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Assessing the ex ante economic impacts of transportation infrastructure policies in Brazil

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This paper uses a fully operational inter-regional computable general equilibrium (CGE) model implemented for the Brazilian economy, based on previous work by Haddad and Hewings, in order to assess the likely economic effects of road transportation policy changes in Brazil. Among the features embedded in this framework, modelling of external scale economies and transportation costs provides an innovative way of dealing explicitly with theoretical issues related to integrated regional systems. The model is calibrated for 109 regions. The explicit modelling of transportation costs built into the inter-regional CGE model, based on origin–destination flows, which takes into account the spatial structure of the Brazilian economy, creates the capability of integrating the inter-regional CGE model with a geo-coded transportation network model enhancing the potential of the framework in understanding the role of infrastructure on regional development. The transportation model used is the so-called Highway Development and Management, developed by the World Bank, implemented using the software TransCAD. Further extensions of the current model specification for integrating other features of transport planning in a continental industrialising country like Brazil are discussed, with the goal of building a bridge between conventional transport planning practices and the innovative use of CGE models. In order to illustrate the analytical power of the integrated system, the authors present a set of simulations, which evaluate the ex ante economic impacts of physical/qualitative changes in the Brazilian road network (for example, a highway improvement), in accordance with recent policy developments in Brazil. Rather than providing a critical evaluation of this debate, they intend to emphasise the likely structural impacts of such policies. They expect that the results will reinforce the need to better specifying spatial interactions in inter-regional CGE models.

Keywords: ex ante impact analysis; transportation; infrastructure; regional analysis; general equilibrium

1. Introduction

One of the main obstacles to economic development in Brazil is the so-called *Custo Brasil*, the extra costs of doing business in the country. Enterprises are faced with a heavy burden that competing firms in other countries do not confront, hampering competitiveness. It

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includes different components that represent distortions in the relation between the public and the private sectors, reflecting inadequate legislation and deficient provision of public goods. Ongoing debate centres on the contribution of different sectors to the *Custo Brasil*: labour costs; transportation infrastructure; the tax system; and the regulatory system.

A study by the World Bank (1996) in the mid-1990s provided a comprehensive examination of the diverse components of the *Custo Brasil* and an exploration of their implications for total firm costs. Regarding land transport costs, which are often viewed as a significant component of the *Custo Brasil*, the available evidence collected for the report suggested that the costs of providing rail and trucking services were high in Brazil. Nevertheless, because of overcapacity and significant competition in trucking, these costs are not passed on to shippers; transport rates per ton-kilometre are low by international standards. The principal problem with land transportation, from the point of view of shippers, is not the unit costs of different modes of transportation, but rather excessive reliance on trucking. Railroad and barge transport over long distances are far cheaper than trucking, particularly for bulk commodities. Inefficiencies and low productivity in the railroad sector have meant that the percentage of total cargo carried by trucks in Brazil is approximately twice as large as the share in Australia and the United States.

More than 10 years after the aforementioned World Bank study, the situation in the transportation sector did not change. Brazilian transport infrastructure is deteriorating fast from lack of investment and maintenance, showing an increased number of critical points, or bottlenecks, in most of the corridors. Decay in the transportation system curtails economic growth, hampering competitiveness both in the internal and external markets. Deterioration of Brazil's transportation network in the past years contributed to high operational costs, obstructing the competitive integration of the country.

The federal government has signalled its intention in reviving long-term planning in transportation in the country. The design of an ambitious *Plano Nacional de Logística e Transportes* (National Plan of Logistics and Transportation) has been initiated, involving different stakeholders. It aims at supporting decision-makers in attaining economic objectives through policy initiatives related to both public and private infrastructure and organisation of the transportation sector.[1]

At the state level, few initiatives have taken place in the realm of transport planning. States such as Bahia, Rio Grande do Sul, Minas Gerais and Pará have all developed thorough diagnosis of the sector, including forward-looking exercises with a long-term view on the available possibilities for policy intervention within the respective state borders.[2]

As a recent report by the World Road Association (2003, p. 7) points out, there is a growing need for economic and socio-economic models for helping improving road management. This paper provides an attempt to meet this requirement. We use a fully operational inter-regional computable general equilibrium (CGE) model implemented for the Brazilian economy, based on previous work by Haddad and Hewings (2005), in order to assess the likely economic effects of recent road transportation policy changes in Brazil. Among the features embedded in this framework, modelling of external scale economies and transportation costs provides an innovative way of dealing explicitly with theoretical issues related to integrated regional systems. The explicit modelling of transportation costs built into the inter-regional CGE model, based on origin–destination flows, which takes into account the spatial structure of the Brazilian economy, creates the capability of integrating the inter-regional CGE model with a geo-coded transportation network model enhancing the potential of the framework in understanding the role of infrastructure on regional development. The transportation model used is the so-called Highway

Development and Management Model, developed by the World Bank, implemented using the software TransCAD.

It is important to notice that the existing, commonly-used policy tools to address issues related to the economic impacts of transportation infrastructure policies do not come anywhere close to capturing some of the most important channels through which exogenous and transportation policy shocks are transmitted to the various dimensions of regional economic structures. Models are issue-specific; trying to 'force' a model to answer questions that it is not designed to address hampers our ability to address relevant policy questions (see Agénor *et al.* 2007). Thus, this paper provides quantitative and qualitative insights (general equilibrium effects) into trade-offs commonly faced by policy-makers when dealing with infrastructure projects in a spatial context. It shows that, given different policy options, decision-makers face non-trivial choices, as different projects perform differently in different dimensions, usually presenting outcomes with different hierarchies related to multi-dimensional policy goals.

The remainder of the paper is organised as follows. After the discussion of relevant modelling issues – focusing on the treatment of transportation costs in CGE models – 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. After that, the simulation experiments are designed and implemented, and the main results are discussed in Section 4. Final remarks follow in an attempt to evaluate our findings and put them into perspective, considering their extensions and limitations.

2. Modelling issues

The development of regional and inter-regional CGE modelling has experienced, in the past 15 years, an upsurge in interest. Different models have been built for different regions of the world. Research groups, located especially in Australia, Brazil, Canada, Germany, Scotland, and the United States, as well as individual researchers, contributed to these developments through the specification and implementation of a variety of alternative models. Recent theoretical developments in the new economic geography bring new challenges to regional scientists, in general, and inter-regional CGE modellers, in particular.[3]

Among the potential uses of inter-regional CGE models, we can mention the analysis of transport planning policies with ranging effects on regional and national economies. National and/or state-wide transport planning is a widely institutionalised process in several countries. The use of model-based analytical procedures is in the state of practice, including the application of conventional input–output methods for forecasting freight movements. Nevertheless, the feedback impact of transport actions on the regional and/or national economies is not fully accounted for in these procedures. In recent years, the development of improved techniques was the focus of several efforts joining the transport and economics research fields in the USA (for example, Friez *et al.* 1998) and the European Union (for example, Bröcker 2002), without forgetting efforts of Asian countries (for example, Miyagi 2001) and Brazil (for example, Pietrantonio 1999).

Investments in highways and other forms of improvements in the transportation system represent an important way of achieving regional and national economic growth. Expansion and improvements of transportation facilities can be used as a means to reduce firms' transaction costs and to expand the economic opportunities in a region/country, as it potentially helps to increase income and improve the standard of living of the resident population.

However, investments in transportation, in addition to its impact on systemic productivity, have potential differential impacts across economic spaces. Spatially localised interventions may increase regional competitiveness. External scale economies and accessibility effects would produce the expansion or contraction of the local firms' market areas and generate opportunities to access broader input markets. One of the fundamental elements to be taken into account is the spatial interaction among regions: changes in a given location may result in changes in other regions through the various types of relations (complementary and competitive) associated with the regional agents in the relevant economic spaces.

In this context, the modelling procedure developed in this paper represents an attempt to address some of these issues in the context of a unified approach, which enables the proper treatment of the role of transportation infrastructure in the allocation of resources in a given economy. The explicit modelling of transportation costs, in an inter-regional CGE model integrated into a geo-coded transportation network infrastructure model, will allow us to assess, under a macro spatial perspective, the economic effects of specific transportation projects and programmes.

2.1. Treatment of transportation costs

It has been noticed elsewhere (Haddad 2004) that current CGE models are not without their limitations to represent spatial phenomena. Isard's vision of integrated modelling, which anticipated the proposals reported in Isard and Anselin (1982), provided a road map for the development of more sophisticated analysis of spatial economic systems (Hewings 1986, Hewings *et al.* 2003). Given their many virtues, however, if adequately coped, inter-regional CGE models are the main candidates for the core subsystem in a fully integrated system.

The embedding of spatial trade flows into economic modelling, especially those related to inter-regional trade linkages, usually should go along with the specification of transportation services. Given existing inter-regional CGE models, one can identify at least three approaches for introducing the representation of transportation, all of them considering the fact that transportation is a resource-demanding activity.[4] This basic assumption is essential if one intends to properly model an inter-regional CGE framework, invalidating the model's results if not considered (see Isard *et al.* 1998).

3. The inter-regional CGE model

Our departure point is the B-MARIA model, developed by Haddad (1999). The B-MARIA model – and its extensions – has been widely used for assessing regional impacts of economic policies in Brazil. Since the publication of the reference text, various studies have been undertaken using, as the basic analytical tool, variations of the original model.[5] Moreover, critical reviews of the model can be found in the *Journal of Regional Science* (Polenske 2002), *Economic Systems Research* (Siriwardana 2001) and in *Papers in Regional Science* (Azzoni 2001).

The theoretical structure of the B-MARIA model is well documented.[6] In this paper, we develop a version of the B-MARIA model specified to deal with transportation policies in the state of Minas Gerais. We use a similar approach to Haddad (2004), and Haddad and Hewings (2005) to integrate the inter-regional CGE model with a geo-coded transportation network infrastructure model. However, instead of using a simpler transportation network

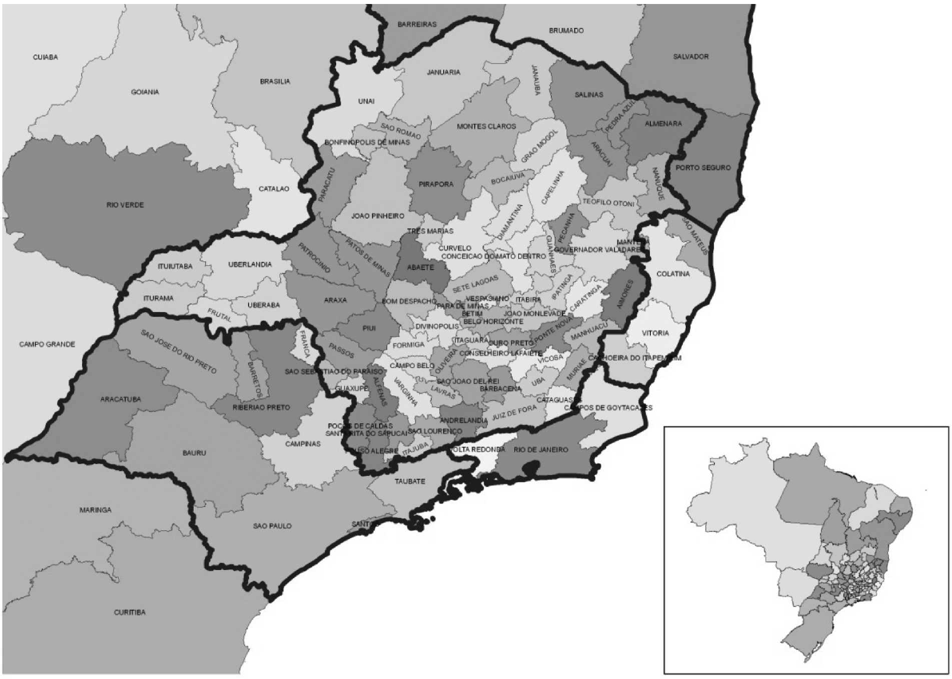

Figure 1. Regional setting in the B-MARIA-MG model.
Source: Elaborated by the authors.

model based on only one attribute of the links to deal with accessibility (that is, maximum speed), we use a more sophisticated model, the Highway Development and Management (HDM-4), developed at the World Bank.[7]

The model recognises the economies of 109 Brazilian regions, 75 within the state of Minas Gerais (Figure 1). Results are based on a bottom-up approach – that is, national results are obtained from the aggregation of regional results. The model identifies eight production/investment sectors in each region producing eight commodities,[8] one representative household in each region, regional governments and one Federal government, and a single foreign area that trades with each domestic region, through a network of ports of exit and ports of entry. Three local primary factors are used in the production process, according to regional endowments (land, capital and labour). The model is calibrated for 2002; a rather complete dataset is available for that year, 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 inter-regional input-output database (FIPE 2007), facilitating the choice of the base year.

The B-MARIA-MG framework includes explicitly some important elements from an inter-regional system, needed to better understand macro spatial phenomena; namely, inter-regional flows of goods and services, transportation costs based on origin-destination pairs, inter-regional movement of primary factors, regionalisation of the transactions of the public sector, and regional labour market segmentation. We list below the additional structural modifications implemented in the basic model, related both to specification issues and to changes in the database.

First, we have introduced the possibility of (external) non-constant returns in the production process, following Haddad (2004). This extension is essential to adequately represent one of the functioning mechanisms of a spatial economy. The modelling procedure adopted in B-MARIA-MG uses constant elasticity of substitution (CES) nests to specify the production technology. 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[9] in each one of the 109 regions were implemented in order to incorporate non-constant returns to scale, a fundamental assumption for the analysis of integrated inter-regional 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 modelling trick allows for the introduction of parametric external scale economies (rationalised as agglomeration economies), by exploring local properties of the CES function.

The second main modification, which addresses some of the modelling issues discussed in the previous section, refers to the introduction of links between the inter-regional CGE core and a geo-coded transportation network model, allowing for a more adequate characterisation of the spatial structure of the economy, in which the role of the transportation infrastructure and the friction of distance is explicitly considered.

3.1. *Modelling 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 supplied from region s and consumed 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.[10] 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.

In B-MARIA, transportation services (and trade services) are produced by a regional resource-demanding optimising transportation (trade) sector. A fully specified production possibility frontier has to be introduced for the transportation sector, which produces goods consumed directly by users and consumed to facilitate trade; that is, transportation services are used to ship commodities from the point of production to the point of consumption. The explicit modelling 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 inter-regional CGE model with a geo-coded transportation network model, enhancing the potential of the framework in understanding the role of infrastructure on regional development.

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 accounts was developed by FIPE (2007). These two sets of information were put together in a balanced inter-regional social accounting matrix. Previous work in this task has been successfully implemented in inter-regional CGE models for Brazil (for example, Haddad 1999, Domingues 2002, Perobelli 2004, Porsse 2005).

3.3. Behavioural parameters

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

One data-related problem that modellers frequently face is the lack of such trade elasticities at the regional level. An extra effort was undertaken to estimate model-consistent regional trade elasticities for Brazil (see Haddad and Hewings 2005).

Other key behavioural parameters were properly estimated; these include econometric estimates for scale economies (Haddad 2004); econometric estimates for export demand elasticities (Perobelli 2004); 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 (Instituto de Pesquisa Econômica Aplicada) (Tourinho *et al.* 2002), for manufacturing goods, and from model-consistent estimates in the EFES (Economic Forecasting Equilibrium System) model (Haddad and Domingues 2001) for agricultural and services goods.

3.4. Closures

In order to capture the effects of improvements in the transportation network, the simulations were carried out under two standard closures, referring to the short run and the long run. 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 inter-industry and inter-regional immobility of capital, the short-run closure would include fixed regional population and labour 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 re-evaluate their investment decisions in the short run. Household consumption follows household disposable income, and real government consumption, at both regional and federal levels, is fixed (alternatively, the government deficit can be set exogenously, allowing government expenditures to change). Finally, preferences and technology variables are exogenous.

A long-run (steady-state) equilibrium closure is used in which capital is mobile across regions and industries. Capital and investment are generally assumed to grow at the same rate. The main differences from the short-run are encountered in the labour market and the capital formation settings. In the first case, aggregate employment is determined by population growth, labour force participation rates, and the natural rate of unemployment. The distribution of the labour force across regions and sectors is fully determined endogenously. Labour is attracted to more competitive industries in more favoured geographical areas, keeping regional wage differentials constant. While in the same way, capital is oriented towards more attractive industries. This movement keeps rates of return at their initial levels.

4. Transportation infrastructure projects

In this section, we illustrate the analytical capability of the unified framework in the evaluation of specific transportation projects contemplated in the *Plano Estadual de Logística e Transportes* (PELT Minas). The case study under consideration refers to two projects of improvement of federal highways – BR-262 and BR-381 – in the State of Minas Gerais (Figure 2). The following analysis suggests a strategy of application of the framework developed here for the ex ante impact assessment of a project in a systemic context, in its operational phase. The impacts of the investment phase are not considered in these illustrative exercises. The goal is to explore the characteristics of the integrated model in the simulation phase and not to proceed with a systematic evaluation of the project, which is outside the scope of this paper. In what follows, we will assess the impacts on national variables, and on a broader set of socio-economic state variables.

The characteristics of the projects are detailed in a document prepared by FIPE (2007) for the Secretaria de Transportes e Obras Públicas. The guidelines that have been used to justify the choice of these specific tracks of the BR-262 and BR-381 highways to be improved are based upon the grounds of the strategic location of this network links in the national transportation system, which constitute two of the main corridors related to the more dynamic regions of the country. Moreover, it is hoped that such improvements will foster regional development in the State of Minas Gerais, one of the leading economies of the country.

With a total length of 441 km, between Betim and Uberaba, the BR-262 project consists of the duplication of the existing road link between Betim and Nova Serrana, and the construction of climbing and passing lanes between Nova Serrana and Araxá. Total costs of the project are estimated in BRL 554 million.[11]

The BR-381 project considers the duplication of the track between Belo Horizonte and Governador Valadares, in a total length of 304 km. Total costs of the implementation are estimated in BRL 1395 million.

BR-262 *BR-381*

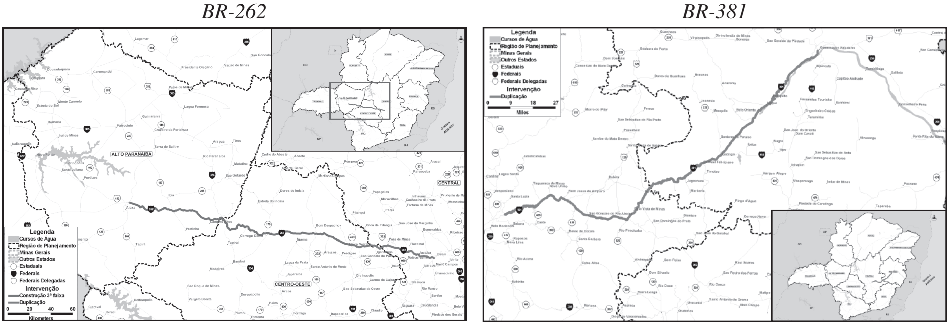

Figure 2. Location of road improvement projects.

Source: Elaborated by the authors based on the Secretaria de Transportes e Obras Públicas, Minas Gerais.

The distinction between the two projects lies on the role they play in the integration of Brazilian regions. While the BR-262 project constitutes a major improvement on the east–west integration of the country, linking the coast of the Southeast to the more agricultural areas of the Midwest, the BR-381 has a strategic role in the integration of the Northeast with the Southeast and South of the country. These distinct axes of integration play different roles in the inter-regional Brazilian system, as spatial competition occurs in a lower degree in the case of the BR-262 than in the case of the BR-381 link. In the latter case, denser economic spaces are directly involved in the spatial process, while in the former case, more specialised spaces have more prominent roles.

4.1. Functioning mechanism

The simulation exercise considers the implementation of two projects related to road improvements in the State of Minas Gerais. According to the model structure, this may represent a margin-saving change; that is, the use of transportation services per unit of output is reduced, implying a direct reduction in the output of the transportation sector. The reduction in transport cost decreases the price of composite commodities, with positive implications for real regional income: in this cost-competitiveness approach, firms become more competitive – as production costs go down (inputs are less costly); investors foresee potential higher returns – as the cost of producing capital also declines; and households increase their real income, envisaging higher consumption possibilities. Higher income generates higher domestic demand, while increases in the competitiveness of national products stimulate external demand. This creates room for increasing firms' output – directed for both domestic and international markets – which requires more inputs and primary factors. Increasing demand puts pressure on the factor markets for price increases, with a concomitant expectation that the prices of domestic goods would increase.

Second-order prices changes go in both directions – decrease and increase. The net effect is determined by the relative strength of the countervailing forces. Figure 3 summarises the transmission mechanisms associated with major first-order and second-order effects in the adjustment process underlying the model's aggregate results.

4.2. Results

The B-MARIA-MG model was used to estimate the short-run and long-run impacts of both projects, during their operational phases. The main results are discussed below.[12]

4.2.1. National impacts. Table 1 presents simulation results for national aggregates. Two distinct pictures emerge, embedding the specific structural differences between the two projects. In the case of the BR-262 project, more standard outcomes associated with commonsense expectation on infrastructure project arise.

Gains in efficiency (real Gross Domestic Product [GDP] growth) are positive in both the short run and the long run, while welfare gains (equivalent variation) are revealed only in the long run. Noteworthy is that, in the long run, the effects on GDP are magnified.

Changes in terms of trade tend to benefit Brazilian exports only in the short run, as the results point to increasing competitiveness of Brazilian products. This conclusion is reinforced by the performance of the international trade sector: exports volumes increase, leading GDP growth in the short run. When compared with other GDP components, international trade is the only component that presents a positive performance in the short run.

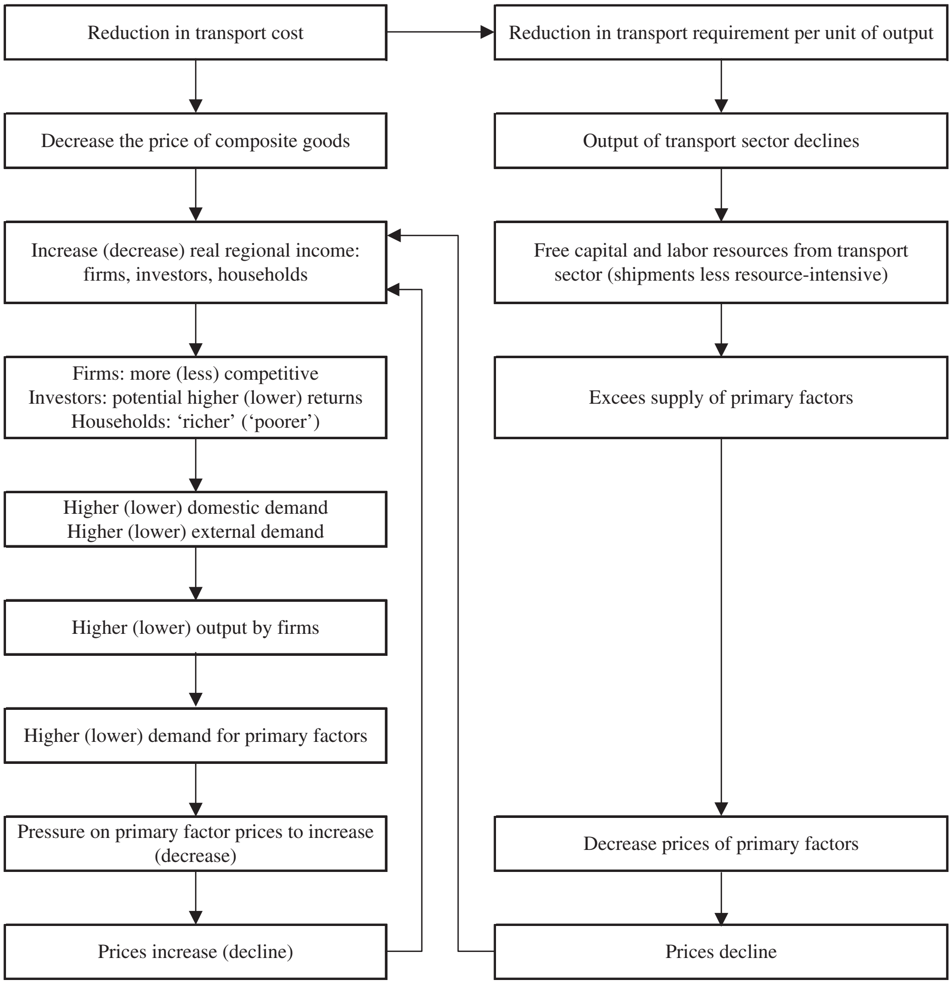

Figure 3. Causal relationships in the simulation.
Source: Elaborated by the authors.

In the long run, however, this situation is reversed. While stronger penetration of imported products is verified, due to the reversal of the terms of trade result, domestic absorption becomes the component in chief, leading GDP growth. The rationale behind this result is as follows. In the short run, components of domestic absorption are less prone to change; while in the long run, primary factors (both labour and capital) are more flexible. Pressures on primary factor prices to increase are, thus, less sensitive, allowing stronger fall in domestic costs of production. However, in this specific simulation, prices of exports tend to increase in relation to domestic prices, hampering the international trade balance.[13] This fact is intrinsically related to the location of the project, which situates in a position linking agricultural markets (in the west and central parts of the country) to important domestic centres of consumption, in the east. As this east–west link is not substantially associated with export corridors of the agricultural production, the positive impacts are heavily associated with benefits to domestic markets. Moreover, the very distinct nature of the respective

Table 1. National results: selected variables (percentage change).

	BR-262		BR-381	
	Short run	Long run	Short run	Long run
Aggregates				
Real GDP	0.00022	0.00105	0.00018	(0.00293)
Equivalent variation – total (change in $1,000,000)	(12.3)	58.6	(48.3)	6.4
Economy-wide terms of trade	(0.00180)	0.00040	(0.00674)	0.00299
GDP price index, expenditure side	(0.00240)	(0.01598)	(0.00818)	0.00242
GDP components				
Real household consumption	(0.00047)	0.00139	(0.00132)	(0.00344)
Real aggregate investment		0.00001		(0.00002)
Real aggregate regional government demand	(0.00217)	0.00129	(0.01301)	(0.00156)
Real aggregate federal government demand	(0.00047)	0.00139	(0.00132)	(0.00344)
International export volume	0.00385	(0.00017)	0.01456	(0.00683)
International import volume	(0.00239)	0.00019	(0.00823)	(0.00397)

Source: Elaborated by the authors.

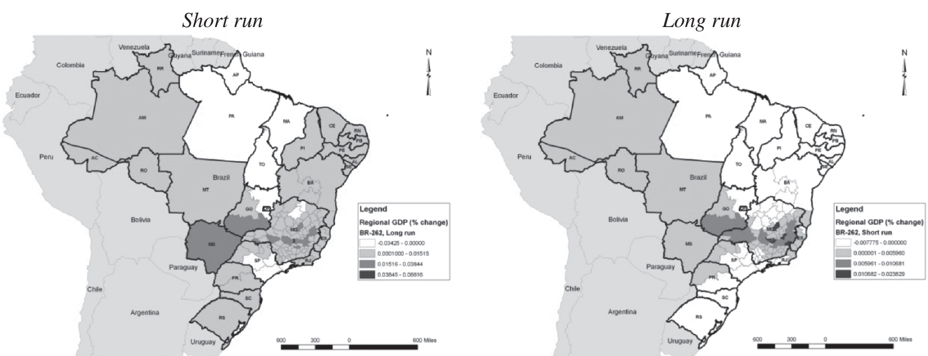

Figure 4. Spatial results: real GDP (percentage change): BR-262 project.
Source: Elaborated by the authors.

economic structures of the linked spaces imposes very weak spatial competition among regions in the area of influence of the BR-262.

In this sense, the spatial effects on GDP (Figure 4) reveal, both in the short run and in the long run, positive impacts in regions directly influenced by the BR-262. Noteworthy is that these positive impacts spread over space in the long run. Moreover, re-location effects tend to be directed to the agriculture-producing regions in the West as well as to the areas directly linked to the project itself within the borders of Minas Gerais.

Regarding the BR-381 project, macroeconomic short-run results are qualitatively equivalent to those presented by the BR-262 project: GDP growth led by the international sector and improvement in the terms of trade, as well as increasing overall competitiveness.

However, a seemingly surprising (to commonsense) result occurs: real GDP in the long run is projected to decrease, after the duplication project starts to operate. It should be

Short run *Long run*

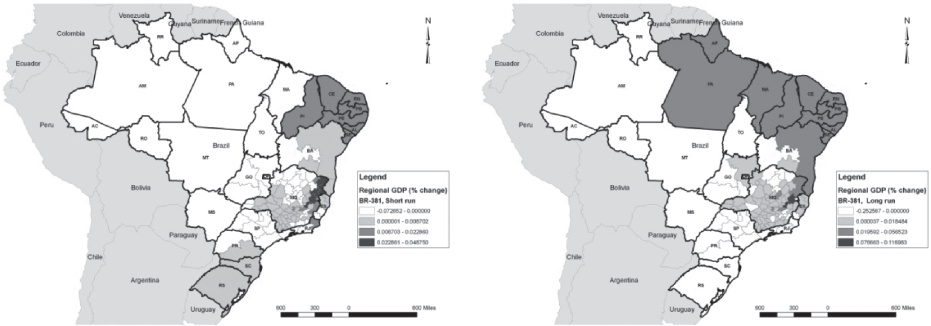

Figure 5. Spatial results: real GDP (percentage change): BR-381 project.
Source: Elaborated by the authors.

emphasised that BR-381 has a relevant role in the integration of the country – it is part of one of the major routes linking the Northeast to the South of the country.

Figure 5 helps us clarify this issue. It presents both short-run and long-run results on GDP, from a spatial perspective. Looking more closely at such results for the long run, an 'accounting' explanation for the negative real GDP result emerges. Regional contributions for national GDP show that regions with positive performance (74 of them) represent a total impact of 0.00388, while regions with negative performance (35) represent a total impact of –0.00682. Thus, the negative impact, in absolute terms, is 75 per cent greater than the positive one. The map indicates that negative impacts are concentrated in the whole South region, all regions in the states of São Paulo and Rio de Janeiro. Fifty-eight per cent of the total negative impact comes from the São Paulo regions, and 12 per cent from Rio de Janeiro. In the regions that present a positive performance, major contributions come from the Northeast, especially Salvador, Aracaju, and Fortaleza, representing 68 per cent of the total positive impact on GDP growth.

Short-run results represent a counterfactual situation characterised by less flexible mechanisms of inter-regional transmission, as the possibility of inter-regional factor mobility is precluded. In the case of the South (including São Paulo), there seems to be stronger competitive interdependence with Minas Gerais and the eastern economies of the Northeast, mainly the more industrialised ones. The results for real GDP, in percentage terms, make this feature more evident, as economic growth of Minas Gerais and the Northeast is verified at the expense of growth in those economies south of Minas Gerais, even though the western economies of the Northeast, Tocantins and Mato Grosso present negative performance.

In the long run, the behavioural parameters have an even more prominent role in the functioning of the model. Re-location effects of capital and labour operate defining a new geography of winners and losers. The state of Minas Gerais and the Northeast place themselves as the main attractors of economic activity, competing directly with the centre-South of the country. The net result is the re-location of activities towards those areas, providing two distinct spatial regimes of potential winners and losers.

In summary, in the case of the BR-381 spatial competition clearly plays a prominent role. Given the favourable scenario for relative costs of production in the Northeast, in a context of systemic low quality of transport infrastructure, the Northeast increases its spatial market area while the richer Southeast suffers from the network (congestion) effects. Lower growth with decreasing regional inequality is the main long-run macro result (see localised spillover models – Baldwin and others 2003 – for a theoretical view).

Before moving to the analysis of the specific impacts in the State of Minas Gerais, it is important to emphasise the systemic nature of the problems under analysis. The issue of coordination of spatial policies should be given its proper role. As has been seen, isolated projects may promote undesirable outcomes if not considered within a context of a well-specified programme of investments. The integrated nature of transport systems may induce policy-makers to achieve mistakes when designing programmes without sound knowledge of this property. Accordingly, it would be important to consider differences between modes of transportation (that is, highways, railways and waterways) and different flows of goods. These requirements imply the need not only for a network model of multimodal transport – as the one used in this paper – but also a more detailed specification of products in the CGE model – still to be developed.

4.2.2. Regional impacts. As both projects locate in the State of Minas Gerais, it is important to assess the specific state impacts. Policy-makers in Minas Gerais may have special interests in such projects, given their strategic role in the state transport network.

Common patterns appear related to aggregate effects of both projects with Minas Gerais (Table 2). In general, positive outcomes are stronger in the BR-262 project than in the BR-381 project. However, they go in the same direction for most of the indicators. Overall, gains in efficiency (real GDP growth) are positive, with bigger impacts occurring in the long run. Real tax revenue also follows the same pattern. Competitiveness indicators suggest improvements in the terms of trade with other countries, and a reduction in the *Custo Minas* – measured in terms of the state GDP deflator. Noteworthy is that in the long run the effects on terms of trade are magnified, what does not happen to *Custo Minas* in the BR-381 project. In the long run, a less favourable situation emerges, as Minas Gerais overall competitiveness seems to be hampered by production costs increases associated with increases in consumer good prices, also affecting welfare in terms of the equivalent variation. This effect is connected with direct spatial competition with similar economies in the Northeast.

Table 2. State results: selected indicators (percentage change).

	BR-262		BR-381	
	Short run	Long run	Short run	Long run
Real GDP	0.00765	0.01554	0.00532	0.00686
Equivalent variation – total (change in $ 1,000,000)	15.4	30.1	7.7	(7.5)
Real tax revenue	0.00269	0.01381	0.00297	0.00425
Terms of trade	(0.00024)	(0.00216)	(0.00001)	(0.00274)
Custo Minas	(0.00379)	(0.02270)	(0.00870)	(0.00629)
Regional concentration	(0.00757)	(0.01528)	(0.00478)	(0.00640)
Poverty	(0.28963)	(1.12426)	(0.16286)	(0.28925)

Source: Elaborated by the authors.

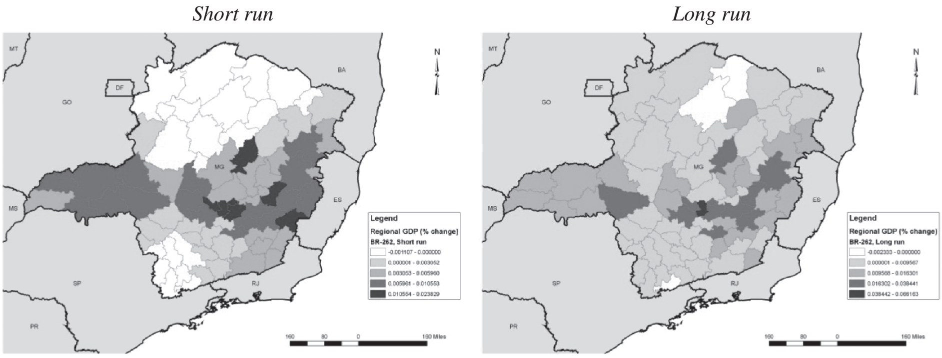

Figure 6. Spatial state results: real GDP (percentage change): BR-262 project.
Source: Elaborated by the authors.

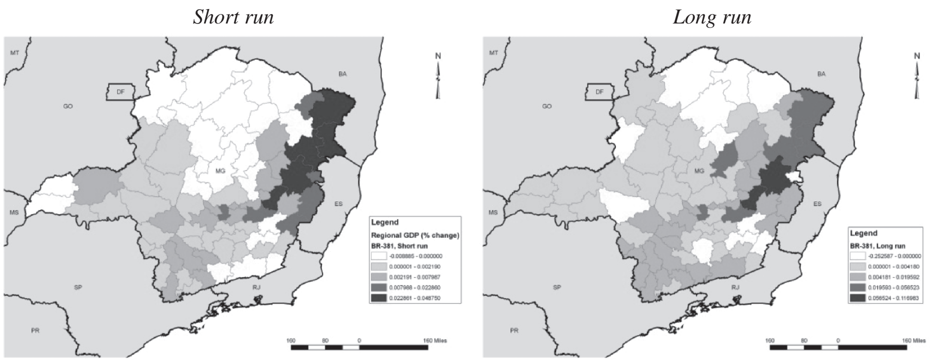

Figure 7. Spatial state results: real GDP (percentage change): BR-381 project.
Source: Elaborated by the authors.

In terms of regional concentration, our indicator considers the relative growth of poorer regions of the State – North and Jequitinhonha/Mucuri. This outcome reveals that both projects are pro-concentration, but it happens to a lesser degree in the BR-381 project. Finally, both projects are also pro-poor, projecting reductions in the headcount poverty index for the State of Minas Gerais, both in the short (weaker) and long run (stronger). In this case, however, the BR-262 project performs better.

Figures 6 and 7 depict the spatial GDP effects of both projects, focusing on the regions of Minas Gerais. Overall, the stronger effects on the areas of influence of the projects are clearly perceived. Moreover, these effects tend to spread over time, as suggested by the smaller number of regions presenting negative performance in the long run.

5. Final remarks

Appropriate tools are needed to assess the ex ante economic impacts of transportation infrastructure policies. This paper has attempted to tackle this issue. It has been suggested that inter-regional CGE models can potentially be used for the analysis of transport planning policies. We have illustrated a way in which this potential use can be implemented.

However, this tool is not yet a recurrent part of the transport planning process. To do so, further amendments are still needed, in order to cope with methodological advances both in economic and transport modelling.

Despite representing the effect of transport infrastructure in a consistent way, the use of current versions of inter-regional CGE models has some drawbacks when intended for replacing conventional models used in national or state-wide transport planning. Future versions of inter-regional CGE models should envisage the incorporation of some usual features of conventional models of transport planning, such as a broader multimodal view, quality and non-price attributes, congestion effects, and a finer spatial disaggregation to allow for finer intra-regional analysis. To some extent, the integrated approach proposed here directly addresses some of these issues. More importantly, however, the results provided are encouraging in the sense that the broader issues dealt in this paper, while difficult, are not insurmountable.

The policy conclusions that can be derived from the results of this study indicate the potential effects (both national and regional) road investments may play in the Brazilian economy. A detailed analysis of the shortage of infrastructure (that is, roads, railways and waterways) in Brazil was not made in the article, which goes beyond the possibilities of the methodology used. However, the results indicate that economic integration of regional markets in Brazil can amplify the benefits of transport investments with differential spatial impacts. Accordingly, given the systemic interconnectedness in the economy and in the transportation network, more appropriate transport policies in Brazil would envisage national coordination, which very often is not the case. Coordination may play an important role in optimising the multi-dimensional outcomes of transport policies.

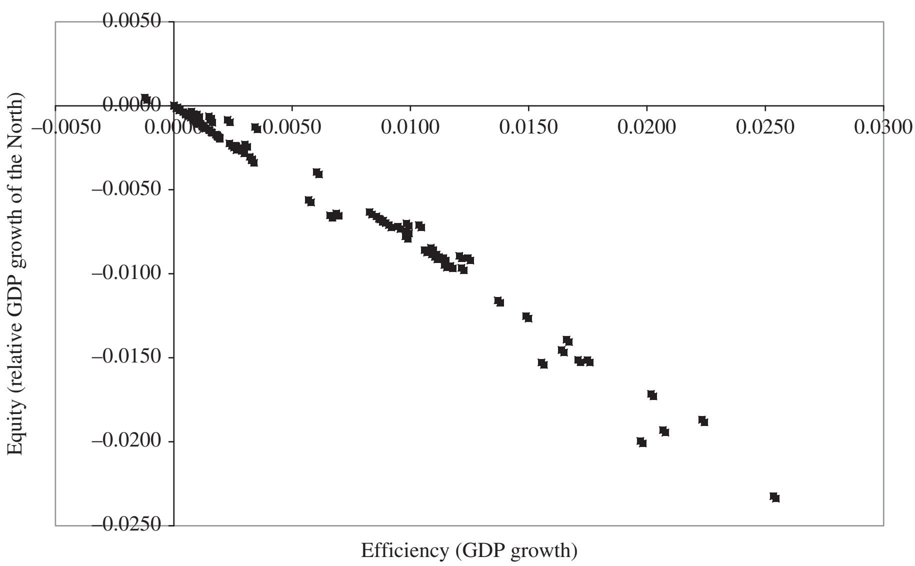

Figure 8. Regional equity-efficiency trade-off of transportation infrastructure investments in Minas Gerais, Brazil.

Source: Elaborated by the authors.

This paper makes it clear that the choice of the 'best' infrastructure projects depends on the policy goals to be achieved. Different trade-offs may appear when considering different investment alternatives. Time trade-offs (short run versus long run), political trade-offs (regional versus national effects), and policy outcomes trade-offs were present in the two illustrative cases drawn from the PELT Minas case.

To make this point stronger, a closer look at the complete portfolio of multimodal infrastructure projects within the PELT Minas reveals further evidence about the nature of the relationship between the provision of transport infrastructure and regional equity. Indeed, transport infrastructure is strongly region-dependent. The spatial structure of the provision of transport infrastructure matters in this question, playing a fundamental role in determining its effects on the economic system.[14]

Fifty-three projects (simulations) were analysed with a view to the efficiency-equity trade-off associated with investments in transportation infrastructure. Among the 53 projects, three are investments in waterways, five in railways, three in pipelines, and 42 in roads.[15] Figure 8 summarises the results for the effects on efficiency (measured in terms of real gross regional product growth) and regional disparity (measured in terms of the relative growth of the poor regions in the north of the state and the state as a whole; a negative value indicates that the poor region is growing at a slower pace). The results reflect a long-run environment. There is a clear trade-off between efficiency and regional equity. Projects that produce higher impacts on GDP growth also contribute more to regional concentration. Such trade-offs are commonly faced by policy-makers.

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Notes

1. See www.centran.eb.br (*Programa Nacional de Logística e Transportes*).
2. In the Minas Gerais case, the *Plano Estadual de Logística e Transportes* (PELT Minas) was based in the use of state-of-the-art methodological approaches to deal explicitly with the interface between transport and economy, from diagnostics to evaluation of transport projects. A similar approach was followed in Pará.
3. See, for instance, Fujita *et al.* (1999) and Fujita and Thisse (2002).
4. First, it is possible to specify transportation technology by adopting the iceberg transportation cost hypothesis, based on Samuelson (1952). Second, one can assume transport services to be produced by a special optimising transport sector. Finally, a third approach to introduce transportation in CGE models consists of the development of a satellite module, for the transportation system.
5. Among them, five doctoral dissertations: Domingues (2002), Perobelli (2004), Porsse (2005), Ferraz (2010), and Santos (2010).
6. See Haddad (1999), and Haddad and Hewings (2005).
7. See http://www.worldbank.org/transport/roads/tools.htm
8. Agriculture, mining, manufacturing, construction, transportation, trade, public administration, and other services.
9. Only the manufacturing activities were contemplated with this change.
10. Hereafter, transportation services and margins will be used interchangeably.
11. Values as of December 2006.
12. Simulations results were computed using GEMPACK (Harrison *et al.* 1994).
13. Marginal trade balance is assumed to be in equilibrium in the long run.
14. See Almeida *et al.* (2010).
15. Two of them were analysed in more detail in the article.

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