as the transportation activity of the sector in region r, providing transportation services from region q to region qq, denoted by $QRT_{r,q,qq}$. The demand is determined by $QT_{q,qq}$ as the required amount of transportation services between regions q and qq in order to ship the given amount of goods. Equilibrium thus establishes that supply and demand of transportation services in the relation (q, qq) are equal.

$$QT_{q,qq} = \sum_r QRT_{r,q,qq}$$

(EQ30 [r,r])

Equilibrium on the regional factor markets equates labor and capital supplies (given exogenously) and demand in the industries and the transportation sector.

$$L_r + LT_r = ls_r$$

(EQ31 [r])

$$K_r + KT_r = ks_r$$

(EQ32 [r])

3.5. Alternative formulations – iceberg trade costs and regional markets

The model specification given by equations (EQ1)-(EQ32) is based on the composite trade cost and relational market approaches. In this subsection we briefly discuss how the alternative formulations would look like: the iceberg approach and the regional market approach.

Using regional markets instead of relational markets

Using regional markets mean that market equilibrium is defined at the regional level. On the other hand, this also means that the CET supply functions which split regional output between different destination is not necessary. Under this model version we shall define the sum of the demand items as

$$QR_{r,q}^{REG} = CR_{r,q} + XIR_{r,q} + XIRT_{r,q}$$

(EQ33 [r,r])

this $QR_{r,q}^{REG}$ is the composite user good containing raw products and transportation services, so it essentially plays the role of $QR_{r,q}$ in the full model specification above. Then, the only additional difference under the regional market approach is the good market clearing condition which becomes

$$X_r = \sum_q Q_{r,q}$$

(EQ34 [r])

Everything else remains the same under the regional market approach, however, this relatively small change mean that prices are endogenous at the regional level with all its consequences on the adjustment processes.

Using iceberg trade cost instead of the composite trade cost

Iceberg trade costs most importantly mean that transport markups are exogenous parameters of the model, denoted by $\tau_{r,q}$. On the other hand, the formulation of this approach requires much more changes. The first such change is that the whole transport sector vanishes from the model as this approach does not need an explicit transportation sector to work (of course, in a multisector version one may have a transportation sector, but it will not have the same inherent role in providing transportation services as under the composite trade cost approach). So equations (EQ9)-(EQ16) are deleted from the model. Second, we do not need the composite technology of raw products and transport services, so equations (EQ17)-(EQ19) are also deleted. Interregional trade is simply described by the exogenous markup between FOB and CIF prices. As $PQ_{r,q}$ is the FOB price of a unit of output shipped from r to q, the following notation holds:

$$PR_{r,q} = (1 + \tau_{r,q}) \cdot PQ_{r,q}$$

(EQ35 [r,r])

where $PR_{r,q}$ is the CIF price of the same good. $\tau_{r,q}$ is an exogenous parameter of the model reflecting the transport cost of a unit of good.

The demand side of the model remains the same, but equilibrium conditions also change. First, equation (EQ30) is also deleted as we do not need a market clearing condition for the transport sector. And second, the market clearing condition for the good markets (defined on the relational level) becomes:

$$CR_{r,q} \cdot (1 + \tau_{r,q}) + XIR_{r,q} \cdot (1 + \tau_{r,q}) = Q_{r,q}$$

(EQ36 [r,r])

The coefficients with the transport markups seem odd for the first sight as one may expect that the goods produced are consumed by somebody in the economy. The very nature of the iceberg approach is, however, that part of the produced quantities just ‘melts away’ during transportation. This way the amount consumed must be lower than the amount produced, exactly by the transport markup. Putting it differently, having a positive transport markup means that we have different prices for the same products. If market clearing was ‘standard’ in the sense that the quantity produced equals the quantity supplied, this duality of the prices could not hold. In the composite approach this duality is accommodated by the fact that the raw product to which the producer price is attached is physically a different good than the goods purchased as the latter is a composite containing also the transportation services.

4. Some simulation results – what do we learn from the refined approach?

In this section we present the results of some systematic simulation analyses with the baseline model in order to explore the role of the different approaches established in Table 1 in determining some endogenous variables of the model. The setup of the simulation experiment is the following.

We use the baseline model described in Section 3 and calibrate it using three fictional datasets. The three datasets provide three different landscapes of the economy: (i) a homogenous landscape, (ii) an evenly distributed landscape and (iii) an asymmetric landscape. Under the homogenous landscape we mean that all regions produce the same quantities of the industry good and transportation services, consume the same amount and the trade between all region pairs is the same. The even distribution means that the average values of the different quantities are the same across regions and region pairs (in case of trade volumes) but there is a variation around averages in the specific regions and relations. Finally, in the asymmetric case we have a large region and two smaller regions with respect to industry output, a relatively large amount of trade between the large and smaller regions and a weak trade between the two small regions.

Given these three landscapes, or parametrization of the model, we trace the effect of a labor supply shock in the simulations. A 1% shock is given to the labor supply of one region (in the homogenous and even landscapes it is indifferent where the shock hits the economy, whereas in the asymmetric case we apply the shock in the large region).

In each simulation case we trace the effect of the labor supply shock on four variables: regional output levels, regional output prices, interregional trade volumes and transportation costs.

Given the three landscapes and the four different model settings (four combinations of trade cost and market definition choices), we have altogether 12 simulation settings the results for which are presented below, for each variable in turn.

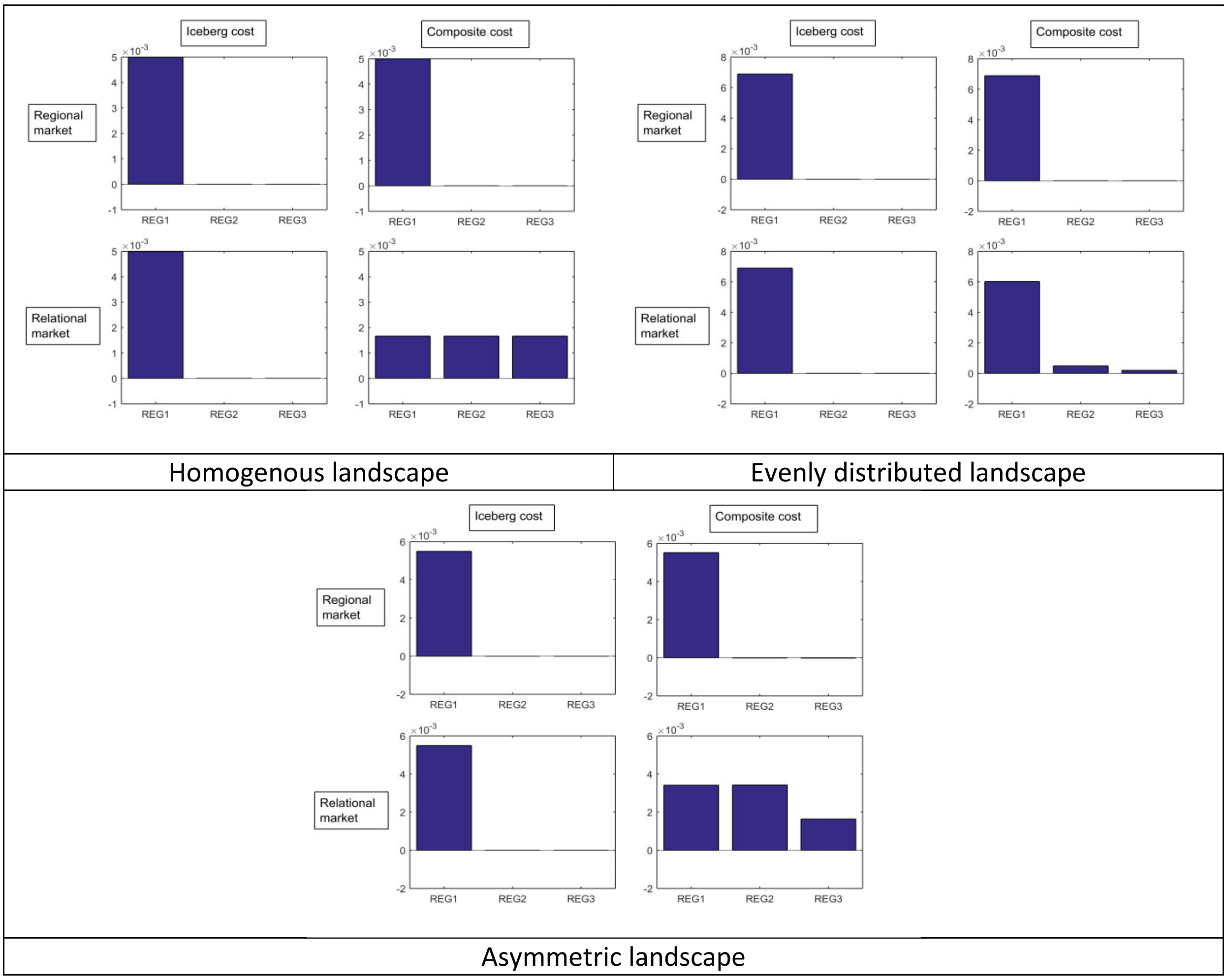
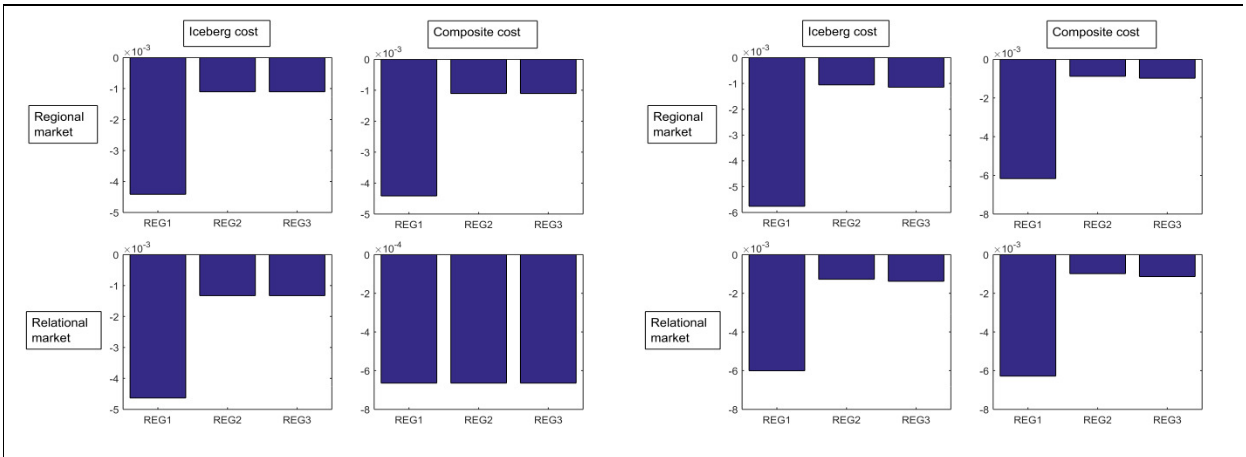


Figure 2 – The effect of a labor supply shock on regional outputs

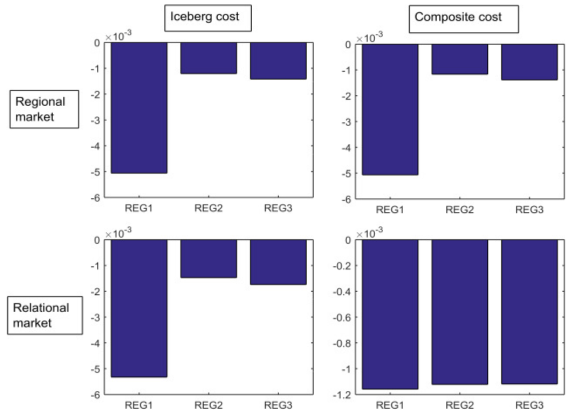
In Figure 2 we can follow the effect of the labor supply shock on regional output levels for all 12 cases. The three panels of the figure show the three landscapes, whereas each panel contains four diagrams for the four model settings (trade cost versus market definition). Within each graph we can trace the change of the output level of the three regions.

The most immediate impression from the figure is that there is no significant qualitative or quantitative difference between three of the model settings: iceberg trade costs with both market definitions and the composite trade cost approach with regional market definition all yield the same results with respect to the shock: an increase of labor supply in Region 1 increases the output of that region but not of the others'. Once we move to the disaggregated relational market approach under the composite trade cost model, the picture changes: the shock in Region 1 have An effect on the output of all other regions as well: the obvious reason for this is that endogenous changes in trade costs allow for a more flexible reaction of the economy as a whole to the shock. We see no qualitative difference with respect to the three different landscapes which provides a good basis to conclude that at least in the case of a labor supply shock's effect on regional output levels using composite trade costs make sense only if the market is defined at the relational level. In any other case the most restrictive model of iceberg trade costs and regional market setting seems to yield the same result as more complicated versions. The slight difference in the output effects between the three landscapes and the composite/relational model can be interpreted quite easily. In the homogenous world the shock is also homogenously 'distributed' in the economy. In the evenly distributed space the highest effect is measured in the shocked region while in the asymmetric case Region 1 and Region 2 show almost the same effect. The difference comes from the fact that in the even landscape regions fall equally distant from each other while in the asymmetric case Region 1 and Region 2 are close while Region 3 is far from the other 2.

Figure 3 then shows the effect of the labor supply shocks on regional output prices in the same structure that we employed in the case of regional outputs. It is not surprising, that the results are qualitatively the same and are of opposite sign compared to output changes: the positive labor supply shock drives down wages, hence production costs, which is then reflected by lower output prices due to perfect competition. However, in contrast to the output levels, prices change also in the regions with no shock even under the iceberg approach.



Homogenous landscape	Evenly distributed landscape

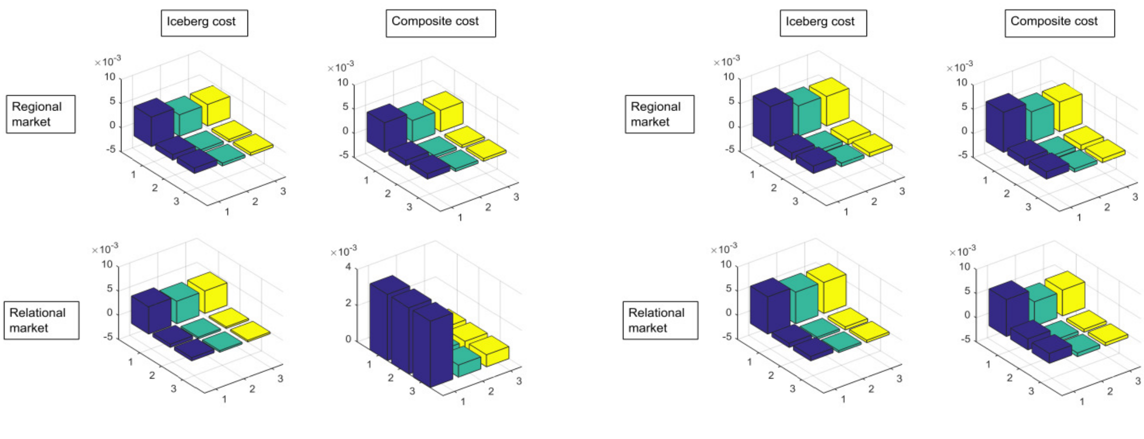


Asymmetric landscape

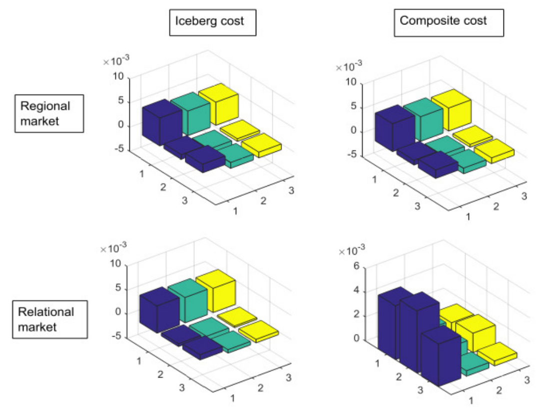
Figure 3 – The effect of a labor supply shock on regional output (FOB) prices

On the other hand, the results reinforce our main conclusion from Figure 2: applying the composite trade cost approach without disaggregating the model to the relational market approach does not add to the picture we gain from the model: the reaction of the regional output prices to the labor supply shock in Region 1 is the same under the iceberg trade cost models and the composite trade cost models with relational market.

In contrast to the two regional level variable before, Figure 4 shows the effect of the labor supply shock on interregional trade volumes. Here the basic structure of the figure is the same as in the previous ones, but for one setting we now show the change in all relations. The same colored bars show one destination region: e.g. the blue bars represent trade between all regions as origin and Region 1 as the destination and so on.



Homogenous landscape	Evenly distributed landscape



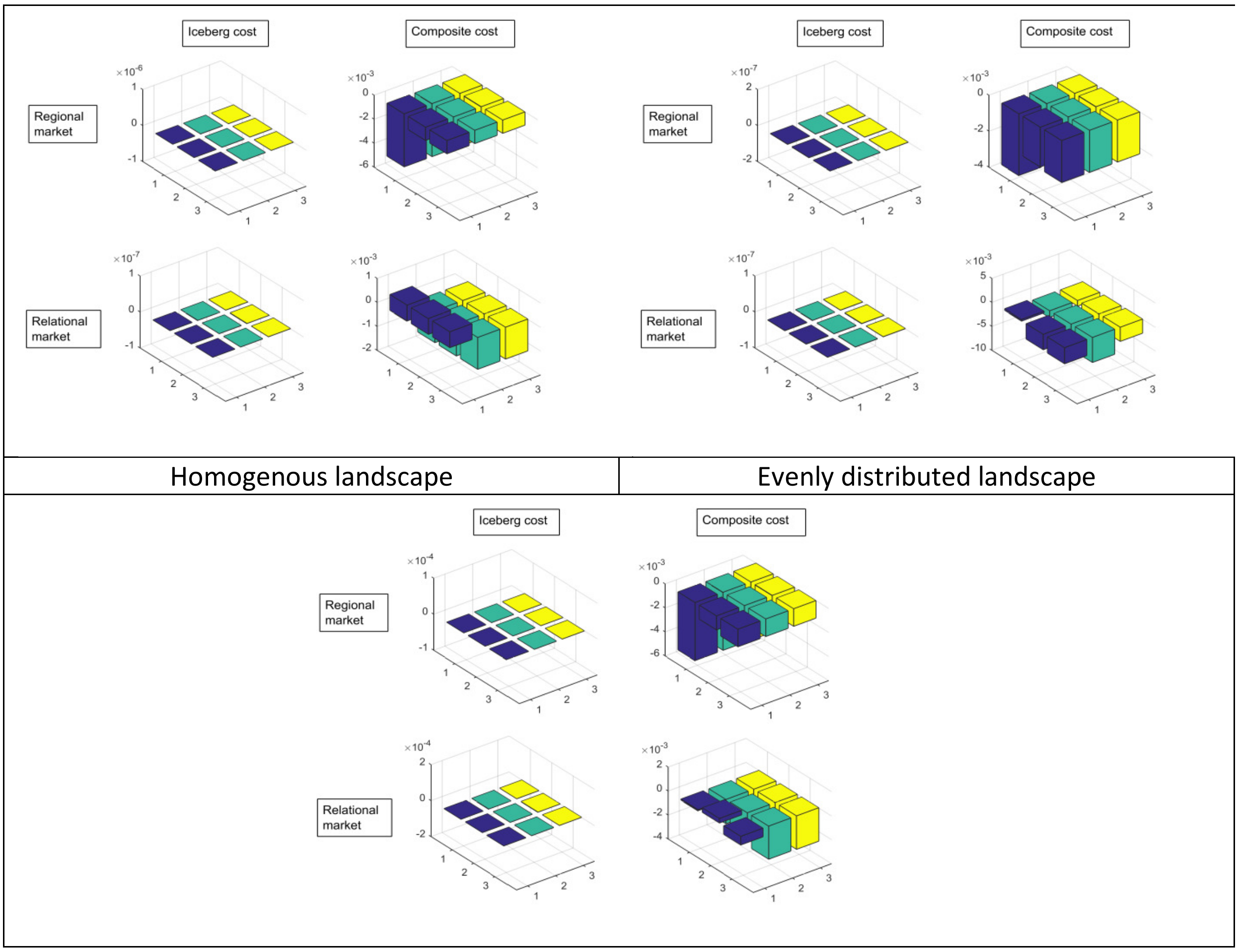
Asymmetric landscape

Figure 4 – The effect of a labor supply shock on interregional trade volumes

In the previous analysis it was not that surprising that we did not observe differences in the shock's effect on regional level variables if the definition of the market is in the regional level. More striking is the result here that our previous observations for regional level variables are also valid for trade volumes between regions which are relational variables: in the case of all three landscapes the effect of the labor supply shock in Region 1 is the same in the two trade cost models if we define the market at the regional level. However, if the market is defined on the relational level and the composite trade cost approach is used, the results change to a large extent (especially in the case of homogenous and asymmetric landscapes). One important thing to note is that even the direction of the effect changes. While e.g. trade between regions 2 and 3 (the middle yellow bar) decrease under the iceberg trade costs and the composite trade costs with regional market, it increases under the composite trade costs with relational market. Thus, employing the disaggregated approach we proposed in the paper has not only a quantitative but also a qualitative effect on the results. Another interesting result is the marked change in the direction of the effects. With iceberg trade costs and with composite trade costs and regional markets the labor supply shock in Region 1 has a large positive effect on trade *from* this region to other regions, a smaller but positive effect on trade *towards* this region from other regions and a negative effect on trade on all other relations. Once composite trade costs are used and the market is defined on the relational level, the labor supply shock in Region 1 has a positive effect on trade on *all* relations. However, with the regional market we observed a large effect on trade *from* this region, now the large effect is on trade *towards* this region (the blue bars).

In Figure 5 we trace the effect of the labor supply shock in Region 1 on transport costs. It is nicely seen that under the iceberg trade cost approach we do not see any change in the trade costs as the transportation markup is exogenous. Once we move to the composite trade cost approach, though, trade costs become endogenous. Therefore, this is the first instance where our results show difference between the iceberg trade cost models and the composite trade cost model with regional markets. The results also mirror the fact that using the composite trade cost approach but retaining the regional market definition trade costs are only partly endogenous: as we have discussed it before, in this case there is one price for each region therefore trade costs can be endogenous also at the regional level. Looking at the upper-right panels we can see that trade costs move in response to the shock, but they move together for an origin region: there is no difference between the change in the trade cost between Region 1 and 2 compared to 1 and 3 or 1 and 1, as the model structure allows for one endogenous trade cost for all (origin) regions.

On the other hand, moving from the regional market to the relational market approach under the composite trade cost model, we observe qualitative differences in the results again. In the homogenous landscape, e.g. all trade costs decrease when the market is defined on the regional level. In contrast, trade costs of transporting towards Region 1 (where the shock hits in) increase when the market is defined on the relational level. There is also an interesting relationship between these results on the trade costs and the patterns observed in Figure 4. In the composite trade cost case with regional markets we observe a relatively large decrease in trade costs between Region 1 as origin and all other destinations. This decrease in the trade cost explains why the trade volumes increase in these relations. However, when we move to the relational markets under the composite trade cost approach, trade costs increase between Region 1 as destination and all other relations while trade also increases. This seeming contradiction can be resolved by recalling the fact that under the relational market approach trade costs can follow economic activities and events in a very refined way. In this setting trade costs are not exogenous, passive 'actors' behind the events: in this specific example trade cost increase on those relations where trade volume is higher, because the higher demand on transport services generated by increased trade can drive up the price of transport services hence trade costs. This simple case shows how the refined composite trade cost approach together with the relational market definition can reflect complex mechanisms behind economic events.



Asymmetric landscape

Figure 5 – The effect of a labor supply shock on transportation costs

To sum up shortly, the results discussed here provides a strong basis to say that the composite trade cost models can be fully utilized only if the definition of the market allows for a truly endogenous trade cost. Having regional markets in these models do not fulfil this requirement and, as evidenced by our results, composite trade cost models with regional markets yield essentially the same results as the more traditional but more criticized iceberg trade cost models. Our proposed method of establishing market equilibrium on the relational level (for all region-pairs) seems to provide a viable solution to this problem: the combination of composite trade costs with relational markets allows a detailed description of interregional economic relationships.

5. An SAM-based calibration

Although the refined model with relational markets and composite trade costs can provide a deeper insight into the effect of shocks to the economy, there is an increased data requirement on the other side of the coin. There is basically two problems which must be overcome if one is to calibrate the refined model with composite trade costs and relational markets.

First, one needs a detailed description of the transportation sector of the economy: to calibrate the model at this detail, we need information on the regional transportation activities, input and factor uses on the one hand, which is typically available in a regional IO table or SAM. On the other hand, we need to know how the activity of regional transport sectors (the transportation services) serves different relations and even sectors/products in a multisector environment. This establishes a very refined data requirement on model calibration.

Second, there is an inherent problem with the transportation service definition of the model as compared to the data availability. Assume e.g. that we have data on transaction values between two sectors. How can we distinguish between the raw product content and the transportation product content? In some cases the statistics may provide a differentiation but in other cases part of the value may be accounted for as product purchase whereas part of the value is clearly transportation.

In what follows we describe briefly a method which provides a first-cut solution to these problems. The basic idea behind the method is that once the available data may be highly inconsistent with the model structure (data requirements), we should start from scratch and build a transportation sector for the model which is consistent with the assumptions used by simply reallocating part of the sectoral transaction volumes for a new, regional transportation sector which provides essentially those transportation services which are required by the model logic.

5.1. A schematic SAM structure

As a starting point for the description of the proposed method, we show a schematic SAM structure in which the data required for the model can be rendered. Figure 6 shows this schematic SAM structure for a multiregional but one sector setting – the scheme can easily be extended for a multisector environment.

		REG1				REG2				REG3				IND1									
		IND1	TRS	FAC	HHD	IND1	TRS	FAC	HHD	IND1	TRS	FAC	HHD	1->1	2->1	3->1	1->2	2->2	3->2	1->3	2->3	3->3	TOT
REG1	IND1																						
	TRS																						

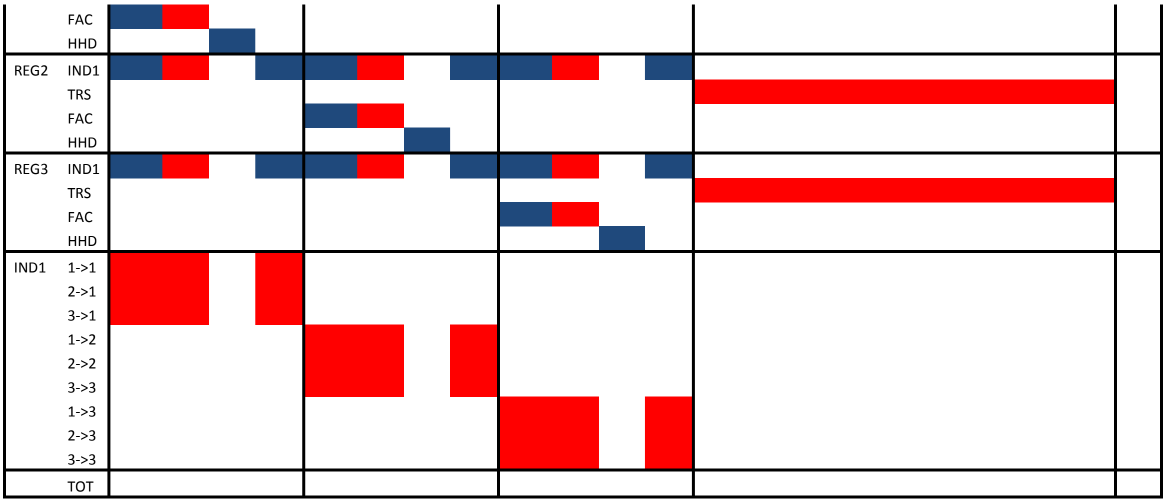


Figure 6 – A schematic SAM for model calibration

The SAM structure can be interpreted as follows. The structure is a square SAM where each row corresponds to a column and column and row sums must be equal for all items. The first three blocks on the header define regional institutions: the industries (IND – merged), the transport sector (TRS), production factors (FAC) and households (HHD). The fourth block contains transportation services for all region-region pair (trade relation). White areas do not contain data in our model logic, while colored cells do. The blue cells are those cells for we typically have data: interregional trade within industries, household consumption broken down for regions, factor payments. Red cells are those for which one may have data or they can be estimated from other data sources. We must note that data on the outlays of regional transport sectors (TRS columns) are usually available in a sector-disaggregated regional IO table or SAM. However, due to the problems mentioned above, this data are typically not suitable for model calibration. Therefore, our method below starts from merged industries and builds up a transport sector suitable for the model purposes.

The basic idea is that we have data for the CIF transaction values between all pairs of regions for all commodities/sectors, factor incomes in all regions and household consumption for all regions – i.e. the blue cells in the schematic SAM in Figure 6. Then, we use a mathematical approach to fill in the red cells, i.e. the transport cost, incomes of the transport sectors and their expenditure structure which is consistent with the model and the SAM. At the same time, CIF transaction values in the blue cells are split between FOB transaction values (which remain in the original position) and transport costs which are written in the transport block of the SAM. Although the SAM above contains only one industry for a compact visualization, the method below is formulated for a multiple industry setting.

We use three assumptions for a unique solution: (i) the modeler has some exogenous information on the transportation markup between all pairs of regions, which is going to be denoted by $\tau_{r,q,i}$ for transporting commodity i from region r to region q; (ii) given an industry in a region, all outlays of this industry (intermediate consumption, factor incomes) are split between the industry itself and the newly built transport sector according to the same fraction; (iii) transportation revenues are allocated between regional transportation sectors according to a constant share, irrespective of the trade relation on which this revenue is generated and the commodity transported.

5.2. A method to redefine regional transport sectors

Let's denote the FOB transaction value of purchasing commodity i by sector j in region q from region r by $Z_{r,q,i,j}$. Given the transportation markup, it is true that

$$Z_{r,q,i,j} = \frac{1}{1+\tau_{r,q,i}} \cdot CIF_{r,q,i,j}$$

(EQ37)

Further, let's denote the FOB purchase value of commodity i by households in region q from region r by $U_{r,q,i}$.

Then, $H_{q,j}$ stands for factor payments of industry j in region q. In line with the model setting, industries in a region pay factor incomes to the households in the same region only.

Finally, $x_{q,j}$ is the ratio with which the transaction values found in the column of industry j in region q is reallocated for the transportation sector in region q. In the schematic SAM for example this means that the values in column IND1 in REG1 (intermediate inputs, factor payments, transport costs) are reduced by a common fraction $x_{1,1}$. On the other hand, column TRS in REG1 gets the values by which the IND1 column was decreased.

In what follows we give those conditions which must be met in order to have a consistent SAM.

1. Reallocation. We must split the FOB values $Z_{r,q,i,j}$ and factor incomes $H_{q,j}$: a fraction $x_{q,j}$ is allocated for the transportation cost and a fraction $(1 - x_{q,j})$ is allocated for industry j

$$FOB^{IND}_{r,q,i,j} = (1 - x_{q,j}) \cdot Z_{r,q,i,j} \quad \text{(EQ38)}$$

$$FOB^{TR}_{r,q,i,j} = x_{q,j} \cdot Z_{r,q,i,j} \quad \text{(EQ39)}$$

$$H^{IND}_{q,j} = (1 - x_{q,j}) \cdot H_{q,j} \quad \text{(EQ40)}$$

$$H^{TR}_{q,j} = x_{q,j} \cdot H_{q,j} \quad \text{(EQ41)}$$

$$FOB^{U}_{r,q,i} = U_{r,q,i} \quad \text{(EQ42)}$$

2. Transport costs must correspond to the exogenous markups

$$TRS^{IND}_{r,q,i,j} = \tau_{r,q,i} \cdot FOB^{IND}_{r,q,i,j} \quad \text{(EQ43)}$$

$$TRS^{TR}_{r,q,i,j} = \tau_{r,q,i} \cdot FOB^{TR}_{r,q,i,j} \quad \text{(EQ44)}$$

$$TRS^{U}_{r,q,i} = \tau_{r,q,i} \cdot FOB^{U}_{r,q,i} \quad \text{(EQ45)}$$

3. Define the total transport revenue generated on all trade relations

$$TOTTRS_{r,q,i} = \sum_j TRS^{IND}_{r,q,i,j} + \sum_j TRS^{TR}_{r,q,i,j} + TRS^{U}_{r,q,i}$$

(EQ46)

4. The row and column sums must be equal for regional transport sectors ($\bar{\beta}_r$ is the share of region r from the transport revenues generated at any trade relation – see the determination of this constant later on)

$$TOTTR_r = \sum_q \sum_{qq} \sum_i \bar{\beta}_r \cdot TOTTRS_{q,qq,i}$$

(EQ47)

$$TOTTR_q = \sum_r \sum_i \sum_j FOB^{TR}_{r,q,i,j} + \sum_r \sum_i \sum_j TRS^{TR}_{r,q,i,j} + \sum_j H^{TR}_{q,j}$$

(EQ48)

5. The row and column sums must be equal for all regional industries

$$TOTIND_{r,i} = \sum_q \sum_j FOB^{IND}_{r,q,i,j} + \sum_q \sum_j FOB^{TR}_{r,q,i,j} + \sum_q FOB^{U}_{r,q,i}$$

(EQ49)

$$TOTIND_{q,j} = \sum_r \sum_i FOB^{IND}_{r,q,i,j} + \sum_r \sum_i TRS^{IND}_{r,q,i,j} + H^{IND}_{q,j}$$

(EQ50)

The equation system in (EQ38)-(EQ50) can be simplified significantly into two equations where we have the given parameters of the problem and the reallocation fractions. From (EQ47) and (EQ48) after substitution we have

$$b_q = \sum_r \sum_i \sum_j x_{q,j} \cdot (1 + \tau_{r,q,i}) \cdot Z_{r,q,i,j} + \sum_j x_{q,j} \cdot H_{q,j}$$

(EQ51)

where $b_q = \bar{\beta}_q \cdot (a + trs^U)$ is a known constant, $a = \sum_q \sum_{qq} \sum_i \sum_j \tau_{q,qq,i} \cdot Z_{q,qq,i,j}$ is the total transportation revenue generated by intermediate purchases of industries and $trs^U = \sum_q \sum_{qq} \sum_i TRS^U_{r,q,i}$ is the total transportation revenue generated by household purchases. Similarly, we can write (EQ49) and (EQ50) in the following form:

$$g_{q,j} = (1 - x_{q,j}) \cdot \sum_r \sum_i (1 + \tau_{r,q,i}) \cdot Z_{r,q,i,j} + (1 - x_{q,j}) \cdot H_{q,j}$$

(EQ52)

where $g_{q,j} = \sum_r \sum_i Z_{q,r,j,i} + \sum_r U_{q,r,i}$ is again a known constant.

Now we should introduce the following notation:

$$t_{q,j} = \sum_r \sum_i (1 + \tau_{r,q,i}) \cdot Z_{r,q,i,j}$$

$$\mathbf{T} = [t_{q,j}]$$

$$\mathbf{H} = [h_{q,j}]$$

$$\mathbf{G} = [g_{q,j}]$$

$$\mathbf{b} = [b_r]$$

$$\mathbf{X} = [x_{q,j}]$$

Equations (EQ51) and (EQ52) can then be written in the following compact matrix form:

$$\mathbf{b} = [(\mathbf{T} + \mathbf{H}) \circ \mathbf{X}] \cdot \mathbf{e} \tag{EQ53}$$

$$\mathbf{G} = (\mathbf{1} - \mathbf{X}) \circ (\mathbf{T} + \mathbf{H}) \tag{EQ54}$$

where $\circ$ denotes elementwise multiplication and $\mathbf{e}$ is a vector of ones and $\mathbf{1}$ is a matrix with ones at all entries. In (EQ54) $\mathbf{G}$, $\mathbf{T}$ and $\mathbf{H}$ are given parameters of this exercise so $\mathbf{X}$ is uniquely defined. Equation (EQ53) then, given $\mathbf{X}$, determines the values of vector $\mathbf{b}$. As $b_q = \bar{\beta}_q \cdot (a + trs^U)$, where the expression in the parenthesis is also given in this calculation, vector $\mathbf{b}$ uniquely defines the values $\bar{\beta}_q$, i.e. the share of each region from the total transport revenues.

Using the method above we can determine the matrix $\mathbf{X}$ given the CIF values of an interregional SAM and some external transportation markups. Once this matrix is obtained, we can fill in the red cells in the schematic SAM using the definitions in (EQ38)-(EQ50).

The method above can conveniently extended for more final users (government, investment, exports) and additional cost elements (taxes, multiple factors, etc.). On the other hand, we applied two assumptions to obtain a unique solution for $\mathbf{X}$. One is that we apply one separate reallocation factor for each industry in each region, but this one factor applies for all outlays (intermediate purchases and factor payments) of the industries. The other is that transport revenues generated on all trade relations and commodities are split between the regional transport sectors under the same share $\bar{\beta}_q$. Once these assumptions hold, the consistent SAM structure determines both the $\bar{\beta}_q$ values and the reallocation factors $x_{q,j}$. In a more flexible approach we may have different reallocation factors for different purchases (in the most general case we may have $x_{r,q,i,j}$ as a 4 dimensional variable) and/or we may allow for a differentiated distribution of transport revenues ($\bar{\beta}_{q,r,qq,i}$ in the most general case). However, once we move away from the solution described here, the degrees of freedom increase significantly in the exercise so we would need to specify an optimization problem to set the $\mathbf{X}$ matrix and the $\bar{\beta}$ values. Although one may find suitable objective functions for such exercises, it is not a straightforward task.

6. Conclusions

In this paper we pointed to the limitation of the currently applied approaches to handle transportation costs in CGE and SCGE models. We have shown that although there is a promising departure from the iceberg trade cost approach, there is still room for further refinement of the models in order to gain full advantage of the composite trade cost approach.

Our proposal suggest that moving the level of market definition from the region to the trade relations (region-region pairs) can further refine the trade cost approach and provide more accurate description of transport cost evolution as it allows for a fully endogenous determination of transport costs at the trade relation level.

In the paper we specified a baseline model for the proposed approach and executed some simulation experiments with different model settings in order to trace the change in some endogenous variables with respect to a labor supply shock. Our main conclusion was that moving from the simple iceberg trade cost approach towards more refined settings leads to important changes in the effects of shocks. Even in the case of regional level variables (regional output levels, regional price levels) we see a quantitative difference in the effect of shocks for the different settings, but for relational variables (trade volumes, transport costs) the difference is even qualitative in some cases. Therefore we conclude that refinement of the model setting can indeed gain important additional insights into the working of the economy.

On the other hand, a more refined model setting requires more detailed datasets to calibrate the model. In the final section of the paper we proposed a method to estimate a SAM which is consistent with the refined model setting. This method builds on some simplifying assumptions but then it can be used to derive the necessary data for the refined model from traditionally available datasets.

This paper describes the first steps towards understanding and describing the costs and benefits of moving towards a refined trade cost modeling. In the future we would like to see the outcomes of different shocks to see when the refined model provides better answers. Also, we need to work on a better understanding of the differences between the various approaches. Moreover, a more systematic experimental design is planned where some randomization helps to estimate the significance of the difference between the results. At the same time there is a work in progress which tries to calibrate a full-scale model o Hungarian data. Running simulations with a real-world model could also help in understanding the relevance of the different approaches.

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