PORT EFFICIENCY AND REGIONAL DEVELOPMENT

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Resumo. Este artigo procura elucidar um dos mecanismos que relacionam barreiras comerciais, na forma de custos portuários, e crescimento e desigualdades regionais. Não apenas custos de transporte terrestre podem ser vistos como uma barreira para ligar liberalização comercial e crescimento (Haddad e Perobelli, 2005), mas também custos portuários. Diferente dos custos rodoviários, congestionamentos nos portos podem ter impactos severos espalhados pelo espaço e tempo enquanto que congestionamento em rodovias pode ser resolvido dentro de muitas horas. Como o porto é uma parte da rede de transportes, qualquer congestionamento/parada provavelmente causa agitação na região adstrita. Neste sentido, é importante modelar adequadamente o papel de congestionamento nodal no contesto de modelos espaciais e comércio internacional. Sendo assim, desenvolvemos um modelo de EGC espacial integrado a um sistema de rede de transporte de forma a simular os impactos de um aumento na eficiência portuária em um contexto de liberalização comercial. O papel dos portos de entrada e portos de saída são explicitamente considerados de maneira a apreender a cena holística em um sistema interregioanal integrados.

Palavras-chave: equilíbrio geral computável, desigualdades regionais, liberalização comercial.

Abstract. This paper attempts to elucidate one of the mechanisms that link trade barriers, in the form of port costs, and subsequent growth and regional inequality. Not only inland costs can be perceived as a further barrier to link trade liberalization and growth (Haddad and Perobelli, 2005), but also port costs. Unlike highway link, congestion at port may have severe impacts spread over space and time whereas highway link congestion may be resolved within several hours. Since port is part of the transportation network, any congestion/disruption is likely to ripple throughout the hinterland. In this sense, it is important to model properly the role nodal congestion plays in a context of spatial models and international trade. Thus, we have developed a spatial CGE model integrated to a transport network system in order to simulate the impacts of increases in port efficiency in a context of trade liberalization. The role of ports of entry and ports of exit are explicitly considered in order to grasp the holistic picture in an integrated interregional system.

Key-words: computable general equilibrium, regional inequalities, trade liberalization.

Área ANPEC: 9.

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1. Introduction

There is increasing recognition of the critical role of infrastructure in the promotion of national and regional economic development. The literature provides a number of alternative approaches, ranging from Martin and Rogers (1995) who adopt a model based on Helpman and Krugman (1985) and the emerging perspectives associated with the new economic geography to the work of Vickerman (1990) who collected papers addressing the role of infrastructure and regional economic development. More recently, there has been significant analysis, using some of the toolbox of spatial econometrics, to explore the role of the EU initiatives in advancing transportation investment as a major vehicle in the reduction of disparities in regional economies (for example, see Dall'erba, 2005). The approach is this paper draws on another set of modest but expanding literature that attempts to link (regional and interregional) macroeconomic models with network-based transportation systems. This later literature will be reviewed more extensively in the next section.

The major contribution of this paper is to explore explicitly the role of nodes, in this case, ports, in the transportation system and their impacts on regional welfare. While a great deal of attention has been directed to efficiencies, congestion and expansion of links in the transportation networks, little attention until recently has been devoted to an examination of the inefficiencies surrounding the transshipment of commodities at ports. The analysis will make use of an interregional CGE model developed for the Brazilian economy integrated with a transport network, the B-MARIA-27 model, described in detail elsewhere (Haddad and Hewings, 2005).

The remainder of the paper is organized as follows. After the review of the literature in the next section, section 3 will present an overview of the CGE model to be used in the simulations, focusing on its general features; section 4 will discuss some modeling issues, more specifically, those associated with the treatment of transportation costs and port costs. After that, the simulation experiment is designed and implemented, and the main results are discussed in section 5. Final remarks follow in an attempt to evaluate our findings and put them into perspective, considering their extension and limitations.

2. Integration of CGE Models and Transportation Networks

The initial research that provided the opportunity to develop links between CGE models and transportation networks was the development of spatial CGE models, first by Roson (1997) and then subsequently by Bröcker (2001). An alternative approach by Kim and Hewings (2003) and Kim et al. (2004) explored ways in which a multi-region CGE model could be linked with a transportation network model to examine the welfare implications of a massive highway construction program in South Korea. Of particular importance were the synergetic effects of simultaneous development of key network links, generating greater impacts than the sum of the impacts arising from sequential development. Sohn *et al*. (2003) provided a conceptually similar linkage but in this case a multi-region econometric input-output model was linked with an interregional commodity flow model in which the network structure comprised not only links but detail about bridges on the links. The objective of this integration was to consider the impacts of a massive earthquake centered in the Midwest on commodity flows, production and income and thus to promote some sense of priorities in the retrofitting of existing infrastructure.

Earlier analysis with the model employed in this paper, by Haddad and Hewings (2005, 2006) provided the methodology for integrating a multi-region CGE model with a transportation network in such a way that the role of both scale economies and transportation costs could be explored in terms of their impacts on both national and regional welfare. The results revealed that the welfare impacts were much more sensitive to changes in transportation costs. The results provided motivation for this paper, attempting to explore the degree to which the nodal components of these costs (especially the ports) played a key role in setting overall transportation costs. Even though interstate transportation costs are a much lower smaller component of total production costs in the US, for instance, there are still some major issues at transfer nodes – both internally and at the interface of interstate and international trade. It would appear that serious congestion occurs still at this transfer points, as the analysis presented in Clark *et al*. (2004) confirms for seaports. The absence of direct rail-to-rail connections in the US (which is still without a national, coast-to-coast railroad) often results in commodities moving by rail from Los Angeles to Chicago in 48 hours only to spend even more time being transferred to a railroad for shipment to the east coast. In contrast, link-based congestion may be much more ephemeral and may dissipate within several hours.

Hence, one of the major challenges to be faced is the modeling of a nodal congestion function that also considers issues of regulation and spatial competition (for example the problem of competing destinations/origins/transfer for the shipment of goods, especially those either sourced outside the country or those produced within the country for export). A second issue concerns the distinction between shippers and carriers with the former serving as essentially coordinating agents who handle the transfer from location r to s and employ one or more carriers to actually move the commodity. This distinction has been handled with bi-level programming techniques (see for example, Kim and Suh, 1988; Suh and Kim, 1989). The choice of carriers (and thus routes) may be significantly affected by the efficiencies of the transfer nodes. As Clark *et al*. (2004) noted from their analysis, the impacts of port inefficiencies are not trivial; improving port efficiency from the 25th to the 75th percentile would reduce shipping costs by 12% in Latin American countries. Inefficient ports also serve to deter bilateral trade with consequent welfare losses. In essence, they noted that "as liberalization continues to reduce artificial barriers, the effective rate of protection by transport costs is now in many cases higher than the one provided by tariffs" (Clark *et al*., 2004, p. 418).

Inefficient ports thus may place a country or region further away from sources of cheaper inputs or markets for goods produced. Drawing on a variety of sources, they revealed that on a scale of 1 (worst) to 7 (best) for port efficiency, Latin American ports scored 2.9 in contrast to scores of 6.35 for the US and 5.3 for Europe. These problems were further compounded by delays in customs clearance that were among the highest in the world.

The problem with port inefficiency in Latin America is the appropriate policy response; in Brazil, there are many competing ports, many of which require significant investments in infrastructure to raise their efficiency. Should ports specialize, and on what basis should investment decisions be made? Can port efficiency be detached from the problem of improving access to the port's hinterland, often a major contributing factor to not only the port's inefficiency but in terms of driving up the total transportation cost?

It would be impossible to address all these questions in one paper; as a result, the focus will be directed to an assessment of the impacts of ports on the efficiency of trade in Brazil by region. In the next section, the adapted methodology for separating out the port transactions costs from the total transportation costs will be presented.

2.1. Handling Port Costs and Competition

Figure 1 shows a stylized transportation cost function for a good that is produced in Brazil and exported. In network terms, this structure is translated into a link-node system as shown in Figure 2. The transfer costs from Figure 1 (for example, moving the container from road or rail to a ship, including the documentation and export charges) are shown as a self-loop. The "transportation costs" on this self-loop would be relatively small (per unit of cargo moved) in the US or Europe but significantly larger in Latin America. In modeling flows and transportation links, a congestion function is often employed to reveal how unit costs may be flat during free-flow periods but rise steeply once congestion occurs. A similar idea can be adopted within the node; as capacity is reached, transfer costs (the self-loop in Figure 2) can be assumed to increase as delays create real losses (not only in an opportunity costs sense, but goods stored in warehouses may be subject to theft or destruction).

A further issue relates to the fact that it would be unrealistic to assume that ports are perfect competitors. For a start, they are likely to have different hinterlands, limited both by the nature of the supporting transportation infrastructure (roads, rail and waterways) as well as link costs from internal markets that are too far removed. Thus, trade areas are likely to overlap only to some degree. In addition, the ports will have different capacities. Hence, the ports need to be considered as placed in an imperfectly competitive market.

If all these considerations are to be taken into account, modeling the system using iceberg transportation costs would be very difficult (see McCann, 2005 for an excellent review of the debate over appropriate transfer costs). As a result, the paper adopts a transportation margins approach in which the link costs are separated from the nodal costs.

Figure 1. Cost function for export of a domestically produced good

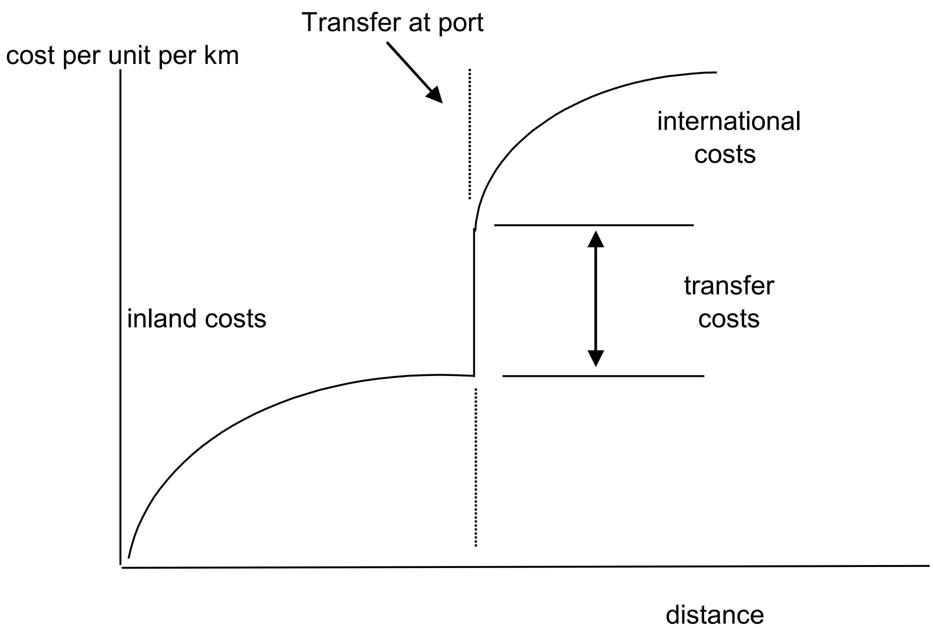


Figure 2. Stylized representation of link and nodal costs

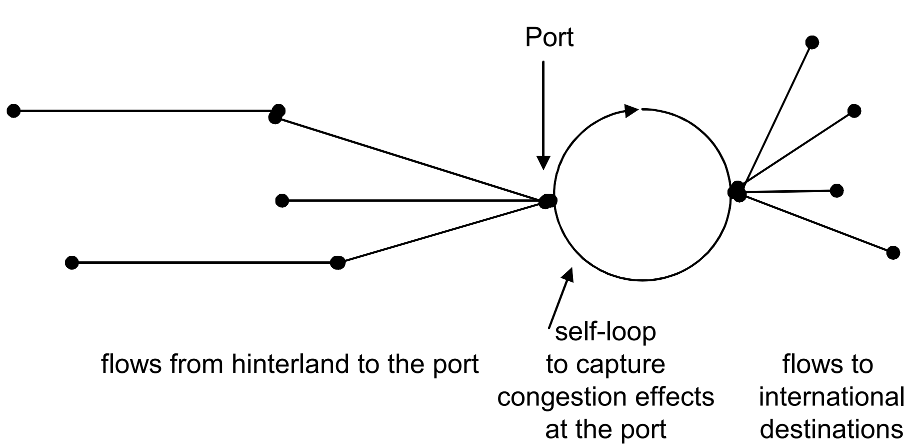
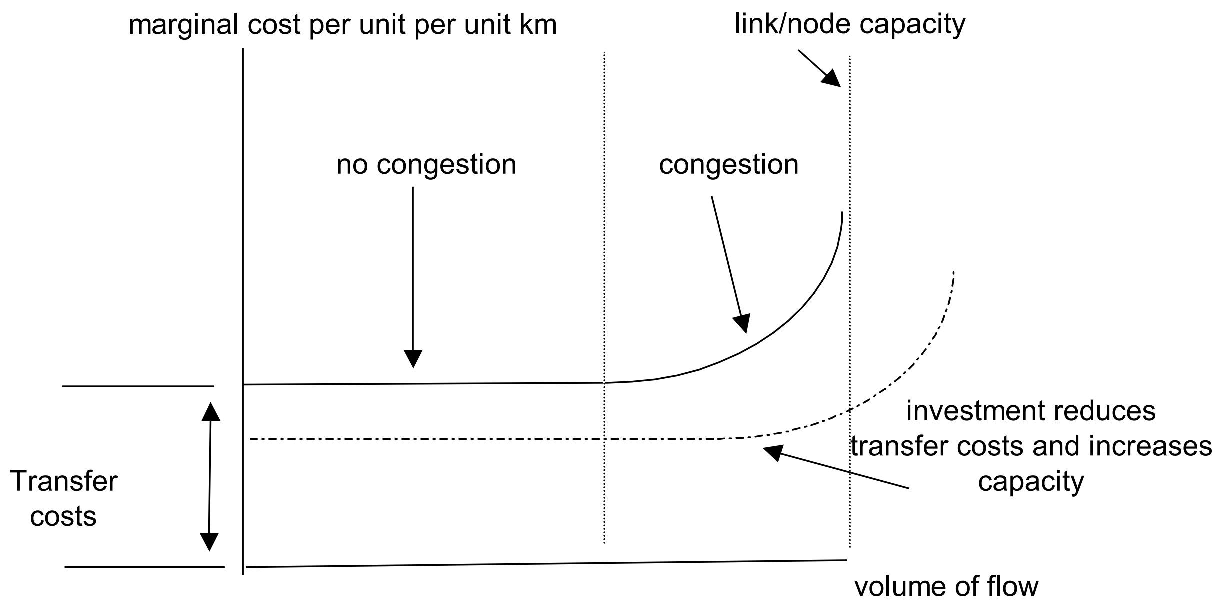


Figure 3. Congestion function at the node



3. The B-MARIA-27 Model

The structure of the model used in our simulations represents a further development of the **B**razilian **M**ultisectoral **A**nd **R**egional/**I**nterregional **A**nalysis Model (B-MARIA), the first fully operational interregional CGE model for Brazil.[4] Its theoretical structure departs from the MONASH-MRF Model (Peter *et al*., 1996), which represents one interregional framework in the ORANI suite of CGE models of the Australian economy. The interstate version of B-MARIA, used in this research, contains over 600,000 equations, and it is designed for forecasting and policy analysis. Agents' behavior is modeled at the regional level, accommodating variations in the structure of regional economies. The model recognizes the economies of 27 Brazilian states. Results are based on a bottom-up approach – national results are obtained from the aggregation of regional results. The model identifies 8 sectors in each state producing 8 commodities, one representative household in each state, regional governments and one Federal government, and a single foreign consumer who trades with each state. Special groups of equations define government finances, accumulation relations, and regional labor markets. The model is calibrated for 1996; a rather complete data set is available for 1996, which is the year of the last publication of the full national input-output tables that served as the basis for the estimation of the interstate input-output database (Haddad *et al*., 2002), facilitating the choice of the base year.

The mathematical structure of B-MARIA-27 is based on the MONASH-MRF Model for the Australian economy. It qualifies as a Johansen-type model in that the solutions are obtained by solving the system of linearized equations of the model. A typical result shows the percentage change in the set of endogenous variables, after a policy is carried out, compared to their values in the absence of such policy, in a given environment. The schematic presentation of Johansen solutions for such models is standard in the literature. More details can be found in Dixon *et al*. (1992), Harrison and Pearson (1994, 1996), and Dixon and Parmenter (1996).

[4] The complete specification of the model is available in Haddad and Hewings (1997) and Haddad (1999).

3.1. General Features of B-MARIA-27

CGE Core Module

The basic structure of the CGE core module comprises three main blocks of equations determining demand and supply relations, and market clearing conditions. In addition, various regional and national aggregates, such as aggregate employment, aggregate price level, and balance of trade, are defined here. Nested production functions and household demand functions are employed; for production, firms are assumed to use fixed proportion combinations of intermediate inputs and primary factors are assumed in the first level while, in the second level, substitution is possible between domestically produced and imported intermediate inputs, on the one hand, and between capital, labor and land, on the other. At the third level, bundles of domestically produced inputs are formed as combinations of inputs from different regional sources. The modeling procedure adopted in B-MARIA-27 uses a constant elasticity of substitution (CES) specification in the lower levels to combine goods from different sources. Given the property of standard CES functions, non-constant returns are ruled out. However, one can modify assumptions on the parameters values in order to introduce non-constant returns to scale. Changes in the production functions of the manufacturing sector[5] in each one of the 27 Brazilian states were implemented in order to incorporate non-constant returns to scale, a fundamental assumption for the analysis of integrated interregional systems. We kept the hierarchy of the nested CES structure of production, which is very convenient for the purpose of calibration (Bröcker, 1998), but we modified the hypotheses on parameters values, leading to a more general form. This modeling trick allows for the introduction of non-constant returns to scale, by exploring local properties of the CES function. Care should be taken in order to keep local convexity properties of the functional forms to guarantee, from the theoretical point of view, existence of the equilibrium.

The treatment of the household demand structure is based on a nested CES/linear expenditure system (LES) preference function. Demand equations are derived from a utility maximization problem, whose solution follows hierarchical steps. The structure of household demand follows a nesting pattern that enables different elasticities of substitution to be used. At the bottom level, substitution occurs across different domestic sources of supply. Utility derived from the consumption of domestic composite goods is maximized. In the subsequent upper-level, substitution occurs between domestic composite and imported goods.

Equations for other final demand for commodities include the specification of export demand and government demand. Exports face downward sloping demand curves, indicating a negative relationship with their prices in the world market. One feature presented in B-MARIA-27 refers to the government demand for public goods. The nature of the input-output data enables the isolation of the consumption of public goods by both the federal and regional governments. However, productive activities carried out by the public sector cannot be isolated from those by the private sector. Thus, government entrepreneurial behavior is dictated by the same cost minimization assumptions adopted by the private sector.

A unique feature of B-MARIA-27 is the explicit modeling of the transportation services and the costs of moving products based on origin-destination pairs. The model is calibrated taking into account the specific transportation structure cost of each commodity flow, providing spatial price differentiation, which indirectly addresses the issue related to regional transportation infrastructure efficiency. Other definitions in the CGE core module include: tax rates, basic and purchase prices of commodities, tax revenues, margins, components of real and nominal GRP/GDP, regional and national price indices, money wage settings, factor prices, and employment aggregates.

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[5] Only the manufacturing activities were contemplated with this change due to data availability for estimation of the relevant parameters.

Government Finance Module

The government finance module incorporates equations determining the gross regional product (GRP), expenditure and income side, for each region, through the decomposition and modeling of its components. The budget deficits of regional governments and the federal government are also determined here. Another important definition in this block of equations refers to the specification of the regional aggregate household consumption functions. They are defined as a function of household disposable income, which is disaggregated into its main sources of income, and the respective tax duties.

Capital Accumulation and Investment Module

Capital stock and investment relationships are defined in this module. When running the model in the comparative-static mode, there is no fixed relationship between capital and investment. The user decides the required relationship on the basis of the requirements of the specific simulation.[6]

Foreign Debt Accumulation Module

This module is based on the specification proposed in ORANI-F (Horridge *et al*., 1993), in which the nation's foreign debt is linearly related to accumulated balance-of-trade deficits. In summary, trade deficits are financed by increases in the external debt.

Labor Market and Regional Migration Module

In this module, regional population is defined through the interaction of demographic variables, including rural-urban and interstate migration. Links between regional population and regional labor supply are provided.

3.2. Structural Database

The CGE core database requires detailed sectoral and regional information about the Brazilian economy. National data (such as input-output tables, foreign trade, taxes, margins and tariffs) are available from the Brazilian Statistics Bureau (IBGE). At the regional level, a full set of state-level accounts were developed at FIPE-USP (Haddad *et al*., 2002). These two sets of information were put together in a balanced interstate absorption matrix. Previous work in this task has been successfully implemented in interregional CGE models for Brazil (e.g. Haddad, 1999; Domingues, 2002; Guilhoto *et al*., 2002).

3.3. Behavioral Parameters

Experience with the B-MARIA framework have suggested that interregional substitution is the key mechanism that drives model's spatial results. In general, interregional linkages play an important role in the functioning of interregional CGE models. These linkages are driven by trade relations (commodity flows), and factor mobility (capital and labor migration). In the first case, of direct interest in our exercise, interregional trade flows should be incorporated in the model. Interregional input-output databases are required to calibrate the model, and regional trade elasticities play a crucial role in the adjustment process.

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[6] For example, it is typical in long-run comparative-static simulations to assume that the growth in capital and investment are equal (see Peter *et al*., 1996).

One data-related problem that modelers frequently face is the lack of such trade elasticities at the regional level. The pocket rule is to use international trade elasticities as benchmarks for "best guess" procedures. However, a recent study by Bilgic *et al*. (2002) tends to refute the hypothesis that international trade elasticities are lower bound for regional trade elasticities for comparable goods, an assumption widely accepted by CGE modelers. Their estimates of regional trade elasticities for the U.S. economy challenged the prevailing view and called the attention of modelers for proper estimation of key parameters. In this sense, an extra effort was undertaken to estimate model-consistent regional trade elasticities for Brazil, to be used in the B-MARIA-27 Model.

Other key behavioral parameters were properly estimated; these include econometric estimates for scale economies; econometric estimates for export demand elasticities; as well as the econometric estimates for regional trade elasticities. Another key set of parameters, related to international trade elasticities, was borrowed from a recent study developed at IPEA, for manufacturing goods, and from model-consistent estimates in the EFES model for agricultural and services goods.

3.4. Modeling of Transportation Costs

The set of equations that specify purchasers' prices in the B-MARIA model imposes zero pure profits in the *distribution* of commodities to different users. Prices paid for commodity *i* from region *s* in region *q* by each user equate to the sum of its basic value and the costs of the relevant taxes and margin-commodities.

The role of margin-commodities is to facilitate flows of commodities from points of production or points of entry to either domestic users or ports of exit. Margin-commodities, or, simply, margins, include transportation and trade services, which take account of transfer costs in a broad sense.[7] Margins on commodities used by industry, investors, and households are assumed to be produced at the point of consumption. Margins on exports are assumed to be produced at the point of production. The margin demand equations show that the demands for margins are proportional to the commodity flows with which the margins are associated; moreover, a technical change component is also included in the specification in order to allow for changes in the implicit transportation rate. The general functional form used for the margin demand equations is presented below:

$$XMARG(i,s,q,r) = AMARG(i,s,q,r)*[\eta(i,s,q,r)*X(i,s,q,r)^{\theta(i,s,q,r)}] \qquad (1)$$

where *XMARG(i,s,q,r)* is the margin *r* on the flow of commodity *i*, produced in region *r* and consumed in region *q*; *AMARG(i,s,q,r)* is a technology variable related to commodity-specific origin-destination flows; $\eta(i,s,q,r)$ is the margin rate on specific basic flows; *X(i,s,q,r)* is the flow of commodity *i*, produced in region *r* and consumed in region *q*; and $\theta(i,s,q,r)$ is a parameter reflecting scale economies to (bulk) transportation. In the calibration of the model, $\theta(i,s,q,r)$ is set to one, for every flow.

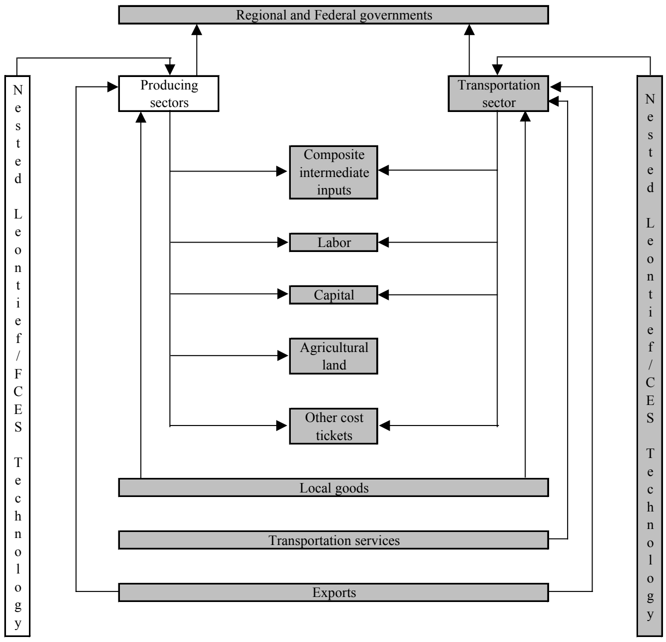
In B-MARIA-27, transportation services (and trade services) are produced by a regional resource-demanding optimizing transportation (trade) sector. A fully specified PPF has to be introduced for the transportation sector, which produces goods consumed directly by users and consumed to facilitate trade, i.e. transportation services are used to ship commodities from the point of production to the point of consumption. The explicit modeling of such transportation services, and the costs of moving products based on origin-destination pairs, represents a major theoretical advance (Isard *et al*., 1998), although it makes the model structure rather complicated in practice (Bröcker, 1998b). As will be shown, the model is calibrated by taking into account the specific transportation structure cost of each

[7] Hereafter, transportation services and margins will be used interchangeably.

commodity flow, providing spatial price differentiation, which indirectly addresses the issue related to regional transportation infrastructure efficiency. In this sense, space plays a major role.

Figure 4 highlights the production technology of a typical regional transport sector in B-MARIA in the broader regional technology. Regional transportation sectors are assumed to operate under constant returns to scale (nested Leontief/CES function), using as inputs composite intermediate goods – a bundle including similar inputs from different sources.[8] Locally supplied labor and capital are the primary factors used in the production process. Finally, the regional sector pays net taxes to Regional and Federal governments. The sectoral production serves both domestic and international markets.

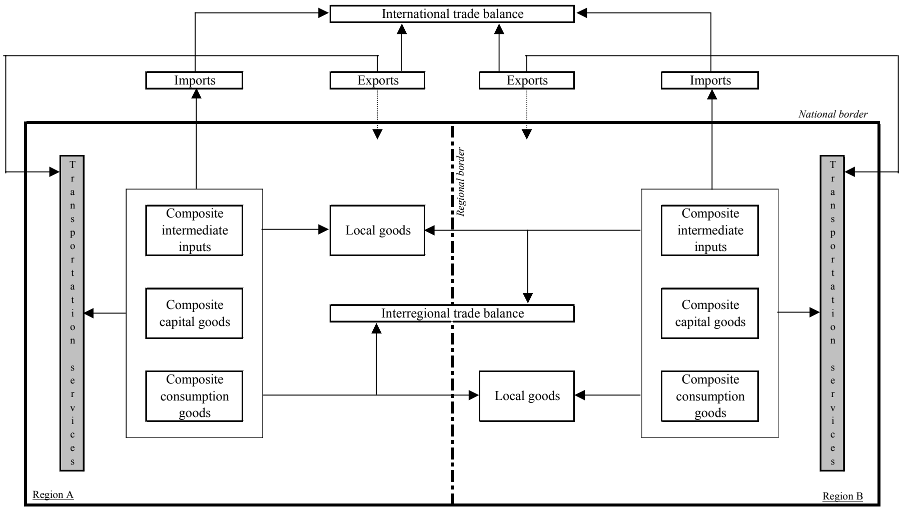
Figure 4. Flowchart with regional production technology in B-MARIA-27: Highlighting the transportation sector



As already mentioned, the supply of the transportation sector meets margin and non-margin demands. In the former case, Figure 5 illustrates the role of transportation services in the process of facilitating commodity flows. In a given consuming region, regionally produced transportation services provide the main mechanism to physically bring products (intermediate inputs, and capital and consumption goods) from different sources (local, other regions, other countries) to within the regional border. Also, foreign exporters use transportation services to take exports from the production site to the respective port of exit.

[8] The Armington assumption is used here.

Figure 5. The role of transportation services in B-MARIA-27: Illustrative flowchart in a two-region integrated framework



The explicit modeling of transportation costs, based on origin-destination flows, which takes into account the spatial structure of the Brazilian economy, creates the capability of integrating the interstate CGE model with a geo-coded transportation network model, enhancing the potential of the framework in understanding the role of infrastructure on regional development. Two options for integration are available, using the linearized version of the model, in which equation (1)[9] becomes:

$$xm\arg(i,s,q,r) = am\arg(i,s,q,r) + \theta(i,s,q,r) * x(i,s,q,r) \qquad (2)$$

Considering a fully specified geo-coded transportation network, one can simulate changes in the system, which might affect relative accessibility (e.g. road improvements, investments in new highways). A minimum distance matrix can be calculated *ex ante* and *ex post*, and mapped to the interregional CGE model. This mapping includes two stages, one associated with the calibration phase, and another with the simulation phase; both of them are discussed below.

3.4.1. Integration in the Calibration Phase

In the interstate CGE model, it is assumed that the *locus* of production and consumption in each state is located in the state capital. Thus, the relevant distances associated with the flows of commodities from points of production to points of consumption are limited to a matrix of distances between state capitals. Moreover, in order to take into account intrastate transfer costs, it is assumed that trade within the state takes place on an abstract route between the capital and a point located at a distance equal to half the implicit radius related to the state area.[10] The transport model calculates the minimum interstate time-distances, considering the existing road network in 1997. As Castro *et al.* (1999) observe, road transportation (i.e. truck) is responsible for the largest share of interstate trade in Brazil, accounting for well over 70% of the total value transported. In Brazil's North, however, fluvial transportation is particularly important, but the low quality of the services implies equivalent (high) logistic costs.

The process of calibration of the B-MARIA-27 model requires information on the transport and trade margins related to each commodity flow. Aggregated information for margins on intersectoral transactions, capital creation, household consumption, and exports are available at the national level.

[9] Equation (A12) in the Appendix.
[10] Given the state area, we assume the state is a circle and calculate the implicit radius.

The problem remains to disaggregate this information considering previous spatial disaggregation of commodity flows in the generation of the interstate input-output accounts. Thus, given the available information – interstate/intrastate commodity flows, transport model, matrix of minimum interregional distances and national aggregates for specific margins, the strategy adopted considered the following steps:

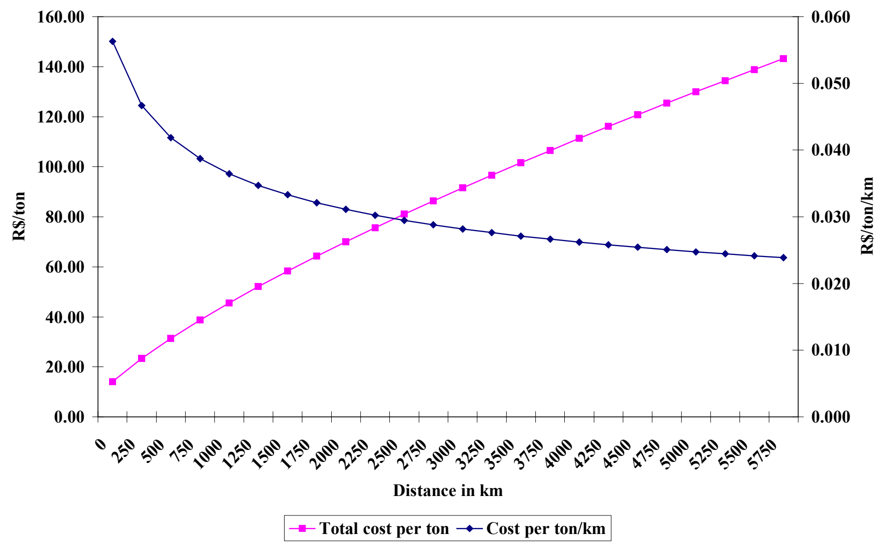
1. In an attempt to capture scale effects in transportation – long-haul economies, a tariff function was used to calculate implicit logistic road transport costs in the interstate Brazilian system.[11] The function considered was estimated by Castro *et al*. (1999), for 1994, using freight cost data: $tariff = 0.25 * dist^{0.73}$, where *tariff* is the road transportation tariff; and *dist* refers to the distance between two points. This information was then combined with the matrix of minimum interstate distances to generate a matrix of tariffs evaluated for each path. Long-haul effects are clearly perceived in Figure 6, which plots tariffs for different distances within the relevant range for Brazilian interstate trade.

2. By using such transportation structure, one can capture not only the above-mentioned scale effects, but also relative transfer costs by different origin-destination pairs, which are to be used further on. With that in mind, an index of relative transportation cost was generated. The rows of the tariff matrix were normalized, providing information on differential transportation costs from a given state capital to other state capital, when compared to intrastate costs.

3. The estimates of the various commodity flows at basic values, embedded in the interstate input-output accounts, were then multiplied by the relevant indices from the normalized tariff matrix. This procedure provides the necessary information to generate a distribution matrix, which considers different spatial-destination weights for commodity flows originating in a given state.

4. Finally, the distribution matrix was applied to national totals, considering disaggregated national information on margins by different users, maximizing the use of available information. Further balancing was necessary during the calibration of the model.

Figure 6. Estimated logistic road transport cost function: (Castro *et al*., 1999)



In summary, the calibration strategy adopted here takes into account explicitly, for each origin-destination pair, key elements of the Brazilian integrated interstate economic system, namely: a) the

[11] The general form of transport cost functions (…) is either linear or concave with distance. These reflect the usual empirical observations of the relationship between transport costs and haulage distance (McCann, 2001).

type of trade involved (margins vary according to specific commodity flows); b) the transportation network (distance matters); and c) scale effects in transportation, in the form of long-haul economies. Moreover, the possibility of dealing explicitly with increasing returns to transportation is also introduced in the simulation phase.

3.4.2. Integration in the Simulation Phase

When running simulations with B-MARIA-27, one may want to consider changes in the physical transportation network. For instance, one may want to assess the spatial economic effects of an investment in a new highway, expenditures in road improvement, or even the adoption of a toll system, all of which will have direct impacts on transportation costs, either by reducing travel time or by directly increasing out-of-the pocket transfer payments. The challenge becomes one of finding ways to translate such policies into changes in the matrix of minimum interregional time-distances, mimicking potential reductions/increases in the distance between two or more points in space. Such a matrix serves as the basis for integrating the transport model to the interregional CGE model in the simulation phase.

One way to integrate both models, in a sequential path, requires the use of either the variable *amarg(i,s,q,r)* or the parameter $\theta(i,s,q,r)$, in equation (2), as linkage variables. Changes in the matrix of interregional distances are calculated in the transport model, so that an interface with the interregional CGE model is created.[12] As in the specification of the margin demand equations the variable distance is only implicitly portrayed in the parameter $\eta(i,s,q,r)$, one has to come up with ways in which the information generated by the transport model can be suitably incorporated. Specific transfer rates are present in the model, and changes in them can be easily associated with changes in the matrix of distances.

Let us consider, as an example, a two-region economy, consisted of regions A and B. Let us assume the minimum distance through the existing road network is 100km, on a highway that allows the maximum speed of 50 km/h. Thus, traveling 100 km between A and B takes 2 hours. Moreover, the transfer rate for the only commodity flow, from A to B, is 10%. If the government undertakes a project to improve the A-B link, so that, in the operational phase, maximum speed increases to 80 km/h, a change in the transfer rate due to a change in distance – in our example, travel time reduces to one hour and fifteen minutes (time reduction of 37.5%) – may be estimated, using a model-consistent transfer rate function. A new highway project may also be considered, and a more efficient road design may reduce distance between A and B to, say, 75 km. In this sense, if the new road speed limit is also 50 km/h, one can consider a shortening of distance of 25%. Other similar examples apply.

In the B-MARIA-27 model, information on transfer (trade and transport) rates is available, and so is information on the relevant distances, enabling estimation of a model-consistent transportation cost function. With that in hand, changes in transfer rates can be estimated and incorporated in the interregional CGE model, as follows. Rearranging equation (1), we have:

$$\frac{XMARG(i,s,q,r)}{X(i,s,q,r)^{\theta(i,s,q,r)}} = AMARG(i,s,q,r) * \eta(i,s,q,r) \qquad (3)$$

with $\theta(i,s,q,r) = 1$ implying that the left-hand-side becomes the specific transfer (trade or transport) rate. A percentage change in the transfer rate can then be mapped into the technology variable,

[12] This procedure assumes one can translate time distance into Euclidean distance. Ideally, one should use a minimum *time* distance matrix to avoid shortcomings in the process mentioned above.

AMARG(i,s,q,r). Thus, in percentage-change form, *amarg(i,s,q,r)* becomes the relevant linkage variable, as:

$$xm\arg(i,s,q,r) - x(i,s,q,r) = am\arg(i,s,q,r) \qquad (4)$$

The parameter $\theta(i,s,q,r)$ can also be used in the simulation phase, especially in sensitivity analysis experiments. Suppose, for instance, that scale effects to transportation appear for a given commodity flow, in a specific path. Changing assumptions on the values of $\theta(i,s,q,r)$ allows for addressing this issue in a proper way, instead of relying on hypotheses on the linkage variable, *AMARG(i,s,q,r)*. On this issue, Cukrowski and Fischer (2000), and Mansori (2003) have shown that these spatial implications are considered in the context of international trade, and therefore, increasing returns to transportation should be carefully considered.

3.5. Closure

B-MARIA-27 contains 608,313 equations and 632,256 unknowns. Thus, to close the model, 23,943 variables have to be set exogenously. In order to capture the "first-round" effects of lowering tariffs, the simulations were carried out under a standard short-run closure. A distinction between the short-run and long-run closures relates to the treatment of capital stocks encountered in the standard microeconomic approach to policy adjustments. In the short-run closure, capital stocks are held fixed, while, in the long-run, policy changes are allowed to affect capital stocks. In addition to the assumption of interindustry and interregional immobility of capital, the short-run closure would include fixed regional population and labor supply, fixed regional wage differentials, and fixed national real wage. Regional employment is driven by the assumptions on wage rates, which indirectly determine regional unemployment rates. On the demand side, investment expenditures are fixed exogenously – firms cannot reevaluate their investment decisions in the short-run. Household consumption follows household disposable income, and government consumption, at both regional and federal levels, is fixed (alternatively, the government deficit can be set exogenously, allowing government expenditures to change). Finally, since the model does not present any endogenous-growth-theory-type specification, technology variables are exogenous (Peter, 1997).

4. Simulation Results

The effects of increases in port efficiency are discussed in this section. The B-MARIA-27 model was applied to analyze the "first-round" spatial effects on the Brazilian economy of a uniform 25% decrease in all transborder rates (efficiency gains). This experiment is called "basic simulation".

The "benchmark simulation" is used to put the results into perspective.[13] It considers trade liberalization with implicit transportation costs associated with hypothetical import/export corridors. In the benchmark simulation, the results are obtained in two stages. First, all exogenous variables were set equal to zero, except the changes in the power of tariffs of tradable goods (agriculture and manufacturing goods), i.e., one plus the tariff rates, which were set such that the percentage change decrease in each tariff rate was 25%.[14] In the second stage, in order to capture the role of the transportation infrastructure in the price transmission mechanism of import prices cuts, the concept of import/export corridors was introduced. In the calibration of the ICGE model, transportation margins on import flows considered only transborder costs, contrary to domestic flows, which, as explained in

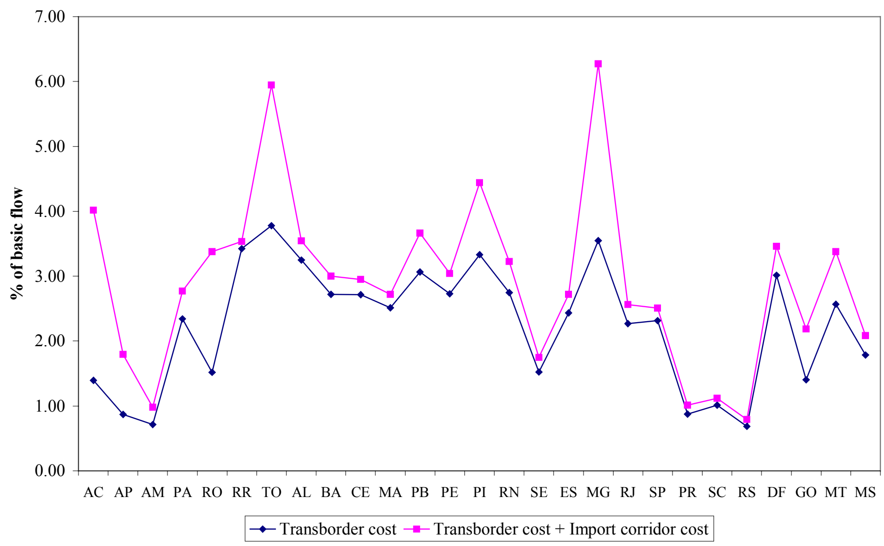
[13] The results are fully described in Haddad and Perobelli (2005).

[14] Because of the nature of the database, it should be pointed out that the model deals with changes in the *real* tariff rates (the ratio of import tax collected over the volume of imports), as opposed to *nominal* tariff rates.

the previous section, fully considered transportation costs based on origin-destination pairs. In so being, imports were assumed to enter directly the specific consumer markets, facing only transborder costs.[15] The implicit assumption was that each state economy constituted the port of entry of its own imports. However, when we observe the spatial distribution of the ports of entry/exit for the state imports/exports, a completely different picture emerges, as some states rely heavily on ports of entry locate outside the state borders.[16]

To deal with this issue, Haddad and Perobelli (2005) estimated the implicit transportation costs associated with hypothetical import/export corridors. They used the information on the spatial distribution of the ports of entry/exit for the state imports/exports and the specific transportation margin rates for each interstate link to estimate the transportation margin rate associated with the 27 (+27) hypothetical import/export corridors. To incorporate these costs in the estimates of the impact of trade liberalization, they then rerun the tariff cut simulation (first stage) including the import corridors cost through specific shocks in the components of the linkage-variable *amarg(i,s,q,r)*. The shocks were calculated considering the percentage change difference between the effective cost (transborder cost and the cost of shipping the goods from the ports of entry to the place of consumption) and transborder costs only (Figure 7 shows the differences for import flows). Two sets of results come out: a) one related to the basic simulation, which **does not include** the transportation costs associated with the import/export corridors; and b) one related to the counterfactual simulation, which **includes** such costs. By comparing the two sets of results, they can assess the role played by the friction of distance and of internal transportation costs in generating an imperfect price transmission mechanism in the country, which potentially hampers the effects of trade liberalization on growth, especially to the more remote regions.

Figure 7. Transborder and import corridor costs: by state (in % of total value of basic flows of imported goods)



By considering explicitly the distribution costs of **imports** from the ports of entry to the place of consumption, they have shown that high internal transportation costs impose spatial impediments for the internal transmission of the potential benefits of trade liberalization, hampering the more remote regions in terms of growth. When the distribution costs of **exports** are also considered, there appears clearly a "coastal effect", characterizing two spatial regimes in the Brazilian economy. In other words,

[15] Transborder costs were measured as a weighted average of transportation margins, based on the volume of imports/exports of each state economy and the national totals by specific import/export flow.
[16] Further complication emerges when we consider also the spatial distribution of ports of exit (exports corridors).

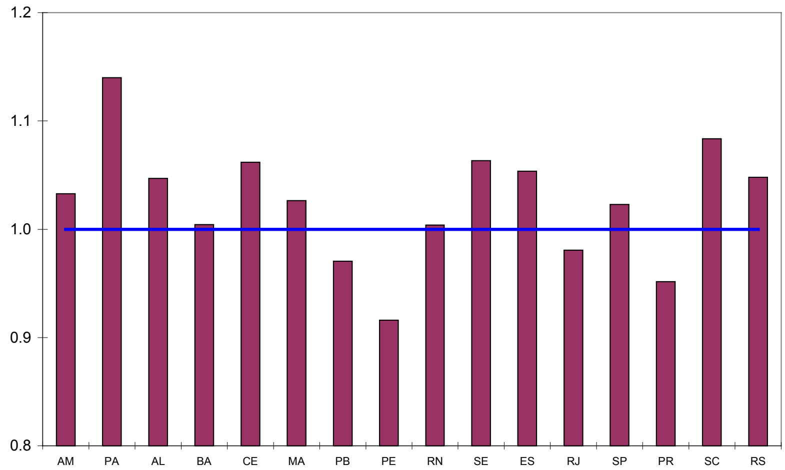
the effects of trade liberalization are further hindered by additional spatial impediments in the form of higher transportation costs associated with the transfer of goods form the points of production to the ports of exit.

Back to the basic simulation, the shocks were given initially in the components of *amarg(i,s,q,r)* related to transborder costs associated with foreign flows of goods at the **ports of entry**, i.e. only the effects on the import side. These costs are constructed considering information on the share of state imports by navigations, the location of ports (Map 1), the distribution of imports by ports of entry, and existing "relative efficiency" among ports (Figure 8).

Map 1. Main Brazilian Ports

Source: Ministério dos Transportes

Figure 8. Relative port efficiency in Brazil: By state



Tables 1 and 2 summarize the simulation results on selected macro and state variables. The firs two columns of results present the results of the benchmark simulation, revealing the compounded effect of the stages. The third and the fourth columns of results, under the "port efficiency" label, includes the efficiency gains in port activities in the two cases of the benchmark simulation, while the fifth column presents the net results associated with reduction in transborder costs in the broader case – which considers not only tariff reduction, but also the cost effects of import corridors.

Overall, efficiency gains in port of entry activities have a positive effect both in real GDP growth and welfare. In terms

The real GDP of Brazil is shown to increase with all the macro-regions positively affected. Regarding the regional distribution of income, the efficiency gains seems to improve the relative position of the Southeast, together with some states outside the more dynamic region of the country, even though that is a Pareto-improvement situation (outcome of port policy is said to be Pareto superior to outcome without transborder costs change, as GRP improves in all the regions).

At the sectoral level, there seems to be a shift against the production of transportation services, as expected. As resources are scarce, the reduction in the production of transportation services is performed at the gains of other sectoral output, especially from sectors producing tradable goods, which face stronger competition from foreign products.

Regarding the spatial effects (Figure 9), there appears to be a spatial shift of the relative benefits of port efficiency gains towards the coastal states, where a large part of the ports locate.[17]

Table 1. Aggregate results: Selected variables (in percentage-change)

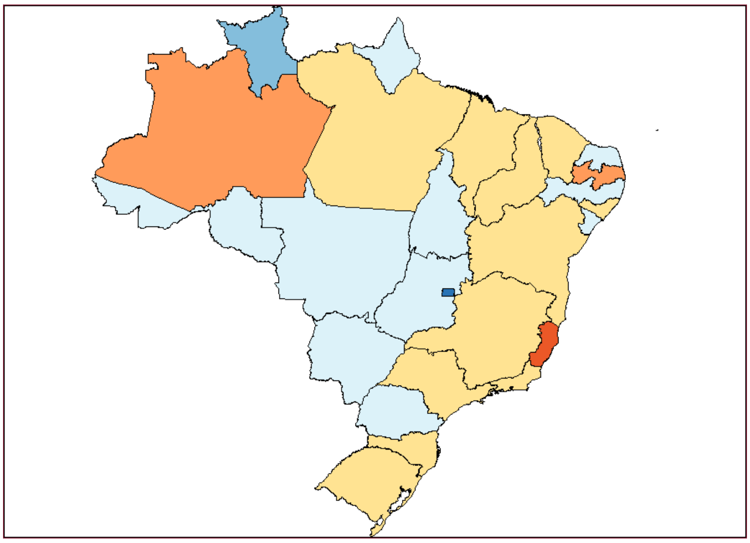
				Port efficiency		
	Import corridors costs			*Import corridors costs*		*Net effect*
	Non-included	*Included*		*Non-included*	*Included*	
Activity level						
Agriculture	0.0252	0.0195		0.0302	0.0245	0.0050
Manufacturing	-0.0112	-0.0224		-0.0006	-0.0118	0.0106
Utilities	0.0155	0.0156		0.0157	0.0158	0.0002
Construction	0.0017	0.0024		0.0010	0.0017	-0.0007
Trade	0.0419	0.0419		0.0408	0.0408	-0.0011
Financial institutions	0.0460	0.0426		0.0540	0.0506	0.0080
Public administration	0.0132	0.0123		0.0145	0.0136	0.0013
Transportation and other services	0.0597	0.0906		0.0286	0.0595	-0.0311
Prices						
Investment price index	-0.5836	-0.5157		-0.6813	-0.6134	-0.0977
Consumer price index	-0.4395	-0.3461		-0.5015	-0.4081	-0.0620
Exports price index	-0.4838	-0.4316		-0.5692	-0.5170	-0.0854
Regional government demand price index	-0.4472	-0.3597		-0.4969	-0.4094	-0.0497
Federal government demand price index	-0.4410	-0.3460		-0.5210	-0.4260	-0.0800
GDP price index, expenditure side	-0.4997	-0.4079		-0.5874	-0.4956	-0.0877
Primary factors						
Aggregate payments to capital	-0.3030	-0.2042		-0.3933	-0.2945	-0.0903
Aggregate payments to labor	-0.3817	-0.2766		-0.4794	-0.3743	-0.0977
Aggregate employment, wage bill weights	0.0580	0.0697		0.0457	0.0574	-0.0123
Aggregate demand						
Real household consumption	0.0521	0.0517		0.0526	0.0522	0.0005
Export volume	1.0028	0.8927		1.1064	0.9963	0.1036
Aggregate indicators						
Equivalent variation – total (change in $)	1670.7	1664.5		1689.8	1683.6	19.0631
Real GDP	0.0326	0.0215		0.0431	0.0320	0.0105

[17] In the reading of the maps, hereafter, warm colors (orange and green) represent values above the average, in terms of standard deviations; cold colors (blue) represent values below the average, also in terms of standard deviations; warmer/colder colors represent outliers.

Table 2. Effects on real GRP

	Import corridors costs			Port efficiency		
				Import corridors costs		Net effect
	Non-included	Included		Non-included	Included	
North	0.0291	-0.0372		0.0509	-0.0154	0.0218
Northeast	0.0128	0.0044		0.0237	0.0153	0.0109
Southeast	0.0235	0.0120		0.0367	0.0252	0.0132
South	0.0109	0.0033		0.0202	0.0126	0.0093
Center-West	0.0214	0.0193		0.0218	0.0197	0.0004

Figure 9. State effects on regional growth (real GSP) – Ports of entry (standard deviation)



5. Final Remarks

So far, we have analyzed only one side of the token. It is agreed that constraints towards export expansion can also be perceived as a further barrier to link trade liberalization and growth. As a topic for further investigation, the role of efficiency gains in **ports of exit** must be considered in order to grasp the holistic picture.

To tackle this issue, we proceeded further by also estimating the GRP effects of increase in efficiency of the ports of exit, in a similar fashion as the procedure for ports of entry. Figure 10 presents the spatial results, showing the joint contributions to the specific deviations of the policy basic outcome, in terms of GDP growth. Figure 11 considers the whole picture associated with both the benchmark and the basic simulation. There appear clearly three spatial regimes in the Brazilian economy. First, a space associated with "primary exporters", in which the transportation infrastructure is sparse and the main links and nodes are easily associated with specific and scattered export activities. Second, an "intermediate space", which assumes a role of transition in the context of the interface of the Brazilian interregional system with the world economy, and is more articulated with the domestic markets. Third, a denser economic space, more integrated with the world economy, where port efficiency plays a crucial role in affecting its overall competitiveness; this third group includes Brazilian "global traders".

Figure 10. State effects on regional growth (real GSP) – Ports of exit (standard deviation)

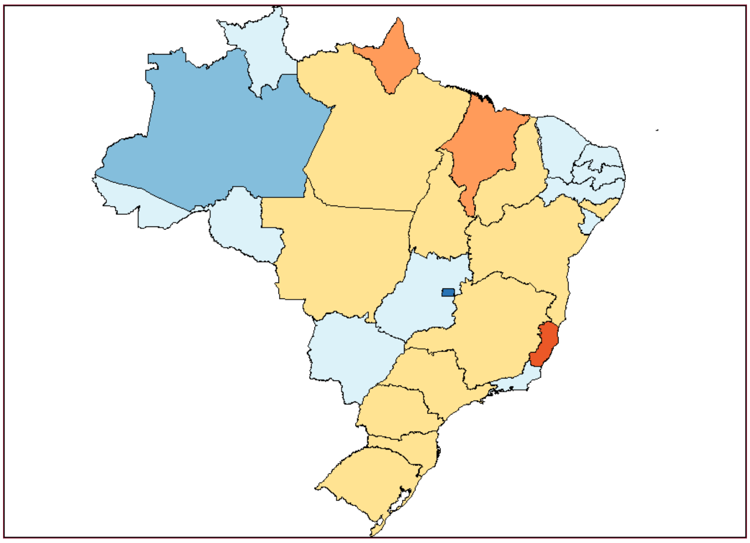
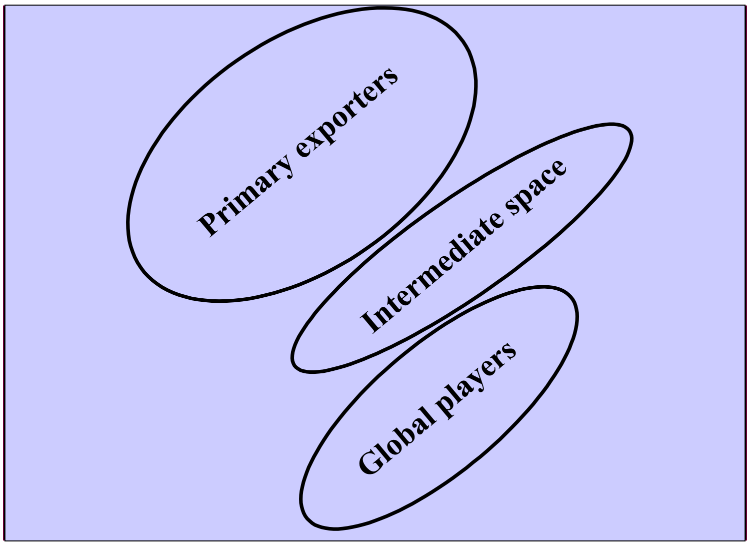


Figure 11. State effects on regional growth (real GSP) – The "whole" picture (standard deviation)



The results of this analysis suggest that formal consideration of nodes in a transportation network is required if the full implications of transportation costs are to be considered in CGE models. While the insights gained from integrating a transport network with the multi-region CGE model are substantial, in cases where nodal inefficiencies play a key role as is in the case in Brazil and much of Latin America, it becomes important to separate out link and node costs. From a policy perspective this separation is even more important. Brazil faces daunting challenges to identify the necessary resources to upgrade its infrastructure; the choice of ports for such investment will have significant implications on the hinterlands serving those ports (and other areas that may be able to access them once the investments have been completed). Hence, there are very strong regional development policy implications; if Brazil focuses attention on upgrading ports in the more developed southeast, the result may be a further erosion of prospects for the less developed north and northeast to grow fast enough to reduce disparities in welfare levels. Further, improvements in port efficiency in the southeast may generate greater bilateral trade with countries whose goods destined for Brazil may further displace those currently produced in the northeast.

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