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Brazil
Evaluating the Macroeconomic and Distributional Impacts of Lowering Transportation Costs

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CURRENCY EQUIVALENTS
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BRL 1 = US$ 0.596

WEIGHTS AND MEASURES
Metric System

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ABBREVIATIONS AND ACRONYMS

ANTAQ	*Agência Nacional de Transportes Aquaviários* (National Agency of Waterborne Transportation)
ANTT	*Agência Nacional de Transportes Terrestres* (National Agency of Overland Transportation)
B-MARIA	Brazilian Multisectoral and Regional Interregional Analysis Model
B&W	Blonigen & Wilson Port Efficiency Index
CES	Constant Elasticity of Substitution
CET	Constant Elasticity of Transformation
CGE	Computable General Equilibrium
CNT	*Confederação Nacional do Transporte* (National Confederation of Transport)
CVRD	Companhia Vale do Rio Doce
DNIT	*Departamento Nacional de Infra-estructura de Transporte*s (National Department of Transportation Infrastructure)
DWT	Dead Weight Tons
EFC	*Estrada de Ferro Carajás* (Carajás Railway)
EFVM	*Estrada do Ferro Vitoria a Minas* (Vitoria-Minas Railway)
FEPASA	*Ferrovias Paulistas S.A* (Paulistas Railroad Company)
GDP	Gross Domestic Product
GRP	Gross Regional Product
GTAP	Global Trade Analysis Project
HDM-4	Highway Development and Management Model
IBGE	*Instituto Brasileiro de Geografía e Estatística* (Brazilian Institute of Statistics and Geography)
IO	Input-Output
LES	Linear Expenditure System
LND	Land Share of Value Added
LSMS	Living Standards and Measurement Survey
MERCOSUL	*Mercosul: Mercado Comun do Sul* (Southern Common Market)
NAFTA	North American Free Trade Agreement
NCM	*Nomenclautra Comum do Mercosul*
NFPS	Non-Financial Public Sector
OECD	Organization for Economic Co-operation and Development o
PAC	*Programa de Aceleraçao do Crescimento* (Growth Acceleration Program)
PAS	*Pesquisa Annual de Serviços* (Annual Survey of Services)
PEI	Port Efficiency Index
PELT	*Plano Estadual de Logistica e Transportes* (State Plan of Logistics and Transportation)
PNAD	*Pesquisa Nacional por Amostra de Domicílios* (National Household Survey)
PNLT	*Plano Nacional de Logística e Transportes* (National Plan of Logistics and Transportation)
POF	*Pesquisa de Orçamentos Familiares* (Household Expenditure Survey)
PPF	Production Possibility Frontier
PPI	*Projeto Piloto de Investimentos* (Pilot Project for Investment)
PPPs	Public-Private Partnership Projects
PPV	*Pesquisas sobre Padrões de Vida* (Living Standards Survey)
RFFSA	*Rede Ferroviária Nacional S.A.* (National Railroad Line Company)
TFP	Total Factor Productivity
TKU	Tons per kilometer

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Executive Summary

The relationship between transportation infrastructure and economic development is both critically important and highly complex. The efficiency of transportation networks influences production decisions and firm competitiveness; it affects the productivity of capital and labor; it impacts the terms of international trade; and it determines the extent to which remote communities and regions are able to participate in the national economy. In this context, the improvement and extension of Brazil's transportation infrastructure is crucial to fostering robust and equitable economic development throughout the country, and as such it is one of Brazil's most important policy challenges. Public investment in transportation and the reform of the sector's administrative and regulatory systems are likely to have substantial effects on national productivity and on other macroeconomic and distributional variables.

The effects of infrastructure development on output are rather well established and, to a certain extent, so are its effects on income distribution. What is less well known, and what this report aims to contribute to, is a better understanding of the impacts that cost reductions in the transportation sector and in different individual transportation modes have on GDP, income distribution, job creation, and fiscal balances in the Brazilian context. The report examines the macroeconomic and distributional effects of lower costs in the transportation sector in general, in the roads and port sub-sectors in particular, and of changes in the mix between competing and complementary transportation modes. Given the pivotal role that roads play in Brazil's regional development and the large share of roads in total freight transportation the report takes a particularly close look at the impact of lower road transportation costs. Similarly, because of the vital importance of ports in international trade and their impact on Brazil's global competitiveness the report also carefully examines the effects of improved port efficiency and capacity.

It is important to note that this report is designed to provide policymakers with estimates of the likely outcomes of an array of potential changes in transportation sector policy. To this end, the report uses a variety of economy-wide models to simulate alternative cost reductions and efficiency improvements. A detailed discussion of the various policies that may yield efficiency gains and cost reductions, as well as the specifics of their implementation, is beyond the scope of the report.

The report is structured to move from a general description of Brazil's transportation sector to more specific analyses and simulations of individual and concerted changes. The first chapter sets the stage by providing a summary discussion of Brazil's transportation sector that includes both an overview of its historical development and a look at the recent evolution of government policies. In the second chapter, the fiscal and economic effects of shifts in public investment between alternative and competing transportation modes (roads, railroads, and waterways) are simulated using a fixed-price input-output model. The report's third chapter uses a computable general equilibrium (CGE) model to analyze the effects of cost reductions in land transportation on macroeconomic variables and income distribution. The fourth chapter uses a multiregional CGE model to simulate the effects of port efficiency improvements on regional economic development (including both short- and long-term growth, employment, and welfare). The fifth chapter uses a similar model to analyze the national- and state-level impacts of two federal highway projects in the state of Minas Gerais in terms of economic growth, regional inequalities, employment, and poverty. The last chapter summarizes the findings and provides conclusions and recommendations.

The following is a very brief summary of the analyses, by chapter, and of key findings and conclusions.

Brief Historical Background and Current Conditions

Chapter 1 analyzes the current condition of Brazil's transportation infrastructure, which is the product of a long and turbulent economic history characterized by: (1) the shifting dominance of various high value commodities—timber, sugarcane, gold, coffee—that led to the rapid creation and later abandonment of vast commodity-specific transportation networks; (2) inadequate long-term planning and inconsistent policy implementation; and (3) levels of public investment that were often insufficient to meet the needs of Brazil's growing economy and its dispersed population.

Underinvestment combined with poor administrative practices, burdensome regulations, and the vicissitudes of the budget cycle has limited the growth of railroads and inland waterways, leading to the heavy overdependence on roads that characterizes Brazil's current transportation matrix. Brazil's reliance on its road network continues despite a steady deterioration of road conditions since the 1980s and the increasing inability of the majority of the country's roads to meet appropriate standards of operation, as well as the unsuitability of roads for the transportation of high volume goods such as agricultural products. This excessive reliance on roads has resulted in increased travel time and transportation costs, more rapid vehicle depreciation, higher accident rates, and higher production costs for Brazilian firms competing in international markets. The demand for transportation continues to grow rapidly, and unless alternative modes of transportation—railroads, inland waterways, multimodal transport systems—can be fully developed, the road system will continue to deteriorate, straining fiscal resources and damaging the Brazilian economy.

Recent and encouraging experiences with privatization have resulted in significant improvements in the efficiency of the railroad system. Still, railroads remain constrained in terms of their reach, capacity, and even their operating speeds because of the poor geometric characteristics of some lines. The World Bank is currently undertaking a detailed logistics study that will analyze many of these issues in detail. The bottom line, however, is that despite significant progress in reforming and improving the rail system much more remains to be done to alleviate the strain on the road network and reduce the cost of transportation for the Brazilian economy.

With one of the longest coastlines in the world, Brazil's ports are critical to its participation in world markets. Unfortunately, these ports are hampered by a series of constraints that cause them to operate below their potential. While port operations have benefited from regulatory improvements and the entrance of private operators, they still lack sufficient investment to expand their operations, and administrative problems reduce their efficiency. Although Brazilian shipping is highly concentrated in the Port of Santos, leading to a desired "hub" structure, it is still constrained by volume limitations that leave it unable to handle the largest container ships and difficulties in utilizing multimodal transportation systems. Further administrative reforms are needed to complement increased investment in port infrastructure.

Macroeconomic and Distributional Effects of Shifts from Roads to Rail and Waterway Systems

Chapter 2 provides an analysis of potential shifts in the level of economic activity from roads to rail and waterway systems. The analysis concludes that the effects of transportation policy on various income groups are not restricted to relative consumption and price levels, but also reflect different producers' reliance on different types of transportation infrastructure. Since different producers employ workers from different income groups, changes in transportation policy will indirectly affect wages and the distribution of income.

The simulations in the chapter suggest that the reallocation of economic activity away from roads involves several tradeoffs. For example, the simulation finds that moving a larger proportion of freight to rail would have a positive impact on income levels and income distribution and would release labor to other sectors as the emphasis shifts from the relatively labor-intensive trucking industry to the relatively capital-intensive rail system. On the other hand, increasing the volume of waterway transportation would produce a greater increase in GDP with a smaller decline in sectoral employment, although its effects on income levels and income distribution would be relatively smaller. The simulations show that an increase in efficiency is achieved by emphasizing alternatives to road transportation; however, the gains are estimated to be minor. According to the simulations a transfer of 10% of the road transportation activity level to the rail system would result in marginally small effects on GDP and a slight reduction in the Gini coefficient. In terms of efficiency, however, the impact of the transfer of activity would free an amount of labor which, assuming the average labor productivity of the overall economy to be constant, would generate an increase of GDP of about 0.1%.

Macroeconomic and Distributional Effects of Improved Efficiency in the Transportation Sector

Chapter 3 argues that overall efficiency improvements in the Brazilian transportation system would not only have a considerable impact on economic growth, but would also have a strong positive effect on the distribution of income. Improving transportation infrastructure would reduce total production costs and enhance factor productivity. These changes would, in turn, improve income and employment opportunities and increase the value of assets held by the poor. Better transportation would also play a critical role in expanding market access to remote and rural communities, opening them up to new industries, extending the reach of their products, expanding their access to consumer goods, and allowing increased competition to lower prices and improve quality. According to one of the simulations US$0.8 billion of new investment in the transportation sector would generate a one time increase in GDP of US$1.8 billion, and a 0.01 percent reduction in income inequality (as measured by the Gini coefficient). This is equivalent to an increase in GDP more than twice as large as the increase in investment. This "multiplier" effect would result from the impact of transportation investment on other sectors and its relative size would depend on the degree of complementarity between these sectors.

From a long-term policy perspective reducing reliance on roads would help to alleviate a number of key problems in Brazil's transportation system. In the short term, however, investment in roads would have a significant impact on overall economic efficiency while generating employment opportunities for the poor and enhancing their market access. Because poor and rural families in Brazil spend a greater than average portion of their income on transportation, and because they rely on the road system most heavily, reducing costly inefficiencies in the road sector would have an especially strong, positive impact on income distribution and result in long-term equity gains. Moreover, taxes on final consumption of transportation services are inherently regressive and reducing them would reduce the cost of participating in the broader regional or national economy. Finally, investments in transportation infrastructure would also have more immediate effects on income distribution and poverty because transportation projects tend to use unskilled labor intensively. This is particularly true of road construction and improvement.

Effects of Increased Port Efficiency

Chapter 4 analyzes the key role port systems play in determining market possibilities and shaping the relative growth and development of Brazil's various regions. Whereas roads and railways are links in the transportation network, ports are nodes—points at which many links converge. Inefficiencies in a transportation network's nodal points are magnified through their impact on multiple links. Thus the high costs imposed by an inefficient port ripple through the regional economy it serves. As interregional CGE modeling indicates, increasing overall port efficiency will have a significant positive impact on economic growth while enhancing the competitiveness of Brazilian firms in international markets and improving Brazil's terms of trade.

The inefficiencies of Brazilian ports stem from a number of factors, including the use of inappropriate administrative models, delays resulting from high concentrations of inland traffic, equipment obsolescence, and lack of investment to improve capacity. While these problems are widespread, their impact depends on the coverage of the efficiency gains. Chapter 4 demonstrates this using a simulation comparing three different scenarios of improvements in port efficiency.

Under the first scenario, the efficiency of all ports is improved regardless of their initial relative efficiency. These nationwide improvements in port efficiency are projected to yield significant macroeconomic gains but do comparatively little to improve interregional equity and do not perform well against programs that scale reform efforts according to relative inefficiency.

In the second scenario, administrative decentralization improves the efficiency of federally-operated ports, which tend to be less efficient than average. In this scenario, because federally-operated ports are far more common in the less developed north and northeastern regions of Brazil decentralization of administrative functions represents a more targeted policy, delivers weaker economic gains than blanket improvements, but improves the relative performance of the less developed regions.

In the third and final scenario, efficiency improvements are targeted at bringing all ports to the standard of Brazil's most efficient port. The approach to improving port efficiency represented by this third scenario, under which reform efforts are directly proportionally to relative inefficiency, is projected to have the greatest impact on the economy, improving real GDP by 0.13%.

From a policy perspective, the interrelated character of regional economies remains a concern, since improving the port efficiency of one region may divert investment and commerce from neighboring regions. Improving the more heavily-trafficked ports in the more developed southern states appears to yield the highest immediate return, but diverting trade from the northern regions could increase regional inequalities.

A Regional Case Study of Two Highways

The difficulties of ensuring equitable regional development are not limited to international transportation modes. Chapter 5 discusses the broad macroeconomic effects of road construction and improvement programs and their implications for the pattern of regional economic development in terms of two proposed road projects in the Minas Gerais region described in the PAC (*Programa de Aceleraçao do Crescimento*). Road projects pose a special challenge for policymakers as massive sunk costs are incurred in order to produce a fixed capital asset that previously did not exist, and the demand for which is uncertain. In order to effectively prioritize the allocation of limited fiscal resources it is vital for policymakers to be able to accurately project the impact of specific projects. Interregional CGE models tailored to the specifics of transportation policy provide useful tools for determining the probable effects of individual projects as well as far-reaching policy initiatives.

National transportation networks shape the patterns of competition and cooperation between various regions, and growth in one may come at the expense of another. While the two proposed road projects offer gains in economic efficiency, employment effects (excluding the investment phase) are positive in the long run in only one of the projects. Differing results between the national and state levels reflect larger positive effects in the regions directly affected by the roads as well as different trade-related effects (trade creation and trade diversion) across regions, all of which point to the systemic nature of the transportation effects involved. Policymakers who fail to fully appreciate the integrated nature of transportation systems and infrastructure investment may make critical errors in program design.

Moreover, the long-run impacts of individual transportation projects are not always obvious or intuitive, and may be sharply at odds with their easier to predict and typically positive short-run effects. For example, in the short-run, road improvements in Minas Gerais would relieve traffic congestion, thereby lowering transportation costs and leading to an overall increase in Brazilian GDP. In the long-run, however, this situation is reversed for one of the two projects analyzed, and GDP actually declines as a result of the new roads. This seemingly counterintuitive outcome results from the fact that while new roads lessen overall traffic, they also divert traffic flows onto roads not explicitly part of the policy initiative. Increased traffic volumes on these ancillary roads would cause higher levels of congestion and road degradation in densely productive areas, increasing total transportation costs for the many producers who rely on them while at the same time imposing greater operational costs on the regional governments and agencies responsible for road maintenance and management. In order to maximize their benefit to the economy and to support long-term development goals, road improvements must take into account effects on factor returns, interregional trade diversion, and overall economic growth in those states both directly and indirectly affected by road improvement and expansion projects.

What Have We Learned?

The models discussed in this report are tools to help understand the economy-wide and interregional impacts of transportation improvements. A wide range of factors influences the effectiveness of transportation infrastructure projects and policy reforms, and any change in the transportation matrix will have a broad and complex impact on the Brazilian economy. In order to achieve a thorough understanding of the implications of transportation projects, policymakers must be fully aware of both their integrated interregional and long-term effects. In summary, the models presented in this report and the simulations performed in Chapters 2 through 5 show that:

1. Reductions in overall transportation costs and increased investment in transportation infrastructure would raise economic output and improve income distribution. According to one of the simulations US$0.8 billion of new investment in the transportation sector would generate a one time increase in GDP of US$1.8 billion, and a 0.01 percent reduction in income inequality (as measured by the Gini coefficient). This is equivalent to an increase in GDP more than twice as large as the increase in investment. Comparatively speaking, the transportation sector is one of the most “productive” sectors in terms of yielding increases in GDP for similar levels of investment.
2. Despite the widely-held perception that Brazil’s transportation policy relies too heavily on a comparatively expensive road network, the analysis indicates that shifting transport volumes from roads to the rail or waterway systems will not yield any meaningful improvement in transportation efficiency, nor will such a shift significantly reduce overall costs, increase output, or improve income distribution. In terms of efficiency, the impact of shifting 10% of road transport volume to other transportation modes does free a small amount of labor, the reallocation of which could generate a marginal increase in GDP of about 0.1%.
3. Improved port efficiency raises output and welfare and improves both the terms of trade and the fiscal balance. Decentralization (transferring federal ports to local authorities) and improvements in port efficiency have an overall positive effect on regional and national growth. Under one of the simulations, raising the efficiency of Brazilian ports to the level of the most efficient Brazilian port increases GDP by over 0.1%.
4. A specific road project, *ceteris paribus*, will raise regional output and reduce regional economic concentration and poverty. However, specific road projects will have both interregional trade creation *and trade diversion* effects. Consequently, the rerouting of interregional trade along new highways, as well as traffic spillover onto ancillary roads not explicitly included in the highway project, could actually *decrease* total economic productivity at the national level while burdening state transportation authorities with increased congestion and road deterioration. These potentially counterproductive effects must be carefully considered before any major highway initiative is undertaken, and this report provides a template for the type of predictive analysis required.

Chapter 1
The Transportation Sector in Brazil

Brazil's transportation sector is characterized by a highly concentrated flow of goods and services through the country's road network and on the underutilization of railroads and other transportation modes, which represent relatively low traffic volumes in the country's transportation matrix. This is the result of Brazil's historical emphasis on road development and a concomitant propensity to under-invest in alternative forms of transportation. Today, at least 60 percent of total freight volume is moved by trucks.[1] Despite the negative repercussions this has on transportation costs and the overall competitiveness of the Brazilian economy, efforts to alleviate the heavy reliance on roads have been limited. This includes recent experiences with privatization that have resulted in improvements in the efficiency of Brazil's railroad system and limited reform initiatives aimed at increase port efficiency that have somewhat improved the contribution of ports to the transportation system. The efficiency and productivity of other modes of transit such as inland waterways and coastal navigation and, to a certain extent, air transportation lag even further behind the efficiency and productivity of Brazil's road and railway systems.

During the past few decades, Brazil's overdependence on its road system has not been matched by significant investment in new road construction or improvements in overall road maintenance. The country's National Confederation of Transport (CNT or Confederação Nacional do Transporte) considers the roads to be in urgent need of investment, with an estimated 75 percent of the total network failing to meet acceptable traffic standards.[2] The country's maritime port system also needs investment in equipment and improved administration in order to keep pace with increasing export volumes. Railroads, once considered a critical element in the process of regional integration, have only recently benefited from efforts to improve efficiency through private participation and have increased traffic volumes to compete with roads in the transportation matrix. Inland waterways and maritime cabotage account for 13 percent of the total freight volume.

1.1 Historical Background

Throughout Brazil's history the country's transportation sector has played a pivotal role in regional development but has been subject to constant changes and interruptions as a result of the shifting nature of economic activity. Consequently, the current state of Brazil's transportation sector is more the result of the country's particular historical development than any recent decisions regarding transportation policy.

According to Lage (1979), during the early colonial period the country's territorial occupation by Europeans was restricted to a narrow coastal strip, which did not exceed 100 miles in width. Transportation relied on animal tracks and primitive roads and was largely devoted to the exploitation of timber (*Pau Brasil*).[3] From the seventeenth to the nineteenth centuries, when

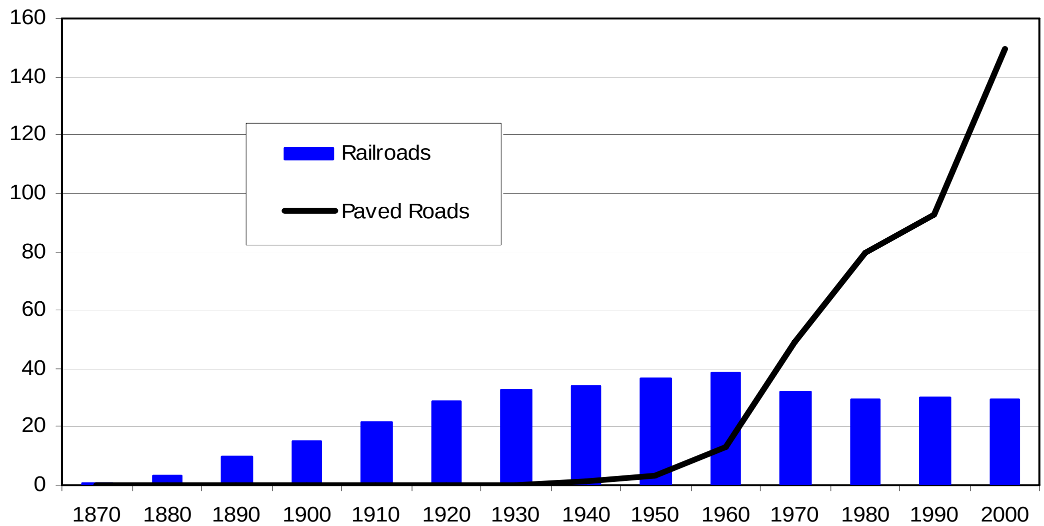
[1] This refers to freight volume measured by TKU (tons per kilometer).
[2] According to CNT (2006a), only 25 percent of Brazil's paved roads could be characterized as being in good or excellent transit condition.
[3] *Pau Brasil* or Brazilwood trees were a large part of the exports and economy of colonial Brazil.

Brazil's economic activity was dominated by sugarcane and gold, several major inland waterways were developed along with the *Estrada Real*,[4] which connected Minas Gerais with Rio de Janeiro. In the late 1800s the coffee cycle brought railroads financed by coffee growers to São Paulo, contributing to the creation in São Paulo of an environment that would prove to be supportive of the industrialization that would occur over the following century.

These four cycles triggered shifting investment policies in Brazil's transportation sector. Transportation infrastructure developed as a response to economic demand, but the transitory nature of some of these regional economic cycles resulted in the establishment of transportation networks comprised of thousands of small routes that were used temporarily, and then largely abandoned.

The nineteenth century represented a period of important expansions in Brazil's transportation network, which extended into the mid-twentieth century with the construction of a transportation system that, despite numerous historical disruptions and a lack of long-term planning, has served as the basis for Brazil's modern transportation sector. The period between 1850 and 1940 witnessed the construction of some very important roads and railroads. By 1950 the Brazilian federal road system was approximately 49,000 km long, while the railroad network was around 30,000 km long. Figure 1.1 provides a comparison between road and rail construction up until the end of the last century.

Figure 1.1 Evolution of Railroads and Paved Roads in Brazil

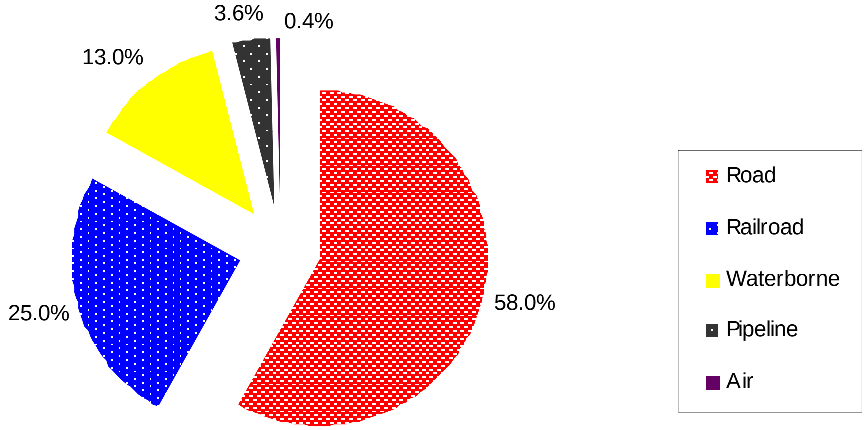


Source: IBGE

[4] The *Estrada Real* (royal road) was built to facilitate the transportation of mineral products to the port of Rio de Janeiro.

After 1940 government efforts to substantially improve Brazil's infrastructure resulted in the construction of a more extensive road network.[5] By 1982, the federal road network had grown to approximately 56,000 km within a total of 1.5 million km of federal, state, and county roads. Beginning in 1982, however, as Brazil faced a serious fiscal and external debt crisis the highway system was frequently overloaded and began deteriorating to an extent not often seen in similar countries, while at the same time the development of the railroad system fell further and further behind.[6] Figure 1.2 depicts Brazil's freight transportation matrix, illustrating the country's heavy reliance on its road system.[7] Figure 1.3 compares Brazil's transportation matrix to that of other countries, demonstrating the similarity of Brazil's current dependence on its road system to that of several smaller European countries while also highlighting its differences with countries of comparable land mass.

Figure 1.2 Brazil: 2004 Transportation Matrix
Ton-Km of Freight (TKU)



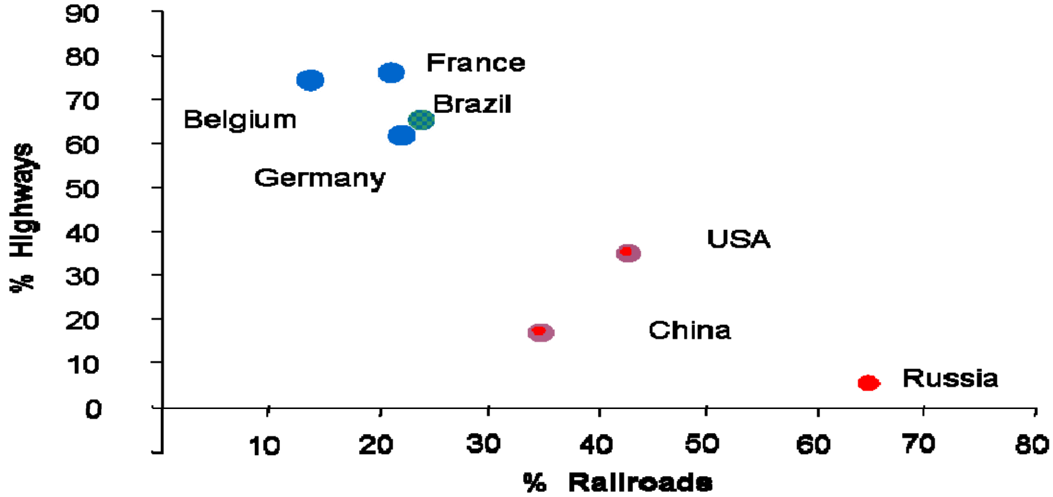
Source: Ministério dos Transportes (2007)

While relying on road construction as the principal method of expanding transportation infrastructure decision makers have often paid insufficient attention to critical matters of design, implementation, evaluation, and, most of all, maintenance over the long term. Poor maintenance has left the Brazilian road network at a level of service that according to most analysts falls below minimum standards of operation. The heavy reliance on roads and their steady deterioration is responsible for significant economic losses, high accident rates, and negative effects on Brazil's global competitiveness. Meanwhile the rail, waterborne and multimodal

[5] According to Lage (1979) beginning in 1927, the Brazilian Federal Highway Commission launched a series of plans that consolidated the role of rails and railroads in Brazil. From the 1950s on, however, the government began to concentrate its investment efforts on road development.
[6] Even though Brazil's railroad era began in the first half of the 19th century (Schoppa 1982), its development only accelerated in the first half of the 20th century. David (1985) points out that although the Brazilian government began to plan for a railroad system in the 1890s, development only occurred in the 1920s.
[7] The transportation matrix shown in Figure 1.2, and derived from official sources, has been questioned by Brazilian transport specialists such as Castro (2004).

transportation alternatives that could have been developed with appropriate public policy reforms are still not adequately represented in the transportation matrix.[8]

Figure 1.3 Transportation Distribution in Brazil as Compared to Other Countries % of Total Freight Volumes (TKU) – Railroads and Highways[9]



Source: Resende (2006b)

1.2 The Economic Importance of the Transportation Sector in Brazil

According to the recently revised national accounts in 2006 Brazil's transportation sector represented 4.4 percent of the country's GDP. Its importance to the Brazilian economy, however, is considerably broader. The significance of the transportation sector is apparent not only in its overall effects on the economy, but also in its impact on regional inequalities. Castro (2004) analyzes the different impacts of transportation policies in Brazil from a logistics perspective, and evaluates the transportation sector's effects on regional economic development through different periods of Brazil's economic history.[10]

Since the early 1990s growth in the transportation sector has exceeded the growth rates of most other economic sectors as well as overall GDP. From 1991 to 2006 the average annual growth rate of value added by the transportation sector exceeded that of total GDP by 0.7 percent per year (Figure 1.4).

The Brazilian transportation matrix is unlikely to experience significant changes in the next few decades, mostly because of the excessive concentration of freight volumes on the road system. As a result, investments in roads may be expected to yield greater returns than similar

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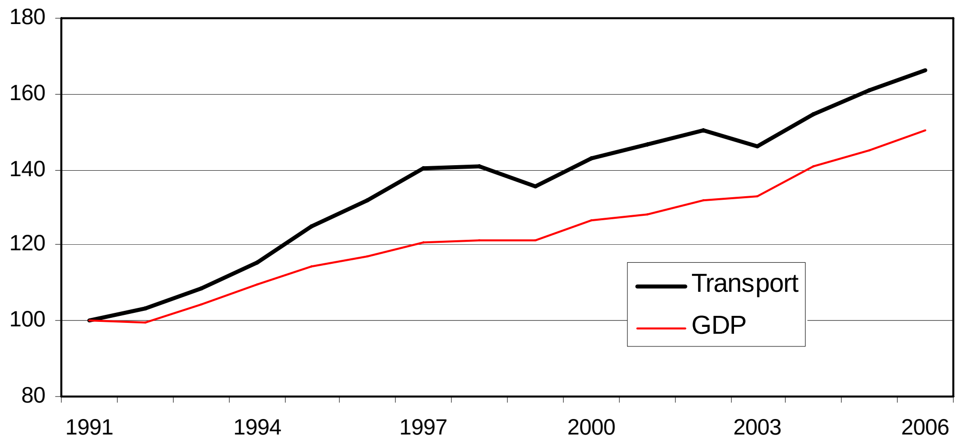
[8] World Bank (1997).

[9] The figure shows Brazil's heavier reliance on roads, as compared with countries of similar land mass such as the U.S., Russia and China. It also shows how comparatively closer Brazil is to some "smaller" European countries that face very different demands for transportation. The figure's depiction of Brazil in close proximity to France, Germany and Belgium, however, does not mean to imply that Brazil has a similar level of development in transportation infrastructure.

[10] The relevance of economic geography through agglomeration and dispersion and the effect of transport has been studied by Haddad (1999) and by Combes and Lafourcade (2001) for France.

investments in other forms of transportation. Given this situation, it is evident that any multi-sector investment program will need to include a strong road improvement component.

Figure 1.4 Transportation Sector and GDP in Brazil, 1991-2006 (1991 = 100)



Source: IBGE

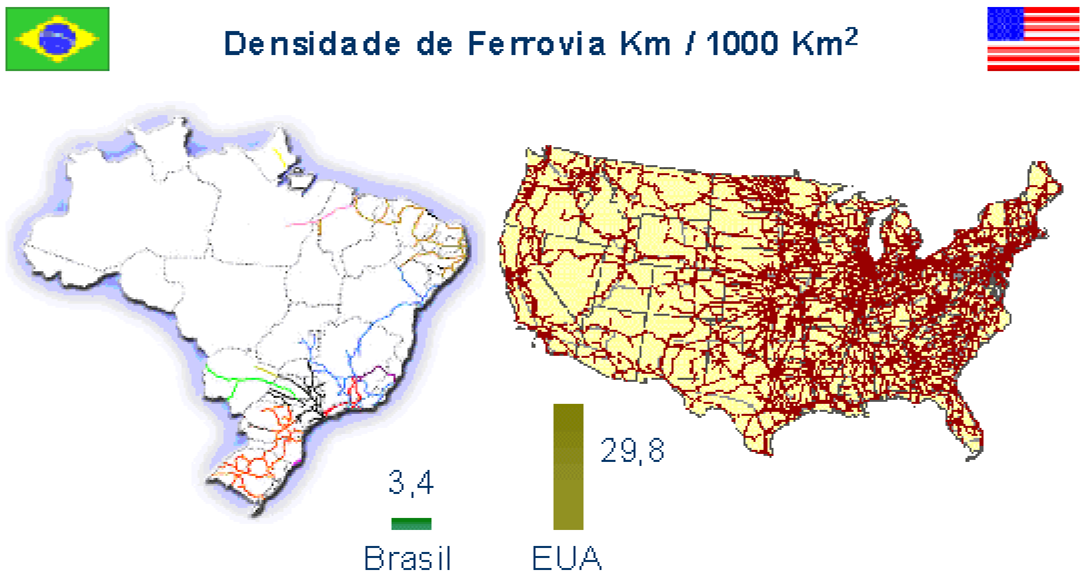
Despite the growth of the transportation sector, transport costs are still very high, largely as a result of the following factors:

- The transportation matrix is concentrated on roads, and competition among transportation modes is very limited. With the exception of iron ore, the railroad network is used for only a relatively small fraction of freight transport.

- Most of the agricultural regions do not have access to transportation modes that enjoy lower variable costs due to the efficient dissipation of fixed costs on high freight volumes such as railroads and inland waterways. Railroads are concentrated in the southeastern and southern regions of the country. Meanwhile, the agricultural frontiers extend to the northern and central-western regions, where there is a significant lack of railroad tracks. Figure 1.5 shows a comparison of railroad density between Brazil and the U.S.

- Lack of investment in multimodal transportation has had negative effects on firm competitiveness as the concentration of roads in the transport matrix leads to excessive costs, which are of particular concern given Brazil's vast size. Compared to other, similar countries, Brazil relies heavily on a relatively more expensive mode of transportation.

Figure 1.5 Railroad Concentrations and Densities in Brazil and the U.S.



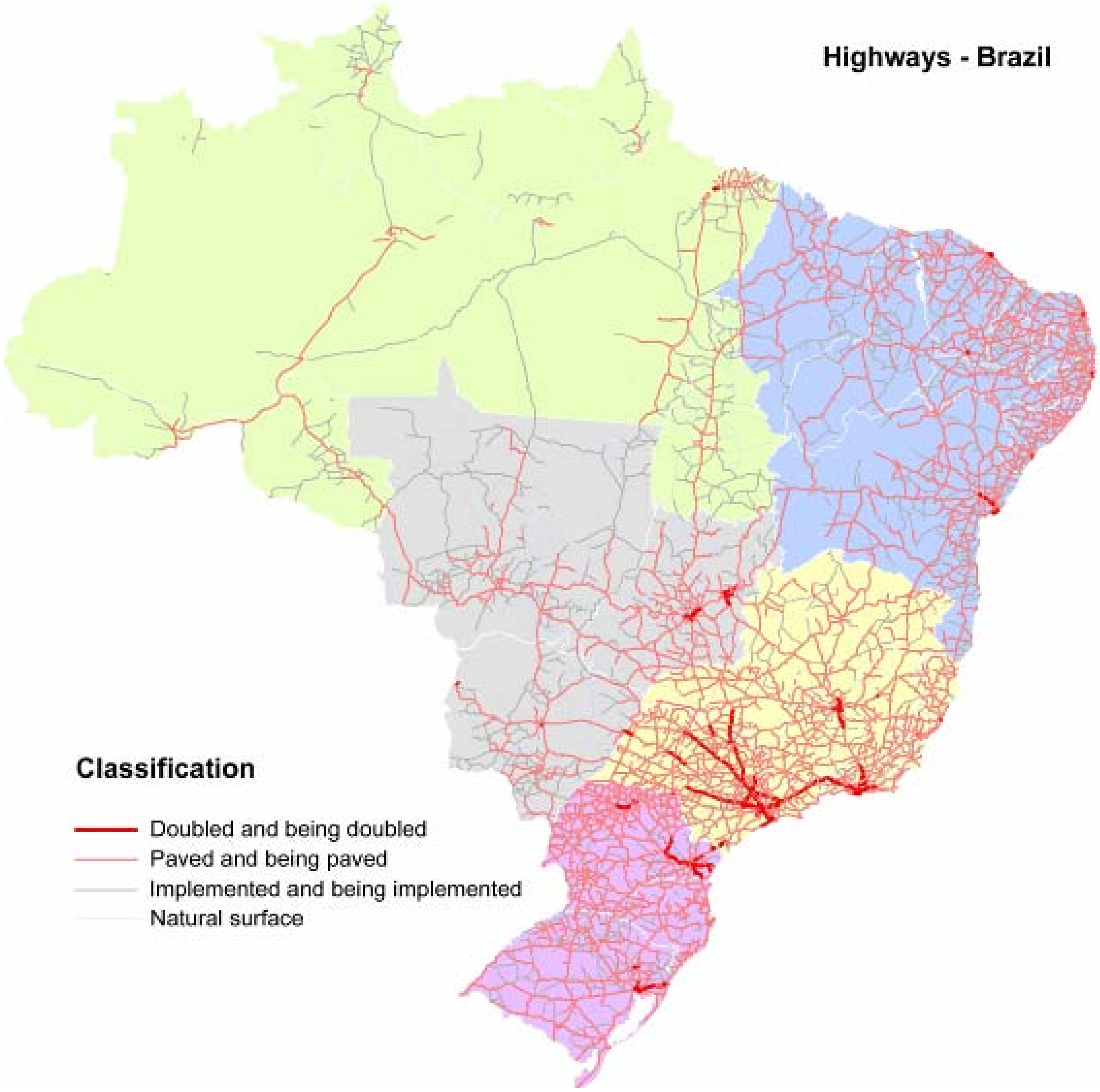
Source: CNT (2006b)

1.3 The Transportation Sector

1.3.1 The Road System

Brazil has the third largest road network in the world at approximately 1.6 million km, but only 196,000 km (around 12%) is paved. The federal road network (which is almost all paved and covers about 58,000 km) accounts for most of the long-distance transport as well as about 70% of all goods transported by road. The overall network is highly concentrated in the eastern part of the country, where the major urban settlements and industrial centers are located (Figure 1.6).

Figure 1.6 The Brazilian Road System



Source: Caliper of Brazil

Although the current condition of the Brazilian road system is deficient, roads are a critically important element of the country's transportation matrix and a critical ingredient of the logistics system in which Brazilian firms must operate.[11] The transport sector is highly dependent upon certain major road links, such as those connecting the northeastern and southeastern regions (BR-116 and 101), the central-western and southern regions (BR-487 and 163), the southern and southeastern regions (BR-116, 101, 153, and 158) and the central-western and southeastern regions (BR-354, 040, 364, and 262). These road links are responsible for approximately 45% of the entire freight volume in the transport matrix and, together with the state roads of Minas Gerais, São Paulo, and Rio de Janeiro, move a significant percentage of the country's GDP. These roads are also responsible for connecting the major production areas to the ports of Santos,

[11] For a brief description of the logistics issue in Brazil see Annex 1.

Rio de Janeiro, Paranaguá, Vitória, and Rio Grande, which are the main points of entry and exit for the largest freight volumes of Brazil's 14 most important industrial sectors.

The expansion of the road network into the Brazilian hinterland greatly contributed to the expansion of the agricultural frontier, a process which accelerated in the 1950s. Despite the long distances involved, road development favored the regional integration of the most distant states. According to Castro (2004), the large construction projects and paving of the Brazilian road network, between the 1950s and 1980s, resulted in sharp reductions of interregional transport costs that contributed to the increase in agricultural production in the northern and central regions of Brazil, increasing agricultural productivity and aiding in the development of the industrial south.[12]

The development of the road system, which occurred largely during a period of rapid growth from the 1950s through the 1970s, slowed down significantly in the 1980s as the fiscal situation in the country worsened. Ultimately, even road maintenance expenditures were scaled back and, as a result, the road system is substantially and increasingly deteriorating. Poor road conditions, in addition to increasing the cost of transportation, contribute to a high rate of accidents. According to CNT estimates, the mortality rate per kilometer on Brazilian highways was 70 times greater than that of Canada and 30 times greater than that of the U.S.[13]

1.3.2 The Port Sector

After roads, ports are the second most important sector in the logistics bottleneck and improvements in port efficiency will have a major impact on reducing transportation costs. The country has one of the largest coastlines in the world, and the presence of harbors in almost all of the coastal states could become an important advantage in international trade (Figure 1.7).

Nevertheless, Brazil's port system suffers from several critical problems that impede its development and contribute to high logistics costs throughout the economy. These include equipment obsolescence, inefficiencies in labor development and labor allocation, lack of harbor capacity, and inefficiencies in the port administration models.[14]

Of all the Brazilian ports, the port of Santos is the most important not only because of its freight handling capacity, but also because of its influence on the national economy. Today, 13 Brazilian states are served by the Port of Santos, and all 27 states move a portion of their trade volumes through it. Santos currently accounts for about 38% of all import and export activity conducted through Brazil's ports.[15] Besides Santos, 4 other ports can also be ranked as major maritime facilities: Vitória, Paranaguá, Rio Grande, and Rio de Janeiro. Another ten could be added due to their potential to become major international ports: Itajaí, São Francisco do Sul, Manaus, Salvador, São Luís, Sepetiba, Aratu, Fortaleza, Suape, and Belém.[16]

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[12] The states of the north and northeast regions of the country, which accounted for about 14 percent of total GDP in 1970, rose to about 20 percent in 2004.
[13] CNT (2007)
[14] Resende (2006a) and Batista (2006).
[15] Average for 2002-03 in value of imports and exports according to Alvares (2006).
[16] Alvares (2006).

Figure 1.7 The Brazilian Port Map

Source: Ministério dos Transportes

Using total freight handling capacity and location as strategic variables, the port of Santos moves approximately 6.5% of the country's GDP, followed by Vitória (2%), Paranaguá (1.9%), Rio Grande (1.6%) and Rio de Janeiro (1.2%). None of the other ports accounts for more than 1% of GDP. These numbers indicate the high concentration of port volumes and movements. This concentration is also affected by a second variable: location. Of the ten major ports, four are located in the southeastern region, three in the southern region, two in the northeast region, and only one in the northern region.

The Port Modernization Law of 1993 opened Brazilian port operations to private companies, which have since taken responsibility for six of the ten major ports in the country. Despite some improvements in the efficiency of ports due to higher levels of private participation in port operations, the current administrative model remains a drag on further efficiency gains.

In addition to administrative reform, investments in port equipment, labor skills, and harbor capacity could lead to important efficiency gains for the Brazilian logistics system. According to Batista (2006), increasing harbor capacity could allow the largest ports to service capesize vessels, which are capable of moving 150 thousand deadweight tons (DWT) at a speed of 23 knots, while the current panamax ships are capable of moving only 50 thousand DWT at 14 knots. Upgrading to capesize vessels could reduce freight costs from approximately US$36 per ton to around US$12 per ton. Currently, only seven of Brazil's ports are able to handle capesize ships, and these do not include the Port of Santos.

The economics of the shipping industry suggests that in addition to larger ship sizes larger shipments, a reduced number of calls, and therefore a reduced number of ports of call would contribute to more efficient operations. In order to achieve this Brazil's port system would need to evolve towards an increasingly hierarchical structure, with fewer major "hub" ports fed by the smaller ports.

1.3.3 Other Transport Modes: Railroads, Waterways and Multimodal Systems.

The lack of modal balance in the Brazilian transportation matrix remains at the center of the logistics discussion. The development of transport modes other than roads, which in the long run could offer lower-cost alternatives for freight transportation, would be highly beneficial, but such a shift will be difficult to implement. Historically, this has been the case with the railroad system especially, which despite some recent improvements made through privatization remains insufficiently developed (Figure 1.8).

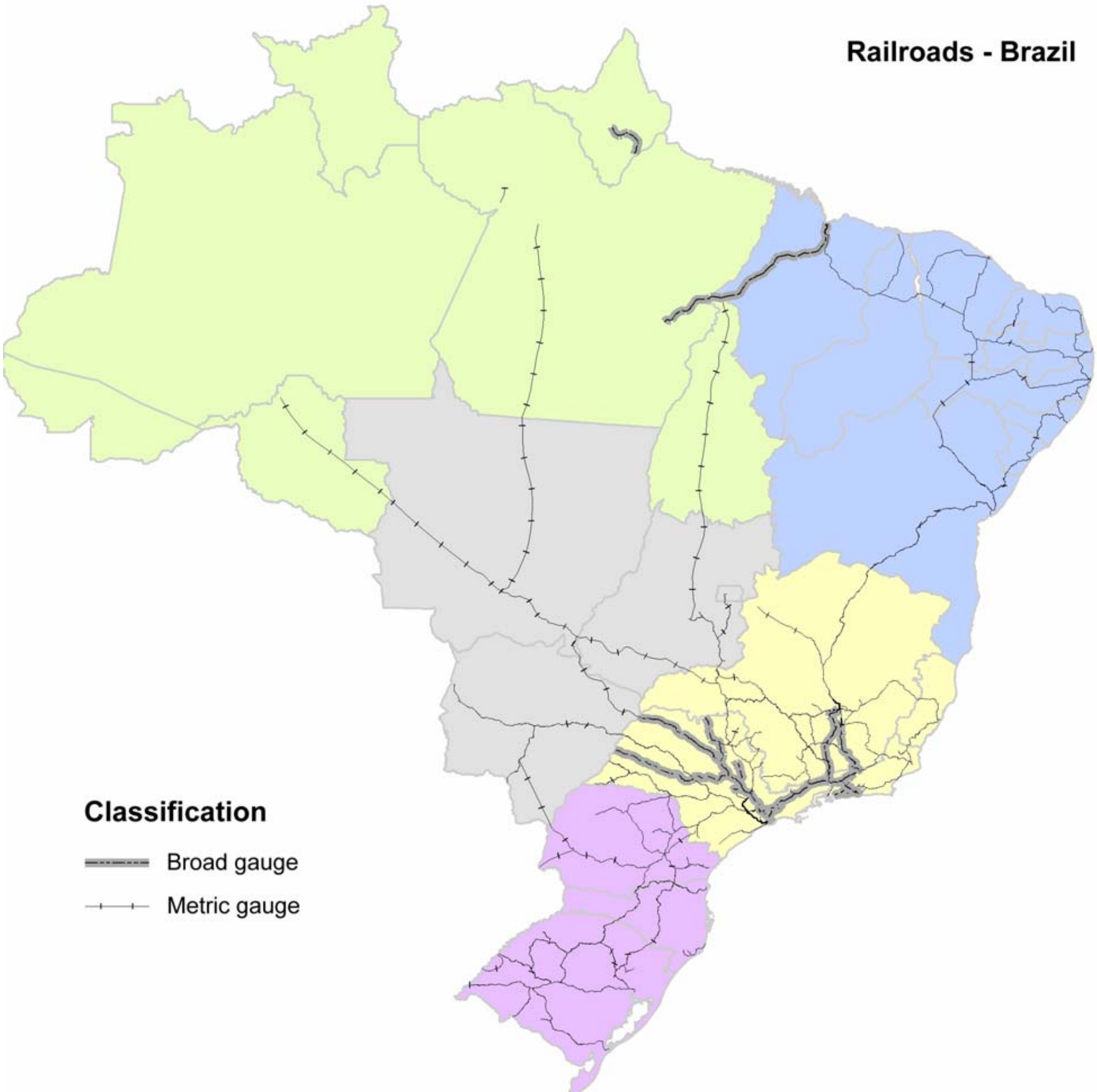
Railroads

Totaling 29,500 km, Brazil's railroads are still inadequate in terms of extension and lack sufficient rail capacity in some high demand areas. Railroads also remain constrained by low operating speeds caused by the poor geometric characteristics of some lines. Despite the fact that railroad costs for freight are on average approximately 40% lower than road costs (CNT 2006b), the railroad system is not able to meet its potential, mainly due to the insufficient size of the network and unfavorable operating conditions. This leaves a number of areas, such as Brazil's agricultural frontiers, without sufficient rail service and results in increased reliance on roads even though the use of roads and trucks to transport goods limits producers' ability to move the high volume freights that are more appropriate to railroads. Still, the railroads' current transportation volume provides a good indication of their potential since 85% of their total freight is export-related.

In the last ten years, under the management of private concessionaries, the Brazilian railroad system has improved significantly. These improvements have been the result of increased investment and have resulted in higher traffic volumes, productivity gains, and accident reductions. Privatization has contributed to improvements in motive power, rolling stock, track maintenance, and marketing and operating practices that have helped the railroads capture increasing and even significant shares in some markets, particularly in agricultural products. Still, despite increased private participation, the railroad system remains relatively fragmented, partly due to the use of different track gauge sizes on different railway lines. This characteristic continues to hinder the development of long haul transportation in the railroad network.

Railroads are responsible for 25% of total freight volume, and this represents a significant increase as railroad transportation has grown faster than road transportation since privatization began in 1996. Investment in railroads increased from US$230 million in 1997 to 1.4 billion in 2005. In the same period, the freight per kilometer (TKU) transported by railroads increased by 60.2% (ANTT 2006).

Figure 1.8 The Brazilian Railroad Map



Source: Caliper of Brazil

Waterways

The development of inland waterways and cabotage (domestic coastal transport), both of which are linked to the development of port infrastructure, represents another alternative that could contribute to significant cost reductions in freight transportation. Accounting for only about 13 percent of the total freight volume, transportation on inland waterways is largely restricted to a small number of rivers, mostly in the northern region.[17] With few exceptions, river transportation in Brazil continues to rely on low quality infrastructure and facilities.

Brazil's inland waterways need urgent improvement in administration and financing in order to enhance their capacity. Waterborne transport also suffers from a lack of harbor facilities capable of handling not only larger volumes but also freight that demands more sophisticated packaging and container systems. The main challenges to improving inland waterways include integrating the system with other transport modes; providing proper legislation for current and future operations; allocating a portion of transportation taxes for improving dam and bridge passages and, finally, assigning proper administrative responsibilities to the transport agency, the Agência Nacional de Transportes Aquaviários (ANTAQ) to control the operation of inland waterways.

Multimodal Transportation

Another important issue in transportation infrastructure is multimodal transportation. The rational and integrated use of more than one mode of transportation is essential to improve logistics efficiency. Although Brazil has made some progress this area, there are still significant obstacles standing in the way of combining the best of each transportation mode to reach higher operational and cost efficiencies. If the cost of each ton per 1,000 km of roads is approximately US$48, while the cost for railroads is US$31, and for waterways US$20, then by combining two out of these three modes, costs can be reduced by approximately 20%, which is especially important for long routes and in the major production and export corridors.

The development of multimodal systems still requires the correction of a number of shortcomings that impede proper improvement and prevent operators from increasing volumes. The most important issues are regulatory and bureaucratic delays that require operators to manage their whole multimodal operations through a single transportation document, establishing regulations defining freight, taxes and insurance; consolidating the Multimodal Transport Law 9611 of 1998 through the formalization of the role of the Multimodal Operator, and implementing tax reforms to avoid double taxation of multimodal operations.

1.3.4 The Logistics Perspective

In the context of integrated logistics and supply chain management, the transportation sector plays a fundamental role illustrated by the logistics equation, where physical distance can be transformed into economic distance.[18] According to Ballou (1992), the concept of economic distance means that efficient and inexpensive transportation systems contribute to greater competition in the marketplace, greater economies of scale in production, and reduced prices for goods. The current conditions of the transportation sector, considered within the framework of integrated logistics, require integrated and robust strategies to improve efficiency so that regional

[17] This figure becomes somewhat smaller when one takes into account that some waterways are characterized by changing water levels that restrict navigation in some rivers to only a few months per year.
[18] Batista (2006).

development, financing consolidation, regulatory firmness, and coherent policies can be achieved across political jurisdictions.[19]

Regulation is the other element that, together with planning and investment, constitutes the basis of the efficiency of the transportation sector. The need for a clear regulatory environment is a growing concern inasmuch as investment (both public and private) is relatively scarce, and a higher level of private sector participation is needed to make up for the fiscal constraints on the public sector.[20] The lack of government investment and the complex regulatory environment has inhibited the growth of an integrated transportation system, and continues to hamper logistics development. Cavalcanti (2002) points to the need for transportation regulations to be equidistant from the three major interest elements, which are the private sector, the government, and the service consumers. In addition to the impartial role of the agencies, the concession process should also consider the specifics of roads, regional development, vehicle mix and other issues related to social welfare and not just the advantages of sectoral interests (Castro 2000).

1.4 Government Investment and Government Policies in Transportation

The government's role in transportation began to shift in the early 1990s from one focused on investment to one focused on regulation. Although the role of the private sector is still very limited in terms of overall transportation infrastructure, the fiscal constraints on public investment and the need to increase overall efficiency have contributed to the improvement of the public sector's regulatory role, despite a number of early policy mistakes.

1.4.1 Government Investment in Transportation

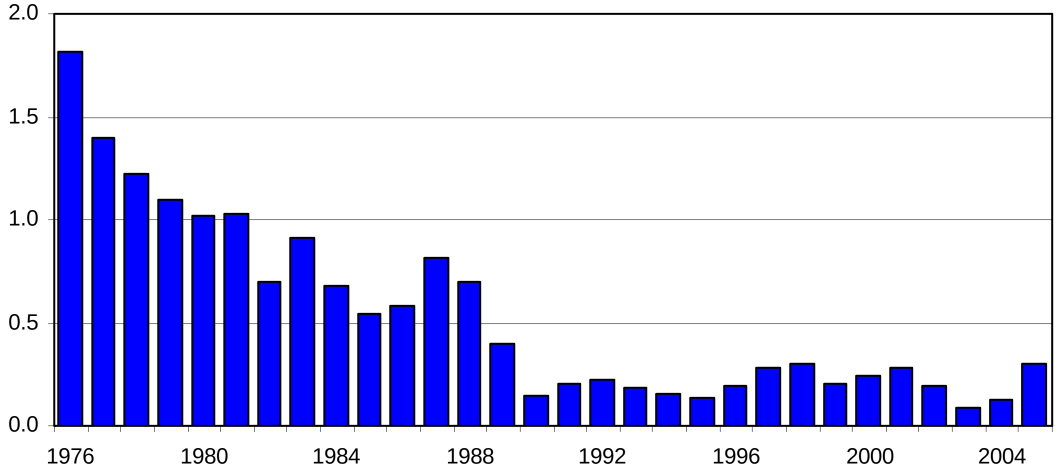
Government investment in transportation infrastructure, along with national infrastructure investment more generally, slowly decreased following the debt crisis of 1982 and the subsequent loss of earmarked funds from the National Highway Fund (*Fundo Rodoviário Nacional*) after the 1988 Constitution sharply reduced investment in transportation. The consolidation of the Real Plan in 1994 and the establishment of a primary surplus target aimed at stabilizing the public debt-to-GDP ratio have also constrained government investment even as current spending has continued to grow. Figure 1.9 shows the decline of transportation investment as a share of GDP. In addition to fiscal space difficulties, transportation investment has suffered from inadequate long term planning, insufficient funds to guarantee continuous transportation improvements, and individual road projects that have made the integration of economic corridors difficult.

The Federal Government's recent approval of the Growth Acceleration Program (PAC or *Programa de Aceleração do Crescimento*) represents an attempt to increase infrastructure investment. The PAC involves investments in transportation projects totaling approximately R$58.3 billion for the 2007-2010 period. These investments, which are to be financed primarily by the public sector, vary from R$33.4 billion for roads, to R$7.9 billion for railroads, R$3 billion for airports, R$2.7 billion for ports, and R$0.7 billion for inland waterways; (the remaining R$10.6 billion will go to the merchant marine). This represents approximately 0.6% of GDP per year, or about twice the current government investment in transportation.

[19] Castro (2004).

[20] Cavalcanti (2002), Ignarra (2002), and Amouzou (2002) point out the recent development of regulation in the transportation sector of Brazil, as well as the need for further reform.

Figure 1.9 Public Investment in Transportation as a Percentage of GDP



Source: Carvalho (2006).

1.4.2 Regulatory Agencies and Policies

Beginning in the 1990s, Brazil experienced a series of important regulatory and policy reforms affecting the transportation sector: old agencies were replaced by new ones that have different roles and responsibilities; policies have been enacted to modernize and consolidate port operations and multimodal operators; regulatory changes have been made in road and railroad concessions; and transfers of administrative authority have taken place from the federal government to the states. The public sector has reduced its participation in transportation, while the private sector has increased it.

The implementation of these new policies and regulations, however, has not been entirely successful and the results vary across transport modes and sectors. In addition to the Ministry of Transportation, the Department of Transportation Infrastructure (DNIT or *Departamento Nacional de Infra-estrutura de Transportes*), is in charge of implementing infrastructure policy for roads, railways, ports, and inland waterways, as well as construction, maintenance and operation.

The agency responsible for the control and regulation of the road and railway systems is the National Agency of Overland Transportation, (ANTT, or *Agência Nacional de Transportes Terrestres*) which is the most important regulatory agency in the transportation sector. There is also a national program of highway concessions (*Programa de Concessões de Rodovias Federais*) that has initiated an ambitious effort to increase private sector participation in the highway system.

The ANTT was established to reduce conflicts among operators, clients, investors, and the public sector and is responsible for the management and operation of all overland transportation, either directly or through regulation of privatized infrastructure. It is in charge of the administration of concession contracts; regulation of tariffs; setting of freight prices for rail transport; registration and control of multimodal operators; and overall promotion of consistent and effective regulatory policies across land transportation sectors. The national agency of waterborne transportation (ANTAQ or *Agência Nacional de Transportes Aquaviários*) has similar responsibilities for ports and inland waterways.

Created in 2001, ANTAQ is charged with regulating ports, maritime transportation and waterborne commerce. Since 1993, the Port Modernization Law has contributed to the privatization of major terminals and the creation of local Port Authorities and Port Authority Councils tasked with regulating the operations of ports to foster increased competition. The reform of the ports sector, however, has not advanced sufficiently because of the absence of clear policies as to how to proceed with further decentralization and privatization of port administration. In addition to lack of investment, labor disputes remain a major impediment to improving port productivity and reducing operating costs.

1.4.3 Privatization, PPPs, and the Role of the Private Sector

The increasing role of the private sector in the provision of transportation infrastructure and services came as a consequence of the limits imposed on the government's fiscal policies that resulted in a substantial drop in government investment in infrastructure (and especially transportation infrastructure). Most importantly, however, privatization was a response to the need to improve efficiency, achieve better service levels, increase the sustainable level of investment, and increase investment in technology and labor training. The privatization of transportation systems also contributed to a reduction in public sector expenditures on the maintenance of transport facilities, thereby leaving greater room for investment in other areas.

The Federal Highway Concession Program (*Concessões de Rodovias Federais*) was originally launched in 1993, but the first federal highway concessions started in 1996. Currently there are about 4,700 km of federal highways under concession to private operators. A second phase of the program, which has been delayed due to legal concerns raised by government auditors, will privatize another 2,600 km. The Law of National Transportation, enacted in 2006, is expected to facilitate concessions. The law establishes that the DNIT may provide financial resources to maintain and build roads to be transferred as well as clarifying its supervisory role. The third phase of highway concessions, involving about 6,700 km, is already planned and its implementation will depend on the success of the second phase.

The beginning of private sector participation in port activity began with the Port Modernization Law of 1993, which emphasized privatization, decentralization and increased competition. Beginning in the late 1990s, concessions of the major terminals to private operators and the establishment of new private terminals have contributed to lower operating costs, but public sector investment in capital improvements and dredging works, though badly needed, has been negligible. Policies necessary to continue the process of privatization and decentralization have not been clearly defined, and only twelve ports have been delegated to their corresponding state or municipality, while twenty ports, including those of Rio de Janeiro and Santos, remain under federal control through the control of eight dock companies. The government has been reluctant to advance in the privatization of these dock companies, is partly because of their precarious financial situation and longstanding labor disputes. As a result, only secondary ports are likely to be privatized in the near future.[21]

[21] World Bank (2007)

The privatization of the Brazilian railroad network in the late 1990s involved the two major government-owned railway companies (RFFSA, the Federal Rail Network Corporation, which was later divided into six regional railroad operators, and FEPASA, which belonged to the state of Sao Paulo). In addition, the then state-owned industrial holding CVRD managed two specialized rail lines: EFVM and EFC. Together these accounted for about 99 percent of the total freight transported on railroads. As per the 1988 Constitution, the federal government remains the owner of railroad assets while private sector companies obtain the right of transportation through a concession. As a result of several regulatory loopholes, including an absence of clear rules for tariff calculations and access prices, a lack of penalties for noncompliance with contract targets, and a lack of adequate structure of ownership to promote competition, the railway sector failed to develop as expected in the first few years of private sector operation. Changes in the regulatory environment, however, as well as the restructuring of the private operators in 2003 resulted in greater capitalization along with a sharp increase in investment and in volume transported.

Closely related to the privatization programs are the Public-Private Partnership Projects (PPPs). This type of partnership has been successfully tested in the US, Canada, Australia, Italy, South Africa, Mexico, Portugal, and Chile, among others. In Brazil, the appropriate regulatory framework has recently been developed, together with the acquisition of the fiduciary resources necessary to support the PPPs. The program began in the states of Minas Gerais and São Paulo, with the MG-050 highway and Line 4 of the São Paulo Subway, respectively. The first project is a 25-year concession in Minas Gerais for the highway connecting Belo Horizonte to the north of São Paulo state. The second project is a 13 km stretch of urban subway in the capital city of São Paulo state. There are currently a considerable number of similar projects at both the federal and state levels, including railroads and ports as well as roads. Despite the fact that there are still some regulatory issues to be resolved, specifically those related to federal fiduciary resources, the PPPs could substantially increase investment in transportation projects.

1.5 Conclusions

The current state of Brazil’s transportation sector, its insufficient quality and inefficient operation, has been the result of the historical development of the Brazilian economy, the lack of appropriate planning, and insufficient investment. Unfortunately, the inadequacy of the Brazilian transportation sector has had a significant negative effect on the country’s competitiveness.

Despite the extensive growth of the road network beginning in the 1950s, the deterioration of roads resulting from cutbacks in maintenance in the recent past is a major concern. Road transportation dominates both short- and long-distance freight markets, and traffic volumes are increasing. Road transportation costs are relatively high, particularly in the agricultural and mining frontiers that dominate Brazil’s export market.

Other transportation modes have not received enough attention and sustained investment to compete with roads, resulting in a vicious cycle. Roads are responsible for greater traffic volumes, and other modes are becoming more and more specific to low value added products with spatial concentration of movement. In addition, multimodal transport has not developed to the point where different modes of transportation can be combined to increase total efficiency.

In principle, Brazil's transportation sector is governed by modern and appropriate policies and effective regulatory agencies. In practice, however, operations are still outdated and undeveloped. Unclear regulation for ports and railroads, excessive numbers of workers at ports and bureaucracy, freight transport modes with low productivities, and agencies operating under ambiguous regulatory mandates have created an environment where operators often work in uncharted territory.

Finally, comprehensive reviews of concession bidding and contract documents, which take too long, have prevented PPPs from becoming an effective means of improving transportation efficiency in the country. Moreover, decentralization of road and port administration continues to move at too slow a pace, which further reduces the efficiency of the transportation sector.

Chapter 2
Efficiency and Income Distribution Effects of Changes in the Modal Composition of Freight Transportation in Brazil

2.1 Introduction

As discussed in Chapter 1, a possible source of inefficiency in transportation is excessive reliance on roads, a more expensive mode than railroads and waterways. Figure 1.2 in Chapter 1 presents the modal composition of freight transportation in Brazil for 2005. It is clear that road transportation dominates, accounting for 58% of total ton kilometers of freight (TKU, freight volume multiplied by distance), and followed by railroads, with a share of 25%, and water transportation at a mere 13% of total TKU. The dominance of roads is a result of the rapid and disproportionate expansion of the road sector relative to other modes. A major cause of the emphasis on the road network is that it is highly flexible and versatile from a policy standpoint: the system is much more easily extended than the rail or waterway networks, it allows for greater fluctuations in traffic volume, and upgrading its freight and passenger capacity is less costly and difficult.

The evolution of road construction, as presented in Chapter 1, shows acceleration from the 1950s to the 1970s. As a result, Brazil's highway system, a map of which is shown in Figure 1.6 of Chapter 1, has been extensively developed across the country. The railroad system, depicted in Figure 1.8, also developed rapidly from 1854, when the first railroad was inaugurated, to 1920 but decelerated afterwards. The 1940s marked the beginning of the stagnation as the central government began to increasingly emphasize the highway system. Many major railroads and branch lines were deactivated, diminishing the total length of the system from 38,287 km in 1960 to 29,659 km in 1980. The petroleum crisis of the 1970s demonstrated the necessity of altering transportation policy, but the adoption of efficient measures to recover, modernize and maintain the national railroad system was restrained by financial constraints.

Any attempt to change the modal composition of freight transportation will require considerable investment. This study is primarily concerned with the impact of these changes on output, employment and income inequality. To quantify these effects, this chapter uses a Leontief-Miyazawa model. The model simulates the effects of changes in the proportional share of different modes of transportation on the variables listed above. The next section summarizes the methodology, a complete description of which can be found in Annex 7. Section 2.3 describes the data used in the study, indicating sources and presenting general information on their main characteristics. The results of the simulation are presented and discussed in Section 2.4. The last section summarizes the findings and conclusions.

2.2 Methodological aspects

The Leontief-Miyazawa model used in this chapter combines a standard Leontief multisectoral fixed-coefficient production model and a Miyazawa consumption demand model where the consumption demand of each sector is a linear function of the incomes of the different income groups, as generated by that productive sector. The model is made dynamic by specifying what part of current consumption depends on past income.

In implementing the model Brazil's 2004 input-output table was used, updated to take into account the recent changes in Brazil's national accounts. The consumption part of the model used the 2004 household survey, which allowed the specification of the sector of economic activity to which each individual belongs. Table 2.2 illustrates by compares Brazil's overall income distribution with the income distribution of those working in transportation sectors.

2.3 Data description

The model summarized in Section 2.2 and more fully described in Annex 7 was applied to Brazilian data in order to assess the impact changes in the modal composition of cargo transportation had on Brazil's income inequality. This section describes the data used.

2.3.1 The productive structure

A Social Accounting Matrix was constructed to account for the effects of changes in transportation on income distribution. The central element in this analysis is the 2004 Input-Output table. Given recent modifications in the calculation of National Accounts[22], the system used in Moreira et all. (2007) was updated, applying the methodology presented in Guilhoto and Sesso-Filho (2005). All productive activities in the economy were allocated to one of the 35 sectors listed in Table 2.1. The transportation sector, which appears as an aggregate sector in the National Accounts System, was disaggregated into four modal sub-sectors (freight transportation, road, rail, water, and air) and an additional sector for passenger transportation. All of these have been highlighted in the Table 2.1. In order to disaggregate the transportation sector, sector-specific information was gathered from the 2004 Pesquisa Anual de Serviços (PAS, Annual Survey of Services), by IBGE[23].

[22] http://www.ibge.gov.br/home/estatistica/economia/contasnacionais/referencia2000/2005/default.shtm

[23] http://www.ibge.gov.br/home/estatistica/economia/comercioeservico/pas/pas2004/default.shtm

Table 2.1 List of Sectors of the I-O Table

1	Agriculture
2	Mineral extraction (except fuel)
3	Petrol and gas
4	Non-metallic minerals
5	Steel and Non-ferrous metallurgy
6	Machinery and equipment
7	Electric material and electronic equipment
8	All types of vehicles
9	Wood and furniture
10	Cellulose, paper and printing
11	Rubber
12	Chemical
13	Petrol refining
14	Pharmaceutical and veterinary
15	Plastics
16	Textiles
17	Apparel
18	Shoes
19	General food
20	Other manufacturing
21	Public utility services
22	Construction
23	Trade
24	**Road Transportation**
25	**Rail Transportation**
26	**Water Transportation**
27	**Air Transportation**
28	**Passengers Transportation**
29	Communication
30	Financial institutions
31	Services to households
32	Services to business
33	Building Rent
34	Public administration
35	Non-business private services

2.3.2 Sectoral distribution of income

The source of income distribution data by sector is the Pesquisa Nacional por Amostra de Domicílios (PNAD), a national survey conducted in 2004[24] using a sample of 389,354 individuals and 139,157 households. The interviewers collected information on the socioeconomic conditions of various households. Of special interest to this study were the sectors of activity each person derives income from or is employed by and the amount of income they receive. Using this data it is possible to associate persons and their respective income levels to sectors. The monthly income in sectoral activity, excluding retirement payments and domestic servants, was considered. Table 2.2 displays income earners divided into ten income brackets. It also displays the percentage of income earners from each income level employed by each

[24] www.ibge.gov.br/

transportation sector. The intervals mirror the ones used by Instituto Brasileiro de Geografia e Estatística (IBGE), Brazil's federal statistics office.

The numbers presented in the table are also plotted in Figure 2.1, in which the cumulative percentage of total income is displayed on the vertical axes. For comparison purposes, the income distribution profile for the aggregate of all sectors is displayed in each graph. Passenger transportation follows a similar pattern to the average of all sectors for the first two income classes, and a more equitable distribution for the higher income classes, which indicates that it is less conducive to income concentration than the average. At the other extreme, air transportation is heavily reliant on high income workers, and presents the least equitable income distribution.

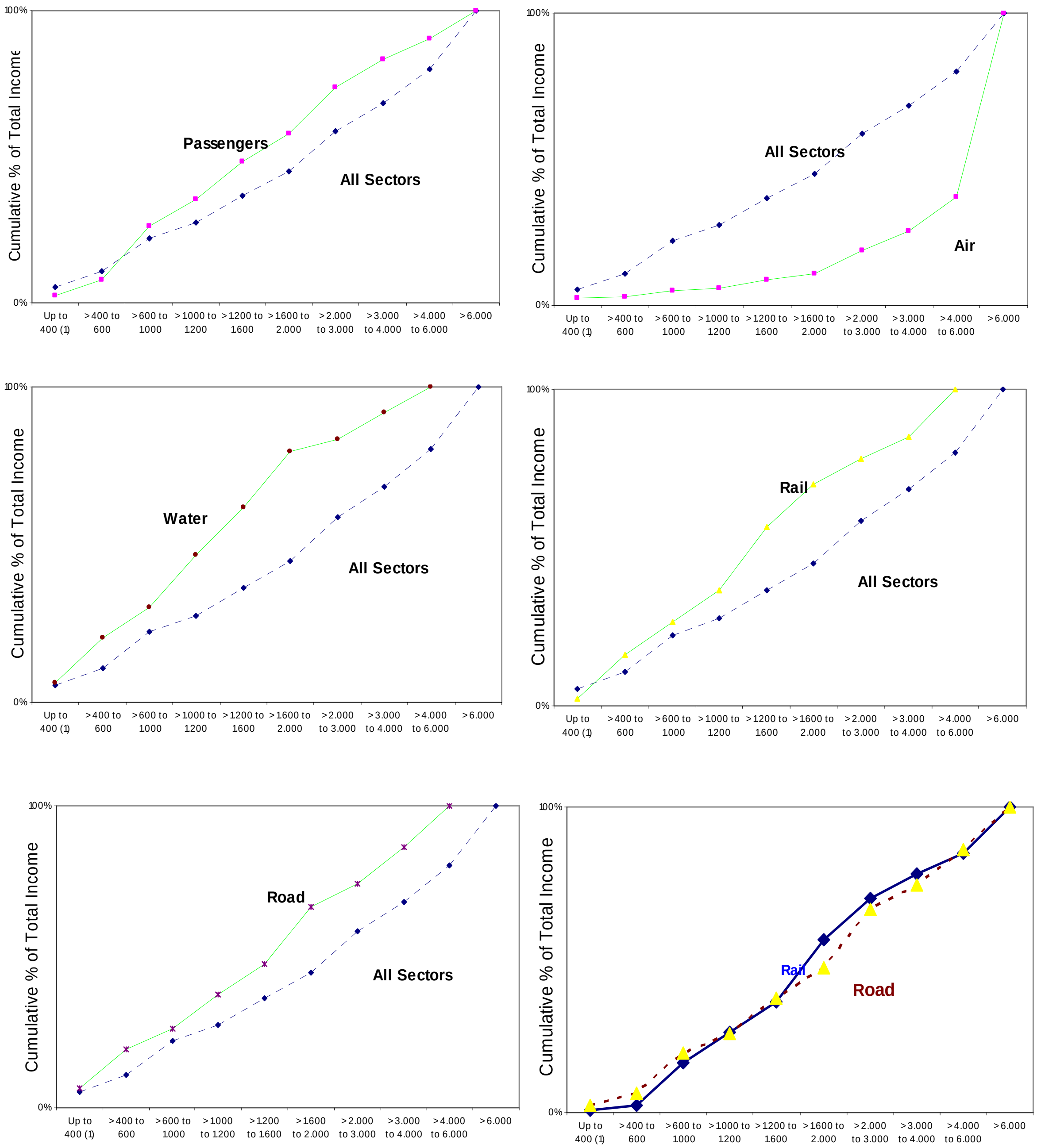
Table 2.2 Income Distribution by Sector

Income classes (R$/month) (monetary and non-monetary)	Share in Income					
	All Sectors	Transportation Sectors				
		Passangers	Cargo			
			Rail	Road	Water	Air
Up to 400 (1)	5.3%	2.5%	1.0%	2.4%	3.5%	2.6%
> 400 to 600	5.4%	5.6%	1.5%	4.1%	2.6%	0.2%
> 600 to 1.000	11.5%	18.2%	13.8%	13.0%	14.4%	2.2%
> 1.000 to 1.200	5.3%	9.1%	10.2%	6.6%	9.6%	0.7%
> 1.200 to 1.600	8.9%	12.8%	10.0%	11.2%	16.6%	2.8%
> 1.600 to 2.000	8.3%	9.8%	20.4%	10.2%	15.1%	2.4%
> 2.000 to 3.000	13.7%	15.8%	13.4%	19.2%	17.6%	7.7%
> 3.000 to 4.000	9.7%	9.7%	8.0%	7.7%	4.0%	6.7%
> 4.000 to 6.000	11.9%	7.2%	6.9%	11.8%	8.4%	11.6%
> 6.000	19.8%	9.4%	15.0%	13.9%	8.2%	63.0%
All Classes	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: PNAD, 2004 *(1) Includes people without income*

The two most important sub-sectors, rail and road transportation, present similar profiles with both distributing more income to the lower income brackets. In spite of several small differences, a one-to-one comparison shows that employment in road transportation provides a relatively greater share of total employment for workers in the low-income levels, and rail transportation is responsible for a greater share of employment in the middle-income levels. This provides a preliminary indication that the effect of changes in the modal distribution of transportation between road and rail would probably have little influence on overall income distribution.

Figure 2.1 Income Distribution Profiles within Transportation Sectors



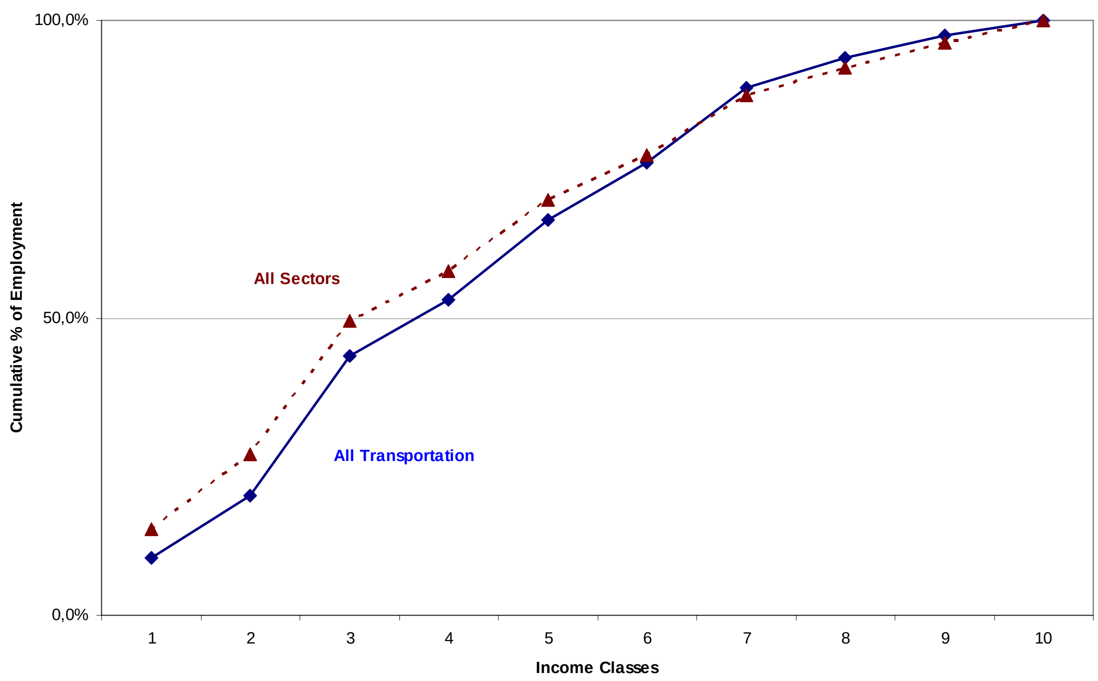
Source: Data based on authors' estimation.

2.3.3 Employment by sector

PNAD also provided information on employment by sub-sector within transportation, which is displayed in Table 2.3. The transportation sector employs a total of 3.46 million with the two largest users of labor being road freight transportation which employs 1.561 million employees, and passenger transportation which employs 1.553 million. Rail is the smallest employer, with 53,013. The aggregate of all sub-sectors is responsible for 3.93% of total employment. The share of employment is higher for workers in income brackets 3 to 8, and lower in the two extremes of the distribution, indicating that employment in transportation is more concentrated in the middle income brackets, especially in income levels 6 and 7.

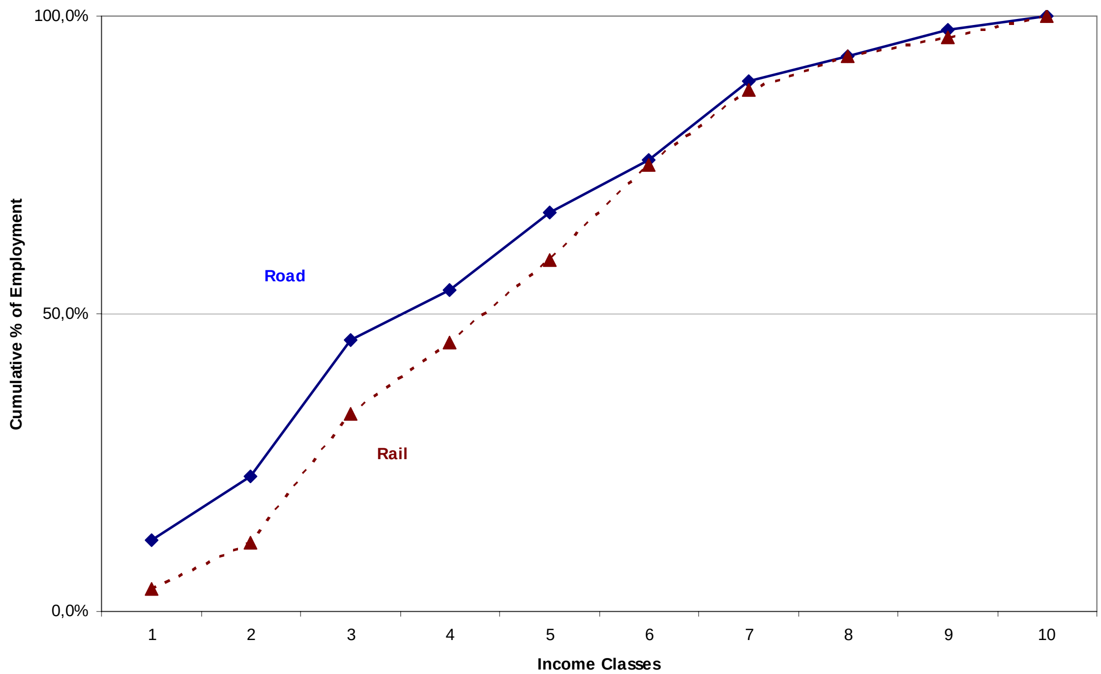
For all sub-sectors except air transportation the majority of employees come from the five lowest income brackets. Compared to all sectors of the economy, the cumulative percentage of employment across income brackets—displayed in Figure 2.2—is smaller for low-income workers, meaning that the labor use profile is more concentrated. As Figure 2.3 indicates, road transportation employs more workers from the lower income brackets than rail transportation.

Figure 2.2 Distribution of Employment by Income Bracket



Source: Table 2.3

Figure 2.3 Distribution of Employment: Road x Rail



Source: Table 2.3

Table 2.3 Employment by Sub-sector within Transportation

	Income Classes										
	1	2	3	4	5	6	7	8	9	10	All Classes
Number of Employees											
Rail	2,037	4,129	11,456	6,322	7,312	8,528	6,704	2,980	1,610	1,935	53,013
Air	3,390	1,688	14,465	3,328	7,398	5,634	12,986	7,351	13,198	8,576	78,014
Passengers	119,858	175,177	395,568	164,550	216,373	147,348	183,024	78,222	38,795	34,035	1,552,950
Water	20,215	12,195	41,708	19,672	31,901	28,313	31,084	16,999	9,726	8,294	220,107
Road	187,132	168,773	356,389	132,193	201,350	139,964	205,801	65,727	67,910	36,482	1,561,721
All Transportation	332,633	361,962	819,586	326,066	464,334	329,787	439,600	171,277	131,240	89,322	3,465,805
All Sectors	14,411,658	11,546,593	19,837,852	7,220,592	10,024,344	6,395,858	8,364,594	3,800,058	3,391,335	3,252,071	88,244,954
Shares											
Rail	0.01%	0.04%	0.06%	0.09%	0.07%	0.13%	0.08%	0.08%	0.05%	0.06%	0.06%
Air	0.02%	0.01%	0.07%	0.05%	0.07%	0.09%	0.16%	0.19%	0.39%	0.26%	0.09%
Passengers	0.83%	1.52%	1.99%	2.28%	2.16%	2.30%	2.19%	2.06%	1.14%	1.05%	1.76%
Water	0.14%	0.11%	0.21%	0.27%	0.32%	0.44%	0.37%	0.45%	0.29%	0.26%	0.25%
Road	1.30%	1.46%	1.80%	1.83%	2.01%	2.19%	2.46%	1.73%	2.00%	1.12%	1.77%
All Transportation	2.31%	3.13%	4.13%	4.52%	4.63%	5.16%	5.26%	4.51%	3.87%	2.75%	3.93%
Cumulative percentage											
Rail	3.8%	11.6%	33.2%	45.2%	59.0%	75.0%	87.7%	93.3%	96.3%	100.0%	
Air	4.3%	6.5%	25.1%	29.3%	38.8%	46.0%	62.7%	72.1%	89.0%	100.0%	
Passengers	7.7%	19.0%	44.5%	55.1%	69.0%	78.5%	90.3%	95.3%	97.8%	100.0%	
Water	9.2%	14.7%	33.7%	42.6%	57.1%	70.0%	84.1%	91.8%	96.2%	100.0%	
Road	12.0%	22.8%	45.6%	54.1%	67.0%	75.9%	89.1%	93.3%	97.7%	100.0%	
All Transportation	9.6%	20.0%	43.7%	53.1%	66.5%	76.0%	88.7%	93.6%	97.4%	100.0%	
All Sectors	14.6%	27.1%	49.5%	57.9%	69.8%	77.4%	87.5%	92.1%	96.1%	100.0%	

Source: PNAD (2004).

2.3.4 Consumption patterns by sector

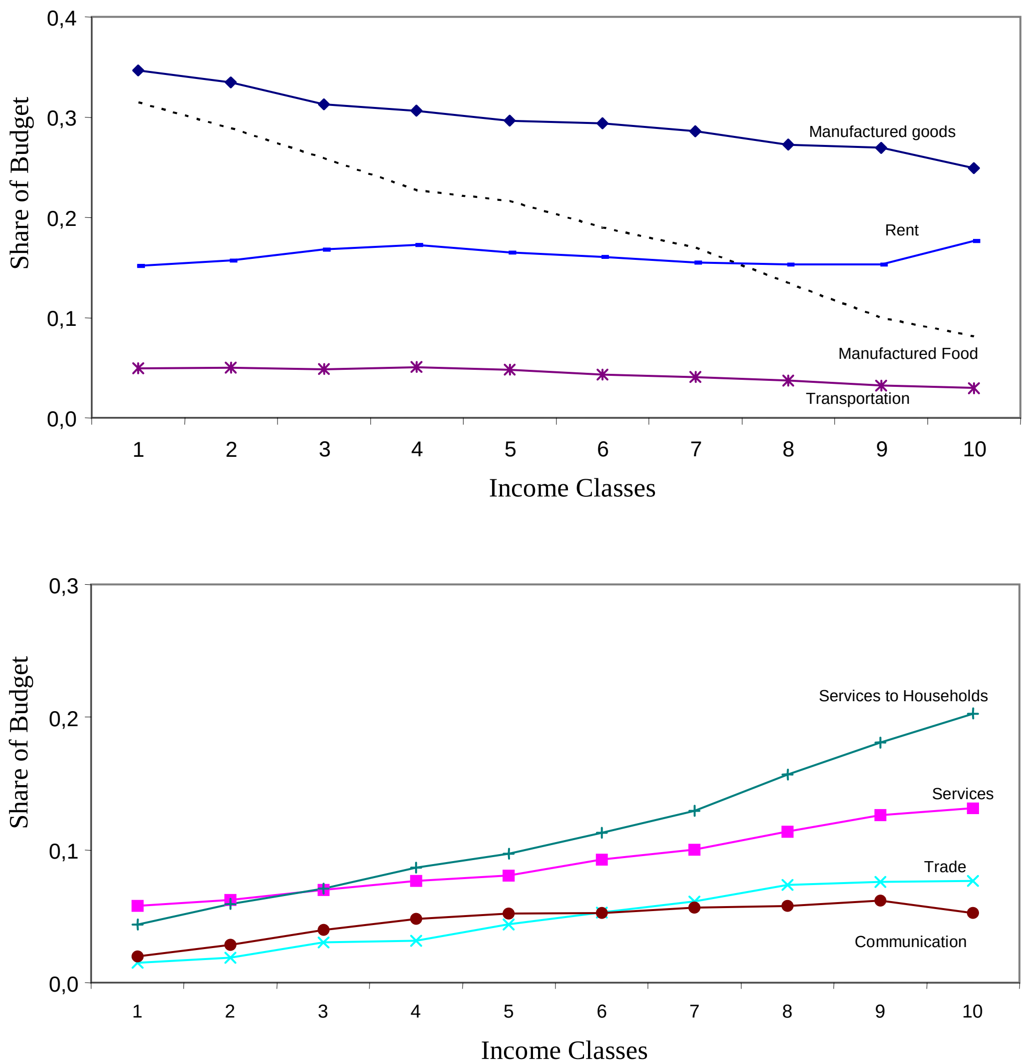
The Brazilian household expenditure survey, POF, was conducted in 2002 and 2003. It records monetary and non-monetary income, as well as monetary and non-monetary consumption. A total of 48,470 households were interviewed, and the sources of income and expenditure were identified for each one. Expenditures by households were allocated among 10,429 types of goods and services. These were aggregated to the 80 more general types of goods and services presented in the national accounts and originally used in this study. Thus, there are estimated expenditure patterns on 80 different types of goods and services by each income bracket. With this information it was possible to identify the consumption patterns of households in each of the ten income brackets defined in the income distribution section for all sectors studied.

Figure 2.4 presents some information on consumption patterns by income bracket for highly aggregated groups of products. Poorer households spend a larger percentage of their income on Manufactured Food, Manufactured Goods, and Transportation. The importance of these products in a household’s budget decreases as household income increases. On the other hand, *Services in General*, *Services to Households*, *Trade*, and *Communication*, all increase in importance as households move from low to high income classes.

Transportation here refers to household spending on transportation services and related goods. It includes expenditures associated with urban transportation (bus, taxi, subway, train, boat, etc.) and long-distance travel services (bus, airplane etc.). It also includes the cost of purchase, maintenance, parts and fuel for private vehicles, as well as parking fees, tolls, and insurance. The data shows that transportation costs decline slightly as income levels increase, especially after the fourth lowest income bracket. Considering the sub-sectors, the share of consumer expenditure on road transportation decreases as income grows, and increases for air transportation. For rail, the share increases until the 7th income bracket, and then decreases.

Similar information is available for each sector, allowing for the calculation of the induced effects of any shock to the system. This provides the direct effects, in the sense that it portrays the first round of consumer expenditure. The amount spent by poor households on road transportation, for example, will increase that sector’s activity, which will in turn distribute income to different households. Such income will be spent in all sectors of the economy, according to the consumption coefficients. The final effects will include all rounds and dimensions of the production system, and might differ from the direct ones presented in this section.

Figure 2.4 Share of Different Goods and Services in Budget



Source: POF – Pesquisa de Orçamentos Familiares 2002/2003 (IBGE)

2.3.5 Intersectoral relations and income inequality

The information on income distribution by sub-sector within the transportation sector indicates that rail and road transportation present a similar profile, which is presented in Figure 2.1. In spite of this general observation, the graphs indicate that road transportation distributes income more intensively for the three lowest income levels, and that rail transportation does so for the 6^{th}, 7^{th}, and 8^{th} income levels.

This information suggests that a more intensive use of trains will have an income concentration effect. In order to assess the full impact, however, other aspects have to be taken into consideration. Income is distributed to households, which in turn spend it according to the consumption patterns already shown. The net effect will depend on which sector's income is spent, and the sectors' distributive profile. Income distributed to low-income households might be spent in sectors with a concentration profile, and vice-versa.

But there is another way to determine the final impact, which is the profile of interrelationships between sectors in the input-output part of the model. In order to illustrate this, we present in Table 2.4 the percentage of purchases made by each transportation sub-sector from sectors with lower-than-average inequality. The latter were defined in Moreira et al. (2007), who estimated the final impact on national income inequality of identical increases in production in each sector of the economy including the direct, indirect, and induced effects. If the marginal increase in production produces an inequality index (Gini) lower than the national average, the sector diminishes inequality, and is labeled pro-poor in this study. Thus, the table presents the share of purchases from the transportation sub-sectors which are made by sectors that promote reduced inequality.

Road freight transportation is the sub-sector with the lowest share of purchases from pro-poor sectors at 45%. Rail freight transportation is in the other extreme, purchasing 68% of its inputs from sectors that directly or indirectly reduce income inequality. Thus it is expected that a change from roads to rail would promote an improvement in income distribution.

Table 2.4 Profile of Intermediate Purchases

		Percent of intermediate purchases from pro-poor sectors
Passengers		51.9%
Cargo	Water	58.1%
	Air	52.5%
	Rail	68.2%
	Road	45.4%

Source: Data based on authors' calculation

Although these partial analyses are important to understanding the mechanics through which changes in the modal distribution of transportation influence income inequality, it is necessary to consider all factors simultaneously. The next section attempts to do that.

2.4 Results

The purpose of this simulation is to observe the effects of a change in the modal composition of freight transportation that puts more emphasis on rail and less on roads. In terms of production value, the shares in the 2004 Input-Output table are presented in Table 2.5.

Table 2.5 Modal Shares in the Input-Output System

	Intermediate Consumption		Final Demand		Total Consumption	
	R$ Million	Share	R$ Million	Share	R$ Million	Share
Road	50,004	61.59%	9,277	13.91%	59,281	40.09%
Rail	4,238	5.22%	2,543	3.81%	6,781	4.59%
Water	8,582	10.57%	5,291	7.93%	13,874	9.38%
Air	2,779	3.42%	3,932	5.89%	6,710	4.54%
Passengers	15,584	19.20%	45,654	68.45%	61,238	41.41%
Sum	81,186	100.00%	66,698	100.00%	147,884	100.00%

Source: Data based on authors' calculations.

Two simulations were carried out: a transfer of 10% of the final consumption of road transportation to the rail system, and the same transfer to waterways. It should be stressed that in absolute terms, the simulations transferred a total of R$5,928 million (US$3,018 million), which represents only 0.17%, of the total production value of the Brazilian economy. A summary of the results of the simulations is presented in Tables 2.6 and 2.7.

As is presented in Table 2.6, the simulated change from road to rail would have a small but positive impact on personal income (0.019%) and GDP (0.0026%), with a decrease in employment (-0.091%) and a slight improvement in the Gini index (in the tenth digit after the decimal point).

Table 2.7 shows the effects of a shift from roads to waterways. There was practically no change in aggregate personal income (+0.000012%), and a small improvement in GDP (+0.0043%). Employment decreased by 0.065%. The effects on aggregate GDP were larger than in the simulated change from road to rail. For each additional R$ spent on waterway transportation, there was an increase in aggregate GDP of R$1.909, considering direct, indirect and induced effects. This was slightly larger than the equivalent for either road or rail transportation. An extra R$ million of waterway transportation generated a total of 73.9 jobs in the economy (again considering direct, indirect, and induced effects), which is smaller than the number of jobs created by road transportation (83.4) and explains the aggregate decrease in employment.

In terms of income distribution, as in the previous case, there was also a very small improvement measured by the Gini index (also in the tenth digit after the decimal point). The case is similar to the change from road to rail: the waterway transportation sector buys a larger share of intermediate inputs from pro-poor sectors than the road system (58.1% versus 45.4%), but distributes slightly less direct income to the lower income groups. However, the positive effect of pro-poor intermediate purchases on income inequality exceeds the negative effect of direct income distribution.

Table 2.6 Overall Economic Impact of a Transfer of 10 percent of the Final Consumption in the Road System to the Rail System

	Before	After	Change Values	Change (percent)
Personal Income [a]	1,255,042	1,255,284	242	0.019
GDP [a]	1,941,498	1,941,548	50	0.0026
Employment [b]	88,244,954	88,164,235	-80,719	-0.091
GINI Index [c]	0.4860704672	0.4860704671	-0.0000000001	-0.000000014

Notes: a. R$ Million; b. number of persons; c. the value of the Gini index differs from the official figures, because it was estimated taking into consideration the input-output system

Source: Data based on authors' calculations.

Table 2.7 Overall Economic Impact of a Transfer of 10 percent of the Final Consumption in the Road System to the Waterway System

	Before	After	Change Values	Change (percent)
Personal Income [a]	1,255,042	1,255,042	0.16	0.000012
GDP [a]	1,941,498	1,941,582	84	0.0043
Employment [b]	88,244,954	88,187,862	-57,092	-0.065
GINI Index [c]	0.486070467196	0.486070467203	0.00000000001	0.0000000015

Notes: a. R$ Million; b. number of persons; c. the value of the Gini index differs from the official figures, because it was estimated taking into consideration the input-output system

Source: Data based on authors' calculation.

In terms of productive efficiency, given the reduction in overall employment and the marginally positive effect on output, the results show that a significant increase in efficiency was achieved by shifting activity levels (final consumption) from roads to either railroads or waterways, as a small number of workers were able to produce slightly more. In the case of a shift from roads to railways, the efficiency gain was measured by the amount of labor freed, which, assuming the average labor productivity of the overall economy remains constant, would generate an increase in GDP of about 0.09%. The way the simulation was set up there was no implied amount of investment, so the income was a pure efficiency gain effect. It also is the case that this does not represent unemployment, as the model does not include labor market, or prices, for that effect.

2.5 Conclusions

The goal of this work was to measure the income distribution effects of changes in the modal composition of cargo transportation. In order to do so a Leontief-Miyazawa type model was constructed with a base year of 2004. The model took into consideration 31 sectors, of which 4 sectors were related to freight transportation (road, rail, water, and air), and looked at 10 income brackets.

Transfers of 10% of the activity level (final consumption) of road transportation either to the rail system or to waterway transportation were simulated, and the results demonstrated impacts on GDP, aggregate income and employment, and changes in the Gini index. Since the system is linear, the direction of the changes will not change with the size of the percentage of final consumption changed from road to other transportation modes, although the sizes of the impacts will vary.

The results show that the relative impacts were insignificantly small, considering the relative size of the change simulated in relation to the Brazilian economy. Increasing the share of rail or waterway transportation would provide only a very slight boost to GDP growth as well as negligible improvements in personal income and income distribution.

While these projected impacts are not substantial, this study focused only on the distributional aspects of possible changes in the modal composition of freight transportation without considering aggregate efficiency and price changes, aspects that are beyond the scope of this work. Possible efficiency improvements due to changes in the modal composition of transportation can lead to increased aggregate production and changes in the sectoral structure of the economy, since different sectors rely differently on distinct modes of transportation and, therefore, will not be affected equally. Given the present sectoral structure, the direction of the effects are likely to be consistent with those presented above. Based on the model, a reduction in the share of road transportation would have positive, but insignificantly small, impacts on GDP growth, personal income and income distribution.

Chapter 3
Aggregate and Distributional Impacts of Changes in the Transportation Sector

3.1 Introduction

Since 1980, Brazil has witnessed a decrease in public investment in infrastructure. Ferreira and Maliagros (1998) and Ferreira and Araújo Júnior and Ramos (2006) affirm that the overall decrease in Brazil's growth rates since the middle of 1980's has been caused in part by the significant reduction in public investment in infrastructure, and particularly in transportation, which has experienced a drastic reduction in public investment as a percentage of GDP. Given the evidence presented in the literature on the influence of infrastructure on growth, Brazil could increase its growth rate by reversing its current trend of declining infrastructure investment. What would be the effect of an increase in investment in transportation? What would be the impact of a reduction in the costs of transportation? How would such improvements in transportation services impact economic growth, tax revenue, and income distribution?

This chapter discusses the impact of investments and policy changes in the transportation sector on economic activity and income distribution. It empirically investigates the aggregate and distributive impacts of increasing the efficiency and reducing the private cost of transportation services on the Brazilian economy. It uses a computable general equilibrium (CGE) model with several households explicitly represented to simulate alternative scenarios of improvement in transportation services. It also analyzes the importance of transportation services under a trade liberalization scenario, following the argument presented by Winter et al. (2004) concerning the need for coordination between trade policy and infrastructure investments in order to maximize the gains from trade for the poor.

An increase in the stock of infrastructure is expected to generate higher output and factor productivity and to decrease production costs by reducing the cost of inputs.[25] In turn, higher productivity is expected to attract private investments and generate employment by increasing the returns to capital. Several studies have measured the impact of changes in public investment in infrastructure, including transportation, on output or growth. The work of Aschauer (1989), who is considered one of the pioneers in measuring such elasticities, has focused on the aggregate impact of infrastructure on income and output growth for the U.S.[26] Many other researchers have investigated this issue, sometimes expanding the subject to include sectoral detail in the infrastructure characterization, sometimes refining the econometric techniques used, and sometimes considering other countries. Many of these studies are discussed in Gramlich (1994). More recent findings were presented by Calderón and Serven (1994), who focus on Latin American countries, and suggest that an increase in the communication, energy and transportation infrastructure in Latin America to the levels observed in countries in East Asia could increase annual GDP growth rates from 3.2% to 6.3%. In Brazil's case, Ferreira (1996) estimated values of between 0.34 and 1.12 for the income elasticity of infrastructure and between 0.71 and 1.05 for the income elasticity of public capital. Florissi (1997) found smaller numbers:

[25] See Ferreira (1996) and Rigolon and Piccinini (1997).
[26] Aschauer (1989) empirically analyses the behavior of productivity in the U.S. as a result of public sector investment in infrastructure and finds that public sector investment stimulates private investment and growth.

0.08 for the income elasticity of infrastructure and 0.29 for the income elasticity of public capital.

Regarding the impacts of infrastructure on income distribution and poverty, Calderón and Servén (2004) have argued that infrastructure development generates new employment opportunities and higher salaries, due to a resulting increase in labor productivity. Specific links between improvements in transportation infrastructure and reduction in income inequality may relate to increased access to more profitable economic activities for the poor and to a reduction in transportation costs to and from poor rural areas that increase the value of assets held by the poor.[27] Estache et al. (2002) also discuss the role of infrastructure investments in improving access to water, sanitation, energy and transportation, and thus in alleviating poverty and improving the quality of life of the poorest families.

There is empirical evidence that confirms the expected positive impact of improvements in infrastructure on income distribution. For example, Calderón and Servén (2004) have estimated a reduction in the Gini coefficient of between 0.05 and 0.13 in Latin American countries if their endowment of infrastructure was similar to those of East Asian countries. In Brazil's case, Araújo Júnior and Ramos (2006) developed a general equilibrium model of the Brazilian economy and found decreases in the Gini coefficient of between 0.2% and 0.7% resulting from a 1% increase in the ratio of investments in infrastructure to GDP.

This chapter adds to the work described above by focusing on the land transportation sector and its intersectoral linkages in the economy, and also by considering a broader number of households in measuring distributive impacts.[28] The focus on a specific sector avoids the problem of infrastructure substitutability, i.e., that roads cannot be converted into energy transmission lines or that public transportation infrastructure cannot be easily converted into public telecommunication infrastructure. The chapter also expands the scope of inquiry, as it focuses not only on infrastructure but also on the importance of providing land transportation services.

While the Leontief-Miyazawa model in Chapter 2 uses a standard input-output model and a consumption demand model to look at output and distributional effects of shifts on transportation modes, those models do not take into account price changes, or markets for that matter. Those fixed-price models are substantially different from the model developed in this chapter and later in chapters 4 and 5, which are computable general equilibrium models (and flex-price models) where equilibrium prices play a fundamental role in obtaining a solution.

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[27] Calderón and Servén (2004) do not directly analyze the link between transportation and growth on income distribution, but use an aggregate index of infrastructure stock using principal components that include the length of the road network.

[28] Other studies about infrastructure using a CGE model for Brazil are Ferreira and Nascimento (2005) and Araújo Júnior and Ramos (2006). These studies do not consider the transportation sector in isolation from aggregate infrastructure. They also consider fewer sectors in the economy, reducing the scope for inter sectoral linkages. Araújo Júnior and Ramos (2006) have less household categories than those used in this Chapter, capturing the income distribution effects less precisely. Ferreira and Nascimento (2005) do not consider distributive impacts. Both models are smaller in dimension (fewer sectors and households) because they use a dynamic representation of the economy, which imposes size constraints.

The criticisms pertaining to the use of CGE models are well known and are summarized here. These models can be used to simulate policy changes having economy-wide impacts, but they do not necessarily explain well how the new equilibrium is achieved. As in any comparative static (or even dynamic) model a result can be produced but the pattern of how to get there is not always explained. These models are also subject to the "Lucas Critique" in which a number of parameters are used (or have to be estimated in order to be used) and cannot be changed as rational agents can when optimizing and when rational behavior is assumed. The CGE modeler's response to this critique is in testing different and reasonable behavioral parameters and testing for sensitivity, to see how sensible the final results are to changes in these parameters.

The rest of the chapter is organized in three sections. Section 3.2 describes the model. Section 3.3 presents the policy simulations, Section 3.4 discusses the results of these simulations, and section 3.5 presents the main conclusions. Two appendices provide details about the data on households and some sensitivity analysis of the results found in section 3.3.

3.2 The Model

This chapter uses a quantitative model to address the impact of improvements in transportation services on the Brazilian economy. It is a computable general equilibrium (CGE) model based on the GTAPinGAMS[29] model used by Rutherford and Paltsev (2000), and adapted from Harrison et al. (2003 and 2004). The model was originally developed to analyze trade issues, and was modified to address questions regarding a specific sector, in this case transportation. It does, however, preserve some of its original features that make it a proper tool to answer the questions addressed in this chapter. The representation of multiple households is one of those features. It allows measurement of the distributional impacts of improvements in the transportation sector. Annex 2 provides details on the structure of the model and on the data base used.

The analysis conducted through the model focuses on road transportation for several reasons. First, most of the recent literature about the importance of infrastructure on growth and on income distribution uses roads as a proxy for transportation infrastructure.[30] Second, road transportation is the most common form of passenger and freight transportation in Brazil. Finally, the 1996 input-output matrix lacks data on more disaggregated transportation sectors. In this particular case, there is no recent, publicly available input-output data for Brazil that includes multiple transportation systems, such as air and water. In addition, the household surveys tend to have more detailed information about transportation services provided by roads.[31] Therefore, the principal focus of this chapter is on road transportation services, which provide a better representation of the transportation sector and its links with income distribution channels.

[29] A complete characterization of the GTAPinGAMS model with detailed description of equations can be found in Rutherford and Paltsev (2000)

[30] For example, see Easterly and Rebelo (1993), Ingram (1994), Ferreira and Maliagros (1998) and Ferreira and Araújo (2006).

[31] For example, the POF survey from IBGE (2004), one of the most detailed surveys on household expenditure in Brazil, reports as sub-categories of expenses on transportation services those related to urban transportation (mostly done by buses in Brazil), fuel for automobiles, and the acquisition and maintenance of vehicles.

CGE models allow us to represent the key links between transportation services, economic growth, and income distribution. In terms of growth, those links are related to the share of transportation services in total value added and their importance as inputs in other sectors. The macroeconomic impact of investments (or other changes) on transportation will depend directly on those shares. Regarding income distribution, the key connections are through the share of transportation services in each household's total expenses and the share of each primary factor (labor and capital) in household income. Accordingly, the redistributive impact of transportation will depend on the relative size of those shares for poor households.

Table 3.1 presents sectoral data in terms of value added and its contribution to the value of production.[32] This data is the result of the imposition of the 1996 Brazilian IO table on the GTAP database and the correction of some factor shares in value added, which was done in order to better represent the characteristics of the Brazilian economy. In the case of land transportation, what is used are the original capital and labor shares presented in the 1996 Brazilian input-output table (IBGE 1996). As a result, this sector is labor intensive. For the other two transportation sectors (air and water), the data is kept as it appears in GTAP, since there is a lack of sufficiently detailed information about it for Brazil.

Table 3.1 Structure of Economic Activity in Brazil

VA	Value added net of tax ($ millions)	SKL%	Skilled labor share of value added, in percent
VA%	Sectoral value added as a percent of aggregate value added	CAP%	Capital share of value added, in percent
VA/COST%	Value added as % of sectoral cost of production	LND%	Land share of value added, in percent
UNSK%	Unskilled labor share of value added, in percent	RES%	Natural resource share of value added, in percent

	VA	VA%	VA/cost%	UNSK%	SKL%	CAP%	LND%	RES%
PDR (*)	810	0.1	34	72	8	19	1	
GRO	2936	0.4	48	71	8	17	3	
OSD	2811	0.4	44	36	4	49	10	
AGR	15647	2.2	35	67	8	21	4	
OCR	33086	4.7	58	78	9	10	2	
ENR	24547	3.5	31	6	4	85		5
CMT	2452	0.3	15	23	12	65		
OMT	1108	0.2	15	23	12	65		
MIL	2501	0.4	21	13	13	74		
PCR	191		5	23	24	52		
SGR	507	0.1	7	28	25	47		
OFD	13738	2	22	17	18	65		
TEX	4098	0.6	20	21	9	70		
WAP	3547	0.5	23	32	14	54		
LEA	1576	0.2	21	40	14	46		
LUM	4709	0.7	31	30	11	59		
MAN	60618	8.6	32	18	15	67		
I_S	3403	0.5	13	6	10	84		
FMP	6829	1	29	39	17	44		
MVH	9927	1.4	23	12	10	79		
OTP	16885	2.4	40	47	13	40		
ATP	1373	0.2	31	27	18	56		
WTP	278		15	27	18	56		
SER	480585	68.3	65	26	24	50		
DWE	9111	1.3	55	46	14	39		
TOTAL	703273		43	29	20	51		

(*) See Table A4.1 in Annex 4 for the full name of the commodities in this column.

Source: 1996 Brazilian IO table and GTAP database (version 5)

[32] See Harrison et al. (2003).

The Brazilian household data was extracted from the Living Standards Measurement Survey (LSMS) for Brazil, and reflects the characteristics of Brazilian households in 1996[33]. The LSMS represents around 103.6 million people (63% of the total population) living in the eastern regions of Brazil, and consisting of 22.3 million people in rural areas and 81.3 million in urban areas[34]. They were grouped in 20 different types based on income, 10 rural and 10 urban. Table 3.2 presents the key characteristics of several household types. As pointed out by Harrison et al. (2003), the share of the population living on one dollar or less, based on the LSMS data, was 7.3% and the share living on two dollars or less was 17.8%.[35]

Table 3.2 Household Types and Characteristics

Rural	Mean per capita Income *	Mean house-hold income*	% of sample	House-holds** (million)	Urban	Mean per capita income	mean house-hold income*	% of sample	House-holds** (million)	Monthly household income in 1996 Reals
Rhh1(±)	48	129	5.89	6.10	Uhh1(±±)	63	135	4.38	4.54	0 - 206
Rhh2	103	259	3.92	4.06	Uhh2	131	264	5.54	5.74	207 - 313
Rhh3	116	364	2.64	2.73	Uhh3	155	375	6.14	6.36	314 - 431
Rhh4	140	489	2.31	2.39	Uhh4	196	497	6.78	7.03	432 - 564
Rhh5	165	647	1.87	1.94	Uhh5	239	649	7.34	7.61	565 - 741
Rhh6	228	838	1.41	1.46	Uhh6	286	846	8.74	9.05	742 - 964
Rhh7	286	1074	0.7	0.73	Uhh7	390	1123	9.27	9.60	965 - 1290
Rhh8	385	1528	0.96	0.99	Uhh8	479	1561	8.06	8.35	1291 - 1889
Rhh9	615	2282	0.32	0.33	Uhh9	752	2449	8.99	9.31	1890 - 3196
Rhh10	2363	7864	1.52	1.58	Uhh10	2187	6728	13.22	13.70	3197 - 66809
Total Rural			21.54	22.31	Total Urban			78.46	81.27	

* Income figures are in 1996 Reals.

** The number of households the stratified sample is estimated to represent.

(±) Rhhi: Rural household class of the ith income level

(±±) Uhhi: Urban household class of the ith income level

Source: Estimations from the Living Standards Measurement Survey conducted by IBGE.

[33] It is called "Pesquisas sobre Padrões de Vida" (PPV) and was conducted by the Brazilian Institute of Geography and Statistics, IBGE (IBGE, 2001).

[34] As pointed by Harrison et al. (2003), experts who have worked with poverty data in Brazil believe the overall poverty is well represented in the PPV survey, although some regions of the country are not sampled in the survey. Other household surveys are available, as "Pesquisa Nacional de Amostra de Domicílios" (PNAD) and "Pesquisa de Orçamentos Familiares" (POF), both conducted by IBGE. PNAD is an annual survey, but does not provide all the necessary information since it has some limitations in terms of detailed household consumption information as well as information on non-wage sources of income. POF is available for the years 1996 and 2001, and because of its detailed coverage about household consumption, data from it was used to characterize the consumption of transportation services. Still, the overall household income and expenditure data from PPV was also kept in order to be consistent with the rest of the data in the SAM of Harrison et al. (2003).

[35] Regarding the poverty level and income distribution in more recent years, Barros et al. (2007) discuss few changes in Brazil's income distribution from 1995 to 2001, but highlight a 4.6% decrease in the Gini coefficient, from 0.594 to 0.566, in the period between 2001 and 2005. The Gini coefficient is 0.585 in the benchmark used here. Although the data used here reflects the income distribution in 1996 and then does not capture the recent improvements, it does not compromise the estimates, since a 4.6% increase in improved income distribution doesn't seem to dramatically change the patterns of income and consumption among different household types. Also, only the PNAD survey is available after 2002, but it does not provide all the information needed, limiting updates to the income distribution patterns in the database used.

Particularly important to the analysis of income distribution are the household income shares, (Table A3.2 in Annex 3), and the share of household expenditures on each good and service (Table A3.3 in Annex 3). The income shares reflect the fact that the poorest households receive higher shares of their income from unskilled labor, while the income of the richest households comes mostly from capital.

For the purposes of this chapter, it was necessary to separate the transportation sector from the services sector. To do so, some assumptions were used that better represent these relationships in order to evaluate income distribution changes from improvements in the supply of transportation services. The information used came from the LSMS and from the *Pesquisa de Orçamentos Familiares* (POF), for 1996/1997 and 2002/2003. The expenses on land transportation services were defined as those mostly related to urban public transportation and travel by roads, while expenses related to the purchase and maintenance of automobiles and their fuel costs were removed. This allowed the model to capture the types of transportation services used most frequently by poor families.[36] The share of expenses on transportation services for the poorest urban households was also increased to reflect the findings of Gomide et al. (2006) about the heavy burden transportation expenses place on low income families. Annex 4 gives more details on the construction of the household expenditure shares on land transportation. Expenses on water and air transport services were kept the same as in the LSMS survey and GTAP database.

3.3 Policy Simulations

Four sets of scenarios were implemented to assess the impacts of improvements in transportation services on the Brazilian economy and on income distribution. The first set was performed to investigate the role of public infrastructure on transportation. To do so, an alternative formulation of the model was used where capital of infrastructure is combined with other factors and inputs, and then increases simulated in the amount of infrastructure in the land transportation sector. This should reflect public assets such as roads, avenues and streets, and also public buses and trains. One can also think of it as the buildings and equipments used by public authorities and agencies responsible for taking care of roads, transit control, and maintenance.

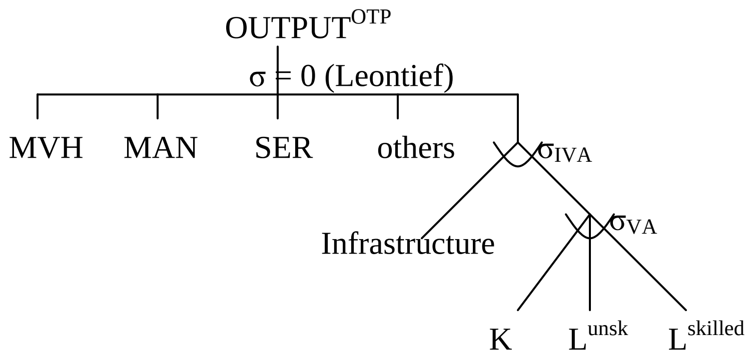
In this alternative approach infrastructure capital was included as a part of the production function for transport services. This was specified at an intermediate level of the CES nested structure. The infrastructure was combined with the value added composite[37], and then the composite of public capital and value added entered a top-level Leontief function with intermediate inputs. Figure 3.1 shows the approach adopted. The model was run with alternative values for the elasticity of substitution between infrastructure capital and the value added

[36] To some extent it makes sense that improvements in land transportation services have an important impact on owners of automobiles. However, as the poorest households have fewer access to automobiles, the inclusion of automobile expenses on the total transportation service expenses would mask the impacts of it on income distribution. For this reason, it was decided to represent the land transport sector as close as possible to those services used mostly by poor people.

[37] The value added composite is the CES combination of capital, unskilled labor and skilled labor, as explained in the description of the model.

composite (σ_{IVA}), ranging from 0 to 0.5.[38] Furthermore as there was no information on the share of infrastructure in total capital employed by the land transportation sector, different assumptions were tested to investigate its importance of representing infrastructure in the production function.[39]

Figure 3.1 Technological Tree of Land Transportation Sector (OTP) in the Alternative Formulation



A second group of scenarios simulates an increase in the efficiency of transportation services by reducing the cost of inputs in the production function. In this case of interest are the effects of the improved efficiency and not the causes. In other words, the question to be answered is: What if land transportation services could be provided with higher efficiency in terms of cost? Accordingly, a formulation of the model to capture the effects of the increase in transportation infrastructure on total factor productivity (TFP) is used that has been pointed out by some authors, including as Ferreira and Isler (1995) and Ferreira and Malliagros (1998). Following their findings, it is assumed that in some alternative simulations an increase in transportation infrastructure improves the TFP. To include this relation in the model an approach is adopted that is similar to that used by Monteagudo and Watanuki (2003). They have included some externalities in a CGE framework, such as improvements in capital productivity as a consequence of increases in aggregate exports. Their approach was adapted for the infrastructure case assuming that for each 1% increase in transportation infrastructure there was an increment on the TFP, as shown in equation 1.

$$TFP = \left(Infra_F / Infra_0\right)^{\gamma} \qquad (1)$$

Where *TFP* is the increment in the productivity of factors, $Infra_0$ is the initial level of infrastructure for transportation services, $Infra_F$ is the level of infrastructure after the

[38] As pointed by Ferreira and Maliagros (1998), some authors haven't found evidence of substitution between public investments in infrastructure and private investments, suggesting complementarity between public and private capital, and others have found the opposite. So, it was decided to test both.

[39] Morandi and Reis (2004) have estimated the aggregate public capital stock in the Brazilian economy as being around 17% of the total stock between 1950 and 2002, considering the capital of public companies as part of private capital. However, they haven't disaggregated the share of public capital for specific sectors, such as transportation. Here, it was assumed that the transportation sector uses a higher share of public infrastructure capital than the average of other economic sectors, so 20% was used as the lower bound share of infrastructure capital in the transportation sector and 40% as the upper bound value.

implementation of improvements,, and γ is the elasticity of infrastructure on TFP, which was considered as 0.2, in accordance with the findings of Ferreira and Issler (1995)[40]. The *TFP* expression is embedded in the stock of factors. The TFP approach was applied to some alternative runs discussed in Annex 5.

A third group of scenarios investigates potential reductions in transportation costs through tax cuts. The purpose of this analysis is not to prescribe ideal tax designs, but simply to provide a more practical and understandable way to address lower costs in transportation and access to it by poor families. In this sense, a tax cut is equivalent to a reduction in the cost of transportation services for those who use it (other sectors or households).

Finally, the last group of scenarios explores the importance of transportation services to complement trade policy liberalization. Infrastructure provision is an important theme in other areas besides growth and income distribution. Calderón and Servén (1994) have discussed the role of infrastructure as a necessary ingredient to increase efficiency in resource allocation and export growth from trade liberalization. To investigate the importance of improved transport services as a complement to trade openness the present study followed the work of Araújo Júnior and Ramos (2006) and implemented some scenarios in which trade barriers were removed with and without improvements in transportation.

In the case of the scenarios simulating efficiency improvements, tax cuts and trade, a choice was made to present only one exercise from each set or group here instead of the several scenarios simulated, since they lead to similar conclusions. The full set of runs is presented in Annex 5. Also, to increase confidence in the results and explore some alternative approaches some additional runs were performed. In one of them, the model was altered to address short term impacts. In another, the effects on TFP were included in scenarios of investments in infrastructure. Some scenarios were also run in which changes were made in the dataset regarding labor and capital shares in the value added of transportation and in the share of household expenses on transportation services to verify the influence data construction had on the results. This "sensitivity analysis" is presented in Annex 6.

3.4 Results

First there is a presentation of the impacts on welfare, GDP, total tax revenue, primary factor returns, sectoral production and prices for the Brazilian economy. Then, there is a discussion of the results for the various household classes. The most important measure reported is the change in welfare as a percentage of consumption. This measure is the "Hicksian equivalent variation", which represents the amount of income required to maintain the initial utility level measured at the initial prices after a new set of prices has been put in place. It can be interpreted in a less technical way as the change in real income. The aggregate measure for the change in welfare is equivalent to the sum of the welfare changes for the twenty household income classes in the

[40] Ferreira and Maliagros (1998) have estimated higher values for the elasticity of infrastructure on TFP in Brazil. However, they weren't able to find causality from infrastructure to TFP, having found the opposite direction in causality. For this reason, it was decided to use the elasticity value found in Ferreira and Issler (1995).

model. In reporting on the impacts on households, the changes in household welfare are reported as are the changes in the Gini coefficient [41].

Improvements in the transportation infrastructure

The impact of public infrastructure in land transportation is explored employing a formulation of the model in which public infrastructure enters the production function. Two sets of alternative structural assumptions are considered. First, infrastructure is viewed alternatively as a complement, or as a substitute to the value-added composite. Two different values for the elasticity of substitution are considered between infrastructure and the composite of value-added. When the elasticity is set equal to zero it is assumed that infrastructure and primary factors composite are complements and can not be substituted for one another. Otherwise, when the elasticity is equal to 0.5 it is assumed that there is some possibility of substitution between infrastructure and value-added. Second, two alternative shares of infrastructure in the total capital used by the transportation sector (20% and 40%) are assumed. Scenario C2 then represents the case when transportation is a complement and transportation infrastructure is assumed at 20% of total capital. In scenario S2 transportation infrastructure is a supplement with 20% of total capital. C4 and S4 represent the cases where the share of infrastructure is 40%. With these alternative assumptions, the impacts of an increase in public infrastructure of 10% (in the case of an infrastructure share of 20%) and 5% (in the case of an infrastructure share of 40%) are then calculated.[42]

Table 3.3 presents the results. The welfare changes are positive in all of the simulations, as are the changes in GDP and tax revenue. Differences in the assumptions affect the results in two ways. First, when infrastructure and value added are complements, the macroeconomic gains are much stronger. As might be expected, a bigger share of infrastructure in the transportation sector means more gains from an increase in the amount of public capital. If, however, there is some substitution between infrastructure and primary factors, the welfare and GDP gains are small and practically the same as under alternative assumptions about the share of public capital in the transportation sector.

Table 3.3 Change in Aggregate Variables from Investments in Infrastructure

	Scenarios			
Variables	**C2**	**S2**	**C4**	**S4**
Welfare (%)	0.32	0.07	0.60	0.05
Welfare (1996 US$ bi.)	1.70	0.36	3.20	0.29
GDP (%)	0.14	0.04	0.26	0.04
Tax Revenue (%)	0.23	0.04	0.44	0.05
Price of Sk. Labor (%)	0.21	0.05	0.42	0.05
Price of Unsk. Labor (%)	0.30	0.04	0.60	0.04
Price of Capital (%)	0.29	0.06	0.53	0.06
Price of Land (%)	0.30	0.07	0.57	0.06

Source: Data based on author's calculations

[41] To calculate the Gini coefficient only the changes in income between groups are counted but not the changes in income within groups. This is similar to the approach followed by Araújo Júnior and Ramos (2006).

[42] The total value of capital (strictly speaking value added, or returns to capital) in the land transportation sector in the benchmark is US$6.82 billions (US$ of 1996). It means that the equivalent of US$1.36 billions increase in infrastructure is considered in the lower case and US$2.73 billions in the upper case. Consequently, an increase in the value added of capital of US$136 million is considered to be counterfactual (equivalent to about US$756 million of new investment considering a return to capital of about 18%, slightly above the prevalent interest rate). To compare with other estimates, Araújo Júnior and Ramos (2006) affirm that the government goal for the 2004-2007 period is a total of 4 billions *Reais* of investments in transportation (around US$1.9 billion).

The factors at work behind this result are described as follows. With substitution, the increase in infrastructure substitutes for the value-added, since infrastructure is a specific factor used only in the land transportation sector, and all other primary factors are demanded by other sectors. In turn, the increase in transportation services will be modest (Table 3.4) and there will be an increase in the availability of primary factors for other sectors, which will stimulate some overall, but low, increase in output. Without substitution, the increase in infrastructure forces the employment of other primary factors to complement it, leading to a considerable increase in the production of transportation services, which in turn will boost other sectors in the economy through their intersectoral links. In this case, there is a strong increase in the returns to primary factors in comparison with the substitution case, as can be observed in Table 3.3. Tax revenue can increase by as much as 2.6% when infrastructure accounts for 40% of capital in transportation.

In practical terms, this result relates to the role of public investments in infrastructure. If the government increases infrastructure that can not easily substitute for private capital, such as roads and streets, it will generate conditions that will attract and stimulate private investments. However, if investment in public capital substitutes for private capital, there will be some displacement of private investments in the transportation sector that will look for other opportunities in the economy. In this case, the overall economic impact of each dollar spent by the government on infrastructure will not be as much as in the former case.

The second way that the assumptions affect the results is that the initial share of infrastructure in the total capital employed in the transportation sector is important when public and private capital are not substitutes, since a bigger share means that infrastructure is more important to the economy. In contrast, when there is substitution between public and private capital, the initial share of infrastructure plays a minor role, since what matters is the shock or increase in public capital, which is the same in absolute terms in both cases. In other words, the new amount of infrastructure will substitute private investments in the same way, regardless of the initial amount, since the new quantity being added to the economy is equal in both cases.

The results are consistent with those of the infrastructure and growth literature. First, they confirm the positive value of the income elasticity of infrastructure. Second, they agree with those of Ferreira and Nascimento (2005). They used a Competitive General Equilibrium Model to investigate the importance of infrastructure investments on the long run growth of the Brazilian economy and found that, if Brazil had kept its public investment at the ratio observed in the 1980's, growth could be 0.5% above its postwar average. Although the comparison is limited due to significant differences in the modeling approach, we nevertheless found similar results in the sense that GDP could increase by 0.26% in our static model as a result of increases in transportation infrastructure.

Table 3.4 presents the impacts on sectoral production and prices. As discussed above, increases in transportation infrastructure induce growth in other sectors much more if public capital and private primary factors are complements. In this case, we observe that a few sectors decrease output, including services and some forms of agriculture, due to the increased competition for resources in the economy. When public and private capital are substitutes, as the increase in transportation infrastructure makes other primary factors more available to other sectors, we observe little if any decrease in output. The changes in prices confirm the results discussed above. As the output of transportation services increases more when there is no substitution between infrastructure and private factors, transportation service prices are also reduced to a much greater extent.

Table 3.4 Changes in Production and Prices from Investments in Infrastructure (percent)

	Scenarios							
	C2		**S2**		**C4**		**S4**	
Sector(*)	Output	Price	Output	Price	Output	Price	Output	Price
PDR	0.11		0.03		0.19		0.02	
GRO	-0.13	0.04	0.01	0.00	-0.28	0.08	0.00	0.00
OSD	-0.15		-0.01		-0.29		-0.02	
AGR	0.09	0.04	0.03	0.00	0.17	0.07	0.02	0.00
OCR	0.06	0.04	0.03	0.00	0.09	0.09	0.02	0.00
ENR	0.50	-0.06	0.10	-0.01	0.99	-0.13	0.09	-0.01
CMT	0.20	-0.03	0.04	-0.01	0.37	-0.05	0.04	-0.01
OMT	0.17	-0.01	0.04	0.00	0.32	-0.02	0.03	0.00
MIL	0.11	0.02	0.03	0.00	0.21	0.04	0.02	0.00
PCR	0.11	0.03	0.02	0.00	0.20	0.06	0.02	0.00
SGR	0.21	-0.03	0.05	-0.01	0.39	-0.06	0.04	-0.01
OFD	0.16	-0.01	0.04	-0.01	0.29	-0.03	0.03	0.00
TEX	0.16	0.01	0.04	0.00	0.30	0.01	0.03	0.00
WAP	0.15	0.01	0.03	0.00	0.28	0.01	0.02	0.00
LEA	0.17	0.00	0.04	0.00	0.31	0.00	0.03	0.00
LUM	0.09	-0.01	0.03	0.00	0.16	-0.02	0.02	0.00
MAN	0.17	-0.01	0.04	0.00	0.33	-0.03	0.03	0.00
I_S	0.48		0.09		0.93		0.09	
FMP	0.16	-0.03	0.04	-0.01	0.31	-0.05	0.04	-0.01
MVH	0.28	-0.01	0.05	0.00	0.53	-0.03	0.04	0.00
SER	-0.15	0.05	-0.01	0.01	-0.29	0.09	0.00	0.01
OTP	2.17	-3.38	0.42	-0.66	4.27	-6.45	0.39	-0.62
ATP	2.46	-0.15	0.48	-0.03	4.74	-0.30	0.44	-0.03
WTP	1.01	-0.09	0.20	-0.02	1.94	-0.17	0.18	-0.02
DWE	0.10	0.03	0.02	0.00	0.20	0.07	0.02	0.00

(*) See Table A4.1 in Annex 4 for the full name of the commodities in this column
Source: Data based on author's calculations

Table 3.5 presents the impacts on households and on the Gini coefficient. Welfare gains for poorer households are above average for the economy when the elasticity of substitution between infrastructure and value added is zero. Also, poor households on average gain more than richer ones. This means that there is an improvement in income distribution when transportation infrastructure increases, which can be confirmed by the decrease in the Gini coefficient. In this case it is important to note that all rural families experience above average welfare gains, reinforcing the importance of transportation infrastructure in increasing their access to the national economy. This effect is represented in the CGE model used here through the increases in agricultural production and the price of land[43]. The positive impacts on households welfare and income distribution come from the combination of income effects, as we observe higher increases in the relative price of unskilled labor, a factor more important to the income of poor and rural households, and a decrease in the expenditures of poor families, for whom expenses associated with land transportation services constitute a bigger share of total consumption than they do for rich families.

Table 3.5 Changes in Welfare and in Gini Coefficient from Investments in Infrastructure (percent)

Household types	Scenarios			
	C2	**S2**	**C4**	**S4**
BRAZIL	0.32	0.07	0.60	0.05
Rhh1	0.44	0.07	0.87	0.07
Rhh2	0.40	0.06	0.79	0.06
Rhh3	0.38	0.06	0.74	0.06
Rhh4	0.35	0.06	0.69	0.06
Rhh5	0.40	0.06	0.78	0.06
Rhh6	0.37	0.06	0.72	0.06
Rhh7	0.40	0.07	0.78	0.06
Rhh8	0.43	0.07	0.83	0.07
Rhh9	0.36	0.06	0.71	0.06
Rhh10	0.40	0.07	0.78	0.06
Uhh1	0.36	0.06	0.71	0.06
Uhh2	0.35	0.05	0.68	0.05
Uhh3	0.32	0.05	0.62	0.05
Uhh4	0.32	0.05	0.62	0.05
Uhh5	0.32	0.06	0.63	0.05
Uhh6	0.32	0.06	0.63	0.05
Uhh7	0.30	0.06	0.57	0.05
Uhh8	0.29	0.06	0.54	0.05
Uhh9	0.25	0.05	0.47	0.04
Uhh10	0.33	0.08	0.61	0.06
Gini	-0.0013	0.0064	-0.0114	0.0019

Source: Data based on author's calculations

Although we observe a decrease in the Gini coefficient when public and private investments are considered complements, the percentage changes are small. As one might expect, the distributive impacts are more favorable the greater the share of infrastructure, since there are stronger overall impacts and household impacts in this case. However, if we assume that infrastructure and value-added are substitutes, there is a deterioration of income distribution, with little difference in welfare gains among different households. This occurs because the price of capital rises faster than the price of unskilled labor in this case, due to the fact that infrastructure replaces the factor most used in the transportation sector, i.e. unskilled labor. A bigger share of infrastructure in value-added means lower impacts in the Gini coefficient, because in the calibration of the model we remove capital from the households to create the stock of public infrastructure based on their contribution to the total capital stock of the economy. Essentially, richer households "donate" more capital, and the share of capital in their total income becomes slightly smaller.

[43] Although some agricultural sectors suffer a decrease in output, the value of aggregate agricultural production increases. The negative results for some sectors are due to the competition for use of land, a specific factor of production. In other words, for some agricultural sub-sectors increased production goes hand-in-hand with land use from other sectors. The choice of sectors contracting and expanding depends on share of inputs in the cost of production and relative prices for outputs and inputs.

Although comparison of our distributive impacts with other studies is limited due to differences in the modeling approach and shock applied, our results seem to confirm those observed by Araújo Júnior and Ramos (2006). They applied a shock in infrastructure around 30 times greater than the one applied here, and it generated a decrease in the Gini coefficient of 0.7% in the long run. This appears to agree with our findings of a modest improvement in income distribution resulting from investments in infrastructure, considering that we have implemented shocks only in the transportation sector.

In order to evaluate the significance of investment in transportation infrastructure, as compared to a similar amount invested in other economic sectors, a simple simulation was done. In this simulation, a similar increase in investment is replicated for each alternative sector, one at a time. Scenarios C2 and S2 were estimated and are presented in Table 3.6. The results show that the land transportation sector (OTP) ranks very close to the top (3^{rd} out of 20) when substitution between the sector and the other sectors is assumed and 7^{th} when the sectors are assumed to be complementary. In both cases the simulations show that investments in transportation have a strong above average "multiplier" effect on output.

Table 3.6 Ranking of Changes in GDP Resulting from Similar levels of Investments Across all Sectors

	Scenario			
	S2		**C2**	
Rank	Sector (*)	GDP (%)	Sector	GDP (%)
1	OFD	0.048	ENR	0.411
2	ENR	0.042	MAN	0.264
3	**OTP**	**0.041**	OFD	0.255
4	AGR	0.039	AGR	0.164
5	SER	0.038	GRO	0.162
6	WAP	0.036	OCR	0.158
7	OCR	0.036	**OTP**	**0.138**
8	TEX	0.034	MVH	0.104
9	MAN	0.033	TEX	0.064
10	CMT	0.030	WAP	0.056
11	MVH	0.027	CMT	0.047
12	FMP	0.022	OSD	0.032
13	LUM	0.021	LUM	0.026
14	OSD	0.017	SGR	0.019
15	GRO	0.017	OMT	0.015
16	OMT	0.016	LEA	0.011
17	LEA	0.014	ATP	0.010
18	IS	0.012	I_S	-0.041
19	ATP	0.010	FMP	-0.076
20	SGR	0.008	SER	-0.296

(*) See Table A4.1 in Annex 4 for the full name of the commodities in this column
Source: Data based on aAuthor's calculations

Impacts of Improvement in Efficiency, Tax Cuts and Interactions between Transportation and International Trade

This section presents the macroeconomic, sectoral, and distributive effects of lowering transportation costs and of liberalizing trade with and without improvements in transport infrastructure. Four scenarios are considered.

In the first scenario, an improvement in the efficiency of transportation services is simulated, reducing the amount of intermediate inputs necessary to produce a unit of service for road transportation. This can be thought of as a decrease in the input-output coefficient reducing the cost of the production of transportation services.[44] An overall reduction of 5% in the cost of production is assumed and the acronym TCI is used to represent it.

The second scenario measures the impact of a tax cut. To do so, the *ad-valorem* tax on final demand for transportation services in the database is removed. This was 5.8% in the benchmark. This can be interpreted as a reduction in the price of transportation services to the final consumers.[45] This scenario is represented by the acronym TPT.

The third and fourth scenarios presented here investigate the importance of improved transportation services in complementing trade openness policies. A scenario is implemented in which trade barriers are removed both with and without improvements in transportation. 50% in unilateral cuts is assumed in Brazilian *ad valorem* import tariffs as the level of trade policy liberalization. Such cuts are performed in two different scenarios: trade openness without improvement in transportation services (scenario TRD) and cuts in tariff rates combined with a 10% increase in public infrastructure (scenario TRK).[46] Scenarios TCI and TPT are implemented in the original model formulation, that is, without infrastructure improvements in the road transportation sector, while TRD and TRK are implemented in the alternative model with infrastructure improvements enhancing the production function for transportation services.

[44] Annex 5 shows the impacts of other ways to improve the efficiency, with reductions in the costs of labor and capital.

[45] Annex 5 also presents the impacts of other tax cuts such as taxes on intermediate consumption of transport services, taxes on production and taxes on intermediate inputs bought by the transportation sector.

[46] This scenario considers the share of 20% of total capital in the land transportation sector as infrastructure and zero elasticity of substitution between it and value-added. Annex 5 also presents scenarios where cuts in tariffs are implemented together with an increase in efficiency in the use of intermediate inputs in the transportation sector as well as cuts in tariffs and removal of taxes on final demand for land transport services.

Table 3.7 presents the impacts of the scenarios described above on some aggregate variables. The TCI scenario suggests that the economy would experience an aggregate increase in welfare of about 0.43% if land transportation services could be provided in a more efficient way that reduces production costs by 5%. The gains in GDP are almost as big as the gains in welfare, and tax revenues grow by 0.33%. The aggregate benefits to the economy are evidenced also by the changes in prices of primary factors, which increase more than 0.3%. The price of unskilled labor increases more than other factors since its use in the land transportation sector is more intensive. All those aggregate gains stem from two effects: first, and foremost, the fact that the increase in efficiency makes transportation services cheaper relative to other sectors in the economy and lowers costs for the final consumers; second, the efficiency improvement means that the transportation sector uses less intermediate inputs, lowering their cost and increasing their availability for use by other economic sectors.

Table 3.7 Change in Aggregate Variables from Alternative Scenarios

Variables	Scenarios			
	TCI	TPT	TRD	TRK
Welfare (%)	0.43	0.27	0.66	0.98
Welfare (1996 US$ bi)	2.32	1.45	3.50	5.21
GDP (%)	0.38	-0.01	0.35	0.49
Tax Revenue (%)	0.33	-0.01	0.31	1.68
Price of Sk. Labor (%)	0.35	-0.07	0.52	0.74
Price of Unsk. Labor (%)	0.43	0.04	0.94	1.25
Price of Capital (%)	0.37	-0.01	0.13	0.41
Price of Land (%)	0.32	0.04	5.23	5.52

*Source: Data based on author's calculation*s

The increase in welfare in the TPT scenario is the result of improved consumption, since cheaper transportation costs create increases in demand through substitution from other goods, and also allow for an overall increase in consumption by reducing the total cost of transportation services, resulting in an "income effect". The results suggest that the "substitution effect" dominates the "income effect", since the returns to unskilled labor, which is used more intensively in the land transportation sector, increase while the opposite happens with capital and skilled labor. In this scenario, a decrease in the returns to capital and skilled labor results in a fall in GDP by the negligible amount of 0.01%. The resulting change in tax revenue follows the decrease in GDP. This means that the removal of a tax on final demand for transportation services, initially at 5%, improves consumption in the economy by almost enough to offset the loss in tax revenue from the removal of the tax.

The gains from trade are expanded when improvements in transport services are simulated together with cuts in tariffs (scenario TRK). The increase in transportation infrastructure adds 0.32 percentage points to the gains in welfare from trade and 0.14 percentage points to GDP growth. This confirms the notion that trade gains can be magnified by improving the supply of transportation services. The model, however, does not capture interaction effects from the combination of trade policy and infrastructure improvements, since the results of the TRK scenario are almost the same as the sum of the results from TRD and KP2_00 (infrastructure improvement alone). Changes in the prices of primary factors show that trade openness favors sectors that are intensive in their use of land and unskilled labor. The increase in infrastructure magnifies the increase in factor prices, but it decreases the difference between factor prices.

The results of the TCI and TPT scenarios are difficult to compare to others in the literature, since they simulate improvements in the provision of transportation services without changes in infrastructure, while the literature typically covers infrastructure improvements. However, the results of the trade scenarios are in agreement with the arguments of Winters et al. (2004) regarding the need for additional polices, such as investments in infrastructure, to enhance the impact of trade liberalization.

Table 3.8 shows changes in output and prices in the scenarios described above. As one might expect, the improvements in efficiency (scenario TCI) are reflected in lower prices and an increase in the production of transportation services. As a consequence, several sectors benefit from cheaper transportation, decreasing prices and increasing outputs. These results highlight the importance of transportation services to other sectors and to the overall growth of the economy as well as demonstrating the benefits from efficiency improvements on transportation.

Table 3.8 Changes in Production and Prices from Alternative Scenarios (percent)

	Scenarios							
	TCI		TPT		TRD		TRK	
Sectors	Output	Price	Output	Price	Output	Price	Output	Price
PDR	0.06		0.02		0.24		0.34	
GRO	-0.35	0.06	0.01	0.00	5.57	-1.56	5.42	-1.52
OSD	-0.31		0.04		10.06		9.86	
AGR	0.05	0.07	0.02	0.00	2.60	-2.56	2.68	-2.52
OCR	-0.01	0.09	0.00	0.01	1.49	-2.38	1.52	-2.33
ENR	-0.24	-0.10	0.35	-0.01	1.42	-2.65	1.93	-2.71
CMT	0.21	-0.02	0.02	-0.01	2.25	-2.45	2.45	-2.47
OMT	0.21	0.01	0.01	-0.01	3.57	-2.92	3.74	-2.93
MIL	0.14	0.04	0.00	-0.01	-2.35	-2.72	-2.25	-2.70
PCR	0.13	0.06	0.01	-0.01	0.91	-2.43	1.01	-2.40
SGR	0.19	-0.01	0.05	-0.02	9.35	-4.03	9.57	-4.06
OFD	0.14	0.00	0.02	-0.01	-0.39	-2.75	-0.24	-2.76
TEX	0.01	0.02	0.09	-0.01	-7.43	-3.48	-7.30	-3.48
WAP	0.19	0.03	0.01	-0.01	-3.67	-2.94	-3.53	-2.93
LEA	0.12	0.02	0.07	-0.02	7.80	-3.94	7.94	-3.94
LUM	0.10	0.01	-0.02	-0.01	-0.42	-2.98	-0.34	-2.99
MAN	0.02	-0.01	0.10	-0.01	-7.79	-3.52	-7.63	-3.53
I_S	0.43		0.11		-0.47		0.07	
FMP	0.02	-0.02	0.06	-0.01	-5.31	-3.77	-5.15	-3.79
MVH	0.04	-0.03	0.15	-0.01	4.38	-2.98	4.66	-2.99
SER	-0.10	0.09	-0.15	-0.02	0.59	-2.27	0.44	-2.22
OTP	2.53	-4.63	3.20	0.00	0.07	-2.11	2.25	-5.41
ATP	2.92	-0.21	0.23	-0.01	23.03	-1.77	25.72	-1.94
WTP	1.11	-0.11	0.17	-0.01	20.40	-2.29	21.54	-2.38
DWE	0.15	0.07	-0.01	-0.01	0.37	-2.29	0.47	-2.25

Source: Data based on author's calculations

When the removal of taxes on final demand for transportation services (TPT) is simulated, the changes in prices are almost negligible and the changes in production happen almost only in the land transportation sector. This confirms the predominance of the substitution effect, since without taxes transportation services becomes cheaper, increasing the demand until the new equilibrium price equals the price before the tax cut. It suggests that there is a potential demand for transportation services in Brazil that is not being served because of high prices.

Compared with the TCI scenario, we notice almost no increase in the output of the air and water transportation sectors resulting from taxes cuts on land transportation. This means that interdependence between transportation sectors is strong, since the TCI scenario simulates cheaper transportation services for intermediate demand. The changes in production also confirm the changes in factor income prices and GDP discussed above. Unskilled labor prices usually increase more than the prices of other factors, since land transportation makes use of labor more intensively. When there is a significant increase in the production of capital intensive goods or services, such as the increase in air transport services in the TCI scenario, the price of capital increases. However, if output from land transportation services increases more than other sectors, as in the TPT scenario, only the price of unskilled labor rises.

In the case of the trade scenarios, Table 3.8 shows that sectoral impacts in prices and output follow the study by Harrison et al. (2004), since the model and database are very similar. As noted by those authors, the tariff structure in the Brazilian economy is relatively more protective of capital intensive and industrial sectors. As a result, the tariff cuts will benefit those sectors which had been less protected previously, such as agriculture and the food industry. The most noticeable difference between the TRD and TRK scenarios in terms of the impacts on output is the much bigger increase in the activity of the land transportation sector in the TRK scenario. Less noticeable, but still important, is that almost all sectors have a slightly better change (greater increase or lower decrease) in output under the TRK scenario, revealing the importance of transportation infrastructure in magnifying the effects of trade liberalization policies.

Table 3.9 presents the changes in household welfare and in the Gini coefficient for alternative scenarios. In all scenarios the welfare gains for the poorest families are generally higher than the average aggregate gains for Brazil. Richer rural families also experience gains above the average in all scenarios, but they gain less than the poorest rural families. On the other hand, rich urban families gain less than the average gain to the overall economy. As a result, the Gini coefficient decreases in all scenarios.

Table 3.9 Changes in Welfare and in Gini Coefficient from Alternative Scenarios (percent)

Household types	Scenarios			
	TCI	TPT	TRD	TRK
BRA	0.43	0.27	0.66	0.98
Rhh1	0.62	0.56	1.57	2.02
Rhh2	0.57	0.47	1.30	1.71
Rhh3	0.54	0.41	1.20	1.58
Rhh4	0.50	0.42	1.59	1.94
Rhh5	0.56	0.44	1.03	1.43
Rhh6	0.53	0.38	1.14	1.52
Rhh7	0.56	0.44	1.05	1.45
Rhh8	0.60	0.40	1.47	1.90
Rhh9	0.51	0.36	1.08	1.45
Rhh10	0.56	0.36	1.48	1.88
Uhh1	0.51	0.45	1.58	1.95
Uhh2	0.50	0.39	1.39	1.75
Uhh3	0.46	0.35	1.26	1.58
Uhh4	0.46	0.34	1.19	1.51
Uhh5	0.46	0.33	0.83	1.15
Uhh6	0.47	0.30	0.94	1.27
Uhh7	0.42	0.28	0.61	0.92
Uhh8	0.40	0.27	0.53	0.82
Uhh9	0.35	0.24	0.26	0.51
Uhh10	0.43	0.23	0.51	0.84
Gini	-0.0134	-0.0364	-0.1540	-0.1563

Source: Data based on author's calculations

The positive impacts on income distribution come from the increases in the returns to labor, the most important factor in determining the income of the poor, and also from a decrease in prices for transportation services and other goods along with the resulting increase in demand. As poorer households receive most of their income from unskilled labor, positive impacts on income distribution are observed if its price increases relative to the prices of other factors. The positive impacts on the consumption side are more evident in the TPT scenario, since the welfare changes for the poorest families are greater than 0.4% and not significantly smaller than the changes observed in the TCI scenario. Nonetheless, the changes in the prices of primary factors are much smaller in the TPT case.

Cuts in tariffs promote more pronounced welfare gains for the poorest families as a consequence of the changes in the relative price of unskilled labor and the overall decrease in the prices of consumer goods. Several rural households enjoy considerable welfare gains due to their possession of land. The Gini coefficient improves, falling by 0.15%. The positive impacts on income distribution are magnified if trade liberalization is accompanied by improvements in land transportation infrastructure. The additional benefits are primarily linked to income effects, since the price of unskilled labor increases more when infrastructure is increased.

These results are in agreement with those in the literature on the relationship between transportation infrastructure and income distribution, Even though Araújo Júnior and Ramos (2006), found impacts from infrastructure on income distribution which were more pronounced than those from trade liberalization, while we found the opposite. The differences are due to aspects of the modeling approach, including the size of the shock and the fact that here the shock is restricted to the transportation sector. Aside from this discrepancy, the same conclusion is reached about the importance of infrastructure investments in improving the income distribution effects of trade liberalization.

3.5 Conclusions

The importance of transportation infrastructure to economic growth and poverty reduction has been addressed in several studies. In the case of the Brazilian Economy, several papers have estimated the importance of infrastructure to aggregate income and growth, but less attention has been given to the effects of infrastructure and transportation on income distribution. Here, a CGE model has been used to contribute to the investigation of the impacts of improvements in the land transportation system on the Brazilian economy and on income distribution. The model used better captures linkages between transportation and the other sectors of the economy. The model also accounts for a greater number of household categories in comparison with other, similar studies of the Brazilian economy. Also, the model captures the importance of transportation services to the poor through income generated by the use of unskilled labor to produce transportation services and by reducing the cost of utilizing these services. Several alternative scenarios representing investments in infrastructure, increases in efficiency, and reductions in cost through tax cuts are analyzed and the gains from trade liberalization with and without improvements in the supply of transportation services are compared.

The conclusion is that improvements in transportation can generate growth and improve income distribution, although such improvements do not represent a comprehensive solution to the problems of slow economic growth and high inequality. The findings suggest that an increase in transportation infrastructure on the order of 5% (or U$140 million at 1996 prices) could result in welfare gains of between 0.3% and 0.6% and a decrease in the Gini coefficient of between 0.001% and 0.01%, depending on the initial infrastructure stock considered. The removal of taxes on the final consumption of transportation services, initially at 6%, will increase aggregate welfare by almost 0.3% and reduce the Gini by 0.04%. Similarly, if transportation services could be provided more efficiently, with a 5% reduction in costs, welfare gains would include a

0.43% increase in consumption and a decrease the Gini coefficient by 0.01%. While these impacts may seem small, they result from very modest shocks in just one sector of the economy.

The combination of trade and improvements in transportation provide a more complete look at the potential inter-sectoral links that can be exploited by providing better transportation services. An overall cut in tariffs by half generates a 0.66% increase in welfare, which can be expanded to rise to 0.93% if transportation infrastructure is also improved. The Gini drops by almost 0.16% as a result of combining trade with better transportation.

The positive results in terms of growth and income distribution are due to several links captured by the model. First, transportation sectors are important as inputs for many other sectors. Consequently, improvements in transport services benefit practically all other sectors of the economy, promoting overall economic growth. Second, transportation services are an important share of the total expenditure of poor families. Any reduction in the cost of transportation brings more benefits to the poor than to richer families. Finally, the transportation sector is relatively more intensive in unskilled labor than the rest of the economy. As a consequence, an increase in the production of this sector may improve the return to unskilled labor, the most important factor in determining the income of the poor.

Chapter 4
The Macroeconomic and Regional Effects of Changes in Port Efficiency

4.1 Introduction

As discussed in Chapter 1, Brazil has enacted a set of regulatory policy reforms to address the high costs associated with port activity, since they hinder the competitiveness of many economic sectors, both on a domestic as well as an international level. The reforms include the 1993 "Port Modernization Law" (Law 8.630/93), which was promulgated to decentralize management, stimulate new investments (including private sector investments), promote competition, and enhance the skills of the workforce in order to meet new technology requirements. If this new law were to be successfully implemented, it would significantly increase port efficiency and, in all likelihood, have an impact on the country's macroeconomic variables and its economic development at large. The present chapter assesses these possible impacts. It identifies and quantifies some of the primary expected economic effects on growth, fiscal balance, job creation, and regional inequality, through simulated changes in current conditions. To do this, this chapter explores the role of ports as nodes in the Brazilian transportation system. It adopts an approach in which nodal (port) costs are unbundled from the cost of links between nodes. This is a departure from previous analyses that have mostly focused on the efficiency, congestion and expansion of links in transportation networks, while not devoting much thought to an examination of the inefficiencies surrounding the transshipment of commodities at ports. The analysis presented herein makes use of an interregional CGE model developed for the Brazilian economy that is integrated with a transport network—the B-MARIA-27 model. A detailed description of the B-MARIA-27 model can be found in Haddad and Hewings (2005). A brief overview of the model's general features can be found in Annex 10 of this report.

The main findings of this chapter show that simulated efficiency gains in ports have positive effects on GDP growth, employment creation and welfare measures. Within output, the larger effects are on tradable sectors. Over the long term, the effects are strengthened. Across regions, most states benefit, with relative losses on the land-locked center-west region. Largely positive effects are also present on the fiscal balance.

The remainder of the chapter is organized as follows. After a brief review of the literature in the following section, section 4.3 discusses efficiency measures for Brazilian ports based on international trade data. Section 4.4 presents an overview of the CGE model used in the simulations, focusing on its general features, while section 4.5 discusses some modeling issues, specifically those associated with the treatment of port costs, and calibration of the model. The simulation experiments are detailed and their main results discussed in section 4.6. The chapter concludes with an evaluation of the findings and an effort to put them into perspective and consider both their validity as well as their limitations.

4.2 Integration of CGE Models and Transportation Networks

There is an increasing recognition of the critical role infrastructure plays in national and regional economic development. The literature provides a number of alternative approaches to analyze this role. Martin and Rogers (1995) adopt a model where infrastructure plays a key role in the geographical location of industries. Following the perspectives associated with the new economic geography, Helpman and Krugman (1985) and Vickerman (1990) present an extensive collection of papers addressing the relationship between infrastructure and regional economic development. More recent literature has begun using spatial econometrics to explore the role of EU initiatives in increasing transportation investment as a major means of reducing disparities across regions (e.g. Dall'erba and Hewings, 2003).[47] The approach taken in this chapter draws on an expanding strand of this more recent literature that attempts to link regional and interregional macroeconomic models with network-based transportation systems. A review of some of the most important contributions to this literature can be found in Annex 8 of this report.

The emerging strand links transportation networks to macroeconomic performance through CGE or econometric models. The CGE approach began with spatial CGE models in the 1990s. The most recent developments in this approach link multiregional CGE models to a transportation network model and allow synergistic effects resulting from simultaneous developments of key network links which generate a greater impact than the sum of the impacts arising from a sequential development of the links. An example of this econometric approach is a multiregional econometric input-output model linked with an interregional commodity flow model, where the network structure provides details of bridges in the links.

The model used in this chapter is a multiregional CGE model with a transportation network that allows for economies of scale effects, while assessing the impact of transportation costs on welfare. In particular, it allows an assessment of the role port costs play in overall transportation costs and port congestion. The model is used in this chapter to assess the impact of changes in efficiency (i.e. costs) on selected economic, macroeconomic and regional variables. The rest of the chapter presents the elements and findings of this assessment in the following order:

- Port costs are discussed to indicate the need to unbundle them from transportation costs.
- Port Efficiency Indexes for Brazilian ports are calculated to calibrate the modeling of ports in the CGE model.
- The Core CGE model and its key parameters are discussed.
- The modeling and calibration of port costs are discussed.
- Three scenarios of improvements in port efficiency are presented.
- The economic effects of increases in port efficiency are discussed.

4.2.1 Port Costs

The use of ports in the transportation process generally involves a step increase in overall transportation costs. This increase can be represented as a cost-to-distance function or as a loop in a link-node system. Figure 4.1 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 4.2. The transfer costs from Figure 4.1 (for example, the cost of moving the container from road or rail to a ship, including the documentation and export charges) are shown as a self-loop.[48] The "transportation costs" per unit of cargo moved on this self-loop would be relatively small in the U.S. or Europe but are significantly larger in Latin America. In modeling flows and transportation links, a congestion function could be employed to reveal how unit costs that may be flat during free-flow periods rise steeply once congestion occurs. A similar idea can be adopted within the

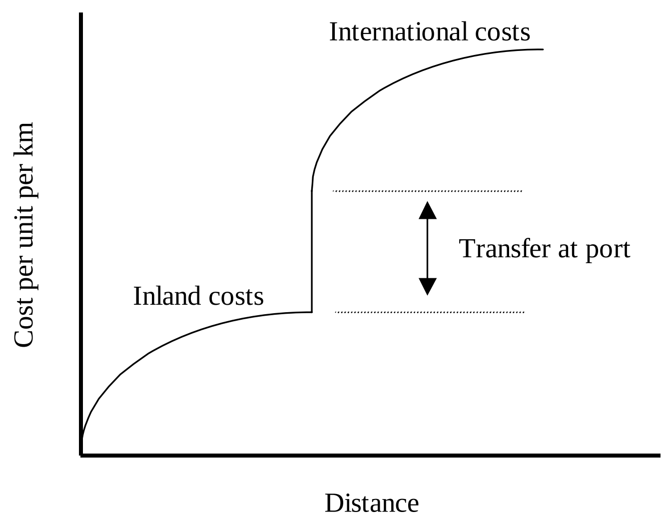
[47] From a national perspective, the link between infrastructure and growth is well explored, especially in cross-country studies (see, for instance, Esfahani and Ramírez, 2003).
[48] A self-loop, or simply a loop, is an edge that connects a vertex to itself.

node. As capacity is reached, transfer costs (the self-loop in Figure 4.2) can be assumed to increase as delays create real losses—not only in an opportunity cost sense, but because goods stored in warehouses may be subject to theft, spoilage or depreciation.

The pricing of port costs is not fully competitive.[49] Ports are likely to have access to different hinterlands, but that access is limited both by the nature of the supporting transportation infrastructure (roads, rail and waterways) as well as by the cost of linking to remote internal markets. Thus, trade areas are likely to overlap only to some degree. In addition, ports will have different capacities to handle certain tasks. Hence, ports need to be considered as functioning in an imperfectly competitive market.

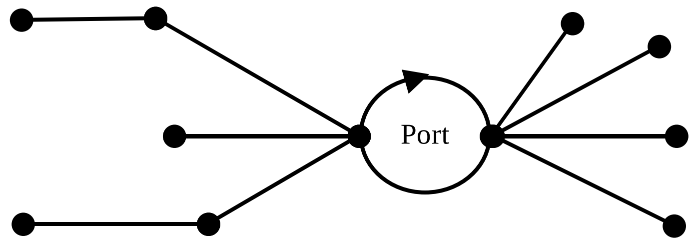
Given the step-wise rise in costs and the monopoly power at ports, modeling the system using iceberg transportation costs would be very difficult.[50] Consequently, this chapter adopts a transportation margin approach in which the link costs are separated from the nodal (port) costs. In the next section, we estimate measures of relative port efficiency in Brazil, taking into account the features depicted in Figures 4.1 and 4.2.

Figure 4.1 Cost Function for Export of a Domestically Produced Good



[49] This does not mean to imply that there is no competition between ports but, rather, that different transportation modes and geography also play a significant role in port competition.
[50] The concept of iceberg transportation cost which was first developed by Samuelson (1954), simply maintains that the cost of moving goods involves the loss of some portion of the product during shipment. For an excellent review of the debate over appropriate transfer costs see McCann (2005).

Figure 4.2 Stylized Representation of Link and Nodal Costs



4.3 Estimation of Port Efficiency in Brazil

Calibration of the model requires estimates of cost differentials among Brazilian ports. Since this information is not readily available, estimates of port efficiency are provided using international trade data and adapting the methodology developed in Blonigen and Wilson (2006).[51] The methodology and the data for the estimation of port efficiency, as well as the results of this estimation are presented in Annex 9.

The econometric estimation to quantify the relative efficiency of Brazilian ports in relation to the port of Santos, which is fixed at 1, is based on the cost of transporting individual products from specific countries to specific ports and states. After an evaluation of the available database, a decision was made to limit the sample to the 13 major ports (Figure 4.3) that in 2002 covered 56.5% of the total value of all Brazilian import activity, or 67.3% of the total tonnage. Since maritime trade that same year accounted for 68.9% of total import activity, these ports accounted for over 80% of maritime imports.[52] The results provide estimates of the relative efficiency of Brazilian ports and offer a new perspective on regional differentials of port efficiency.

[51] For a survey on efficiency measurement in the port industry, see Gonzales and Trujillo (2005).
[52] In terms of exports, in 2002 these ports accounted for 73.3% of total activity (in US dollars).

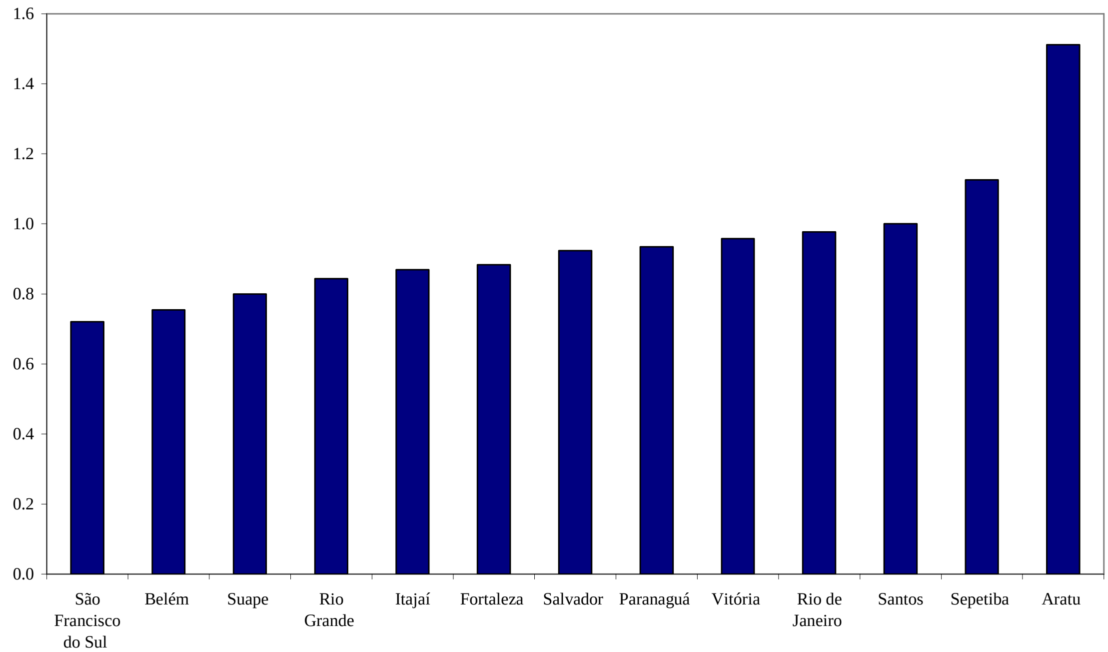
Figure 4.3 Selected Brazilian Ports

4.3.1 Results

As referenced earlier, the results of the estimation are presented in Annex 9. The estimated coefficients for the port dummy variables are noteworthy. At the 10% level, the coefficients for Rio de Janeiro and Sepetiba were not significant, i.e. no significant cost differences were found to exist between these ports and the Port of Santos.[53] Aratu was the only port in the sample found to be less efficient than Santos and, everything else being equal, importing from Aratu (the least efficient) rather than from Santos represented an increase in costs of 51.2%. All the remaining ports were found to be more efficient than Santos, with the Port of São Francisco do Sul being the most efficient of the ports sampled. Figure 4.4 portrays the *PEI* for the 13 ports.

[53] Vitória and Belém presented p-values of 0.1033 and 0.1059, respectively.

Figure 4.4 Port Efficiency Index (Santos = 1)

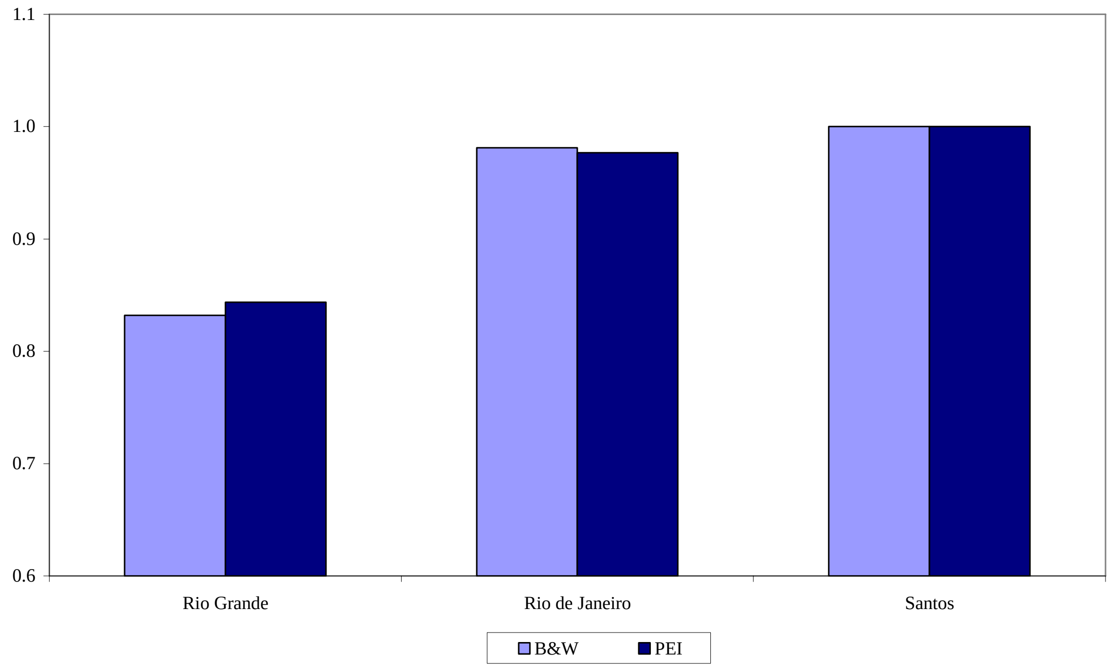


Source: Data based on author's calculations

Comparing the PEI to Other Measures

Few studies seem to systematically deal with port efficiency within countries. For Brazil, the only available source is the above-referenced study by Blonigen and Wilson (2006), which offers some insight into the relative transportation costs of three of Brazil's major ports: Rio Grande, Rio de Janeiro, and Santos. Looking at the determinants of import charges in the US, Blonigen and Wilson used a number of different dummy variables including dummy variables for the ports of origin. Within the sample, the relative efficiencies of the three Brazilian ports were estimated in reference to the Port of Rotterdam. The dummy coefficients can also be used to obtain the relative efficiency of the three Brazilian ports in index form. In order to test the findings of the present report, these findings were compared with Blonigen and Wilson's findings. Figure 4.5 shows the estimated values presented in Blonigen and Wilson's study (B&W), alongside the estimates derived herein (PEI). The Port of Santos was used as the basis of comparison and it was determined that in both sets of estimates the order and the relative magnitudes seemed to conform to each other.

Figure 4.5 Comparison of Efficiency Indices B&W and PEI

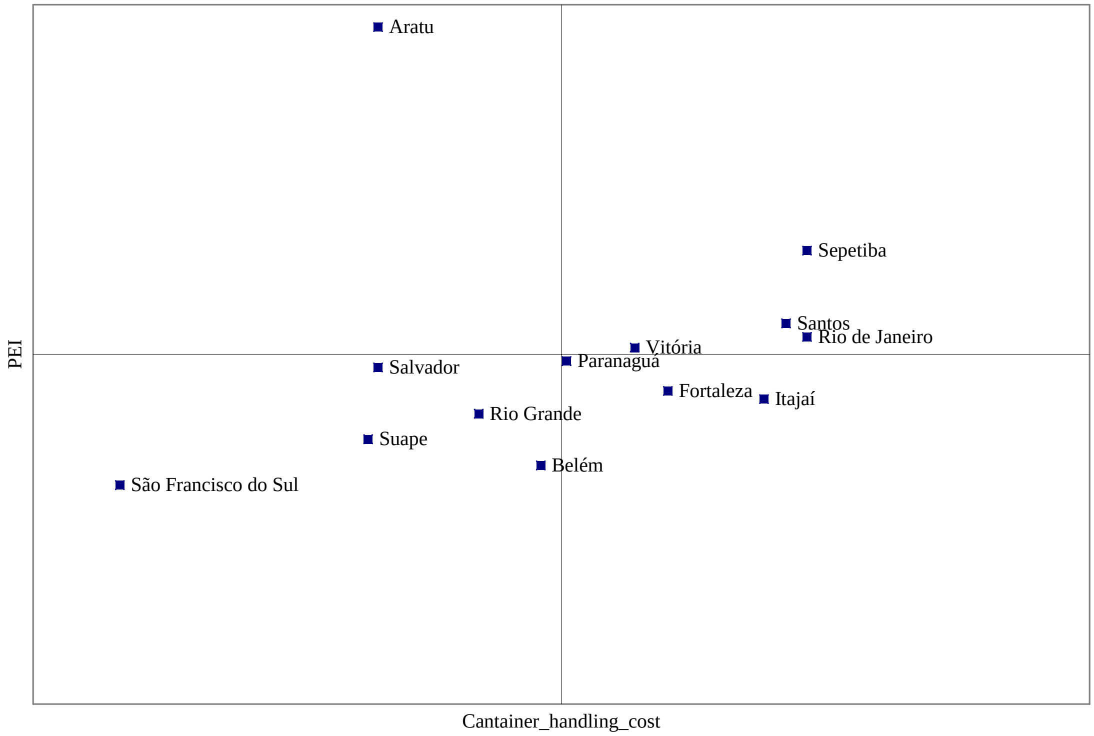


Source: Data based on author's calculations

Another approach used to confirm the accuracy of the estimates presented in this chapter, involved referring to published container handling charges in ports. Since handling charges capture only a very narrow range of port activity, this is a very crude measure of port costs. However, since data on these charges is readily available and comparable among ports, it can at least provide some insight into whether the PEI estimates show any correlation to handling charges. As can be seen in Figure 4.6, with the only exception of Aratu (outlier), our PEI estimates have a strong correlation to container handling costs in Brazilian ports.[54]

[54] When Aratu is excluded, there is a correlation value of 0.74.

Figure 4.6 Correlation between the PEI Estimates and Container Handling Charges



4.4 Overview of the B-MARIA-27 Model

In order to evaluate both the short- and long-run effects of increases in port efficiency under several different scenarios, a departure was made from the B-MARIA-27 model whose structure represents an evolution of the Brazilian Multisectoral And Regional/Interregional Analysis Model (B-MARIA), the first fully operational interregional CGE model for Brazil.[55] 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. 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 under which national results are obtained from the aggregation of regional results. The model identifies eight sectors in each state producing eight commodities, one representative household in each state, 27 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 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 a system of linearized equations. A typical result shows the percentage change in the set of endogenous variables after a policy is carried out, as 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), and Dixon and Parmenter (1996).

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

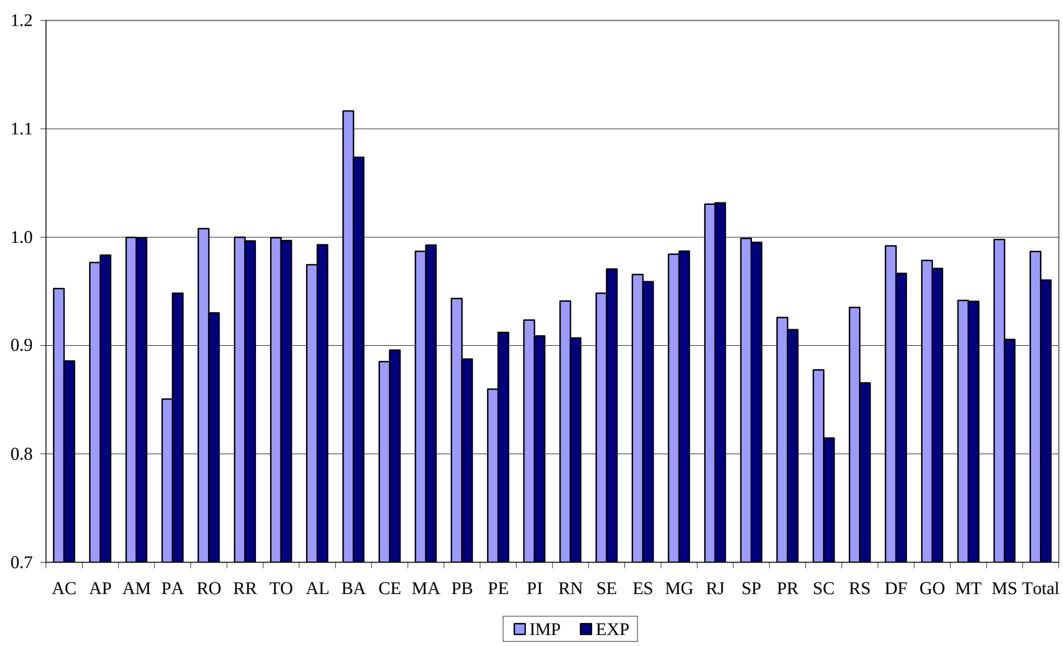
The general features of the B-MARIA-27, including all of its modules, are explained in detail in Annex 10. The structural database for the CGE model, including detailed sectoral and regional information, as well as the behavioral parameters used and the closures of the model are presented in Annex 11.

4.5 Modeling of Port 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 source *s* in region *q* by each user equate to the sum of its basic value plus the costs of the relevant taxes and margin-commodities. This formulation, standard in the preparation of national income and product accounts, is not featured in most of the new economic geography models. The detailed model and estimation of the Port Efficiency Index (PEI) is presented in Annex 12.

With the estimates of PEI_i for every port *i* (see section 4.3)[56], we built the PEI_q as weighted averages of the PEI_i's using the share of each port in the total imports of a given state as the weights. Similar assumptions were used for equation (4).[57] The results are presented in Figure 4.7 for both import and export activities. The estimates for Brazil as a whole suggest that in the case of imports, the port mix of the country's international trade would be 1.3% less costly had all the imports entered the country through the Port of Santos. Similarly, in the case of exports, the national port mix is also more efficient (4% less costly) than a hypothetical concentration in Santos.[58]

Figure 4.7 Port Efficiency Index, by State (Santos = 1)



Source: Data based on author's calculations

[56] PEI_i for *i = other ports and other modes*, was set equal to one.
[57] In this case, the PEI estimates from section 4.3 that were based on import charges, were assumed to be valid for export activities as well.

4.6 Scenarios of Port Efficiency Changes

This section discusses the effects of three different scenarios related to port efficiency changes in Brazil. The B-MARIA-27 model was applied to analyze the short and long-run macroeconomic and spatial effects of these scenarios on the Brazilian economy.

Scenario 1. Testimonials from businessmen as well as empirical studies suggest that Brazil lags significantly in terms of port efficiency standards. The country's score in the "quality of port infrastructure" component of the 2006 Global Competitiveness Index was 2.6, placing it 88th in the ranking, and far behind the scores of Singapore and Netherlands which with respective scores of 6.9 and 6.7 ranked first and second. In another survey-based study conducted by the *Confederação Nacional dos Transportes* [CNT] (2006b) on the quality of port operators—which reflects not only operational efficiency, but also costs and provision of infrastructure and services—Brazil was rated poorly by roughly one-third of the respondents, all of whom were major users of port services. The empirical study by Blonigen and Wilson (2006) estimated a cost differential between Rotterdam and Santos of around 21.3%. These stylized facts suggest that Brazilian port activity can still be improved to achieve international best practice standards. In the first scenario we simulate an overall increase in port efficiency of 20%.

Scenario 2. Even though the "Port Modernization Law" (Law 8.630/93) was promulgated in 1993, port reforms are proceeding at a very slow pace. One of the key elements of the new law, port management decentralization, has not been properly implemented. Most Brazilian ports are still under Federal control.[59] According to our estimates of port efficiency (Table 4.1), the few ports under regional control, i.e. those managed by either state or municipal governments appear to perform better.[60] A simple average of the *PEI* for the sets of federally and regionally managed ports reveals that regionally managed ports are, on average, approximately 18% less costly than those ports controlled by the Union. In our second scenario, we assume that this gap has been eliminated (possibly through management decentralization).

[58] PEI_q for $q = total$, equals 0.987 and 0.960 for imports and exports, respectively.
[59] The port administration detail can be seen in Chapter 1, Figure 1.7.
[60] The econometric model does not test specifically for this management decentralization hypothesis, but the results show that, on average, ports under regional control show better efficiency indexes than those under federal control.

Table 4.1 Port Efficiency of Federal and Regional Ports (Santos = 1)

Port	*PEI*	*Management*
Belém	0.754	Federal
Fortaleza	0.883	Federal
Salvador	0.924	Federal
Vitória	0.958	Federal
Rio de Janeiro	0.977	Federal
Santos	1.000	Federal
Sepetiba	1.126	Federal
Aratu	1.512	Federal
Average	*1.017*	*Federal*
São Francisco do Sul	0.720	Regional
Suape	0.800	Regional
Rio Grande	0.844	Regional
Itajaí	0.869	Regional
Paranaguá	0.935	Regional
Average	*0.834*	*Regional*

Source: Data based on author's calculations

Scenario 3. As seen in section 4.3, the Port of São Francisco do Sul was the most efficient port. As such, it can be considered as lying on the efficiency frontier of the sample used. In this third scenario, regionally differentiated increases in port efficiency are simulated to reach the national efficiency frontier boundary. All 12 of the other ports are assumed to have the same port efficiency index as the one estimated for São Francisco do Sul.

Table 4.2 presents the state PEI values calculated under these three scenarios.

Table 4.2 Port Efficiency Index, by State, for Different Scenarios (Santos = 1)

State	*Benchmark*		*Scenario 1*		*Scenario 2*		*Scenario 3*	
	IMP	*EXP*	*IMP*	*EXP*	*IMP*	*EXP*	*IMP*	*EXP*
AC	0.953	0.886	0.800	0.728	0.932	0.885	0.734	0.704
AP	0.977	0.983	0.806	0.821	0.816	0.832	0.713	0.728
AM	1.000	0.999	0.895	0.928	0.904	0.934	0.828	0.882
PA	0.851	0.948	0.692	0.813	0.678	0.815	0.691	0.761
RO	1.008	0.930	0.823	0.756	0.841	0.900	0.700	0.692
RR	1.000	0.997	0.957	0.987	0.961	0.996	0.930	0.983
TO	1.000	0.997	0.834	0.798	0.847	0.822	0.728	0.673
AL	0.975	0.993	0.863	0.795	0.870	0.814	0.808	0.673
BA	1.116	1.074	0.912	0.871	0.951	0.903	0.704	0.692
CE	0.885	0.896	0.719	0.738	0.714	0.734	0.690	0.706
MA	0.987	0.993	0.792	0.795	0.806	0.811	0.676	0.673
PB	0.944	0.888	0.774	0.737	0.823	0.794	0.703	0.716
PE	0.860	0.912	0.704	0.765	0.818	0.820	0.698	0.729
PI	0.924	0.909	0.776	0.744	0.775	0.741	0.733	0.699
RN	0.941	0.907	0.774	0.742	0.809	0.776	0.707	0.699
SE	0.948	0.971	0.799	0.786	0.822	0.800	0.739	0.688
ES	0.966	0.959	0.807	0.775	0.814	0.783	0.728	0.685
MG	0.984	0.987	0.826	0.806	0.838	0.822	0.734	0.699
RJ	1.031	1.032	0.874	0.847	0.893	0.869	0.753	0.708
SP	0.999	0.995	0.878	0.862	0.890	0.879	0.802	0.780
PR	0.926	0.915	0.788	0.747	0.915	0.904	0.749	0.696
SC	0.877	0.815	0.767	0.671	0.869	0.810	0.779	0.704
RS	0.935	0.866	0.797	0.725	0.867	0.857	0.752	0.726
DF	0.992	0.967	0.939	0.811	0.948	0.818	0.910	0.734
GO	0.979	0.971	0.823	0.808	0.860	0.841	0.738	0.723
MT	0.942	0.941	0.810	0.762	0.909	0.827	0.765	0.687
MS	0.998	0.906	0.939	0.756	0.949	0.859	0.903	0.723
Total	0.987	0.960	0.852	0.807	0.881	0.858	0.774	0.735

Source: Data based on author's calculations

4.6.1 Functioning Mechanism

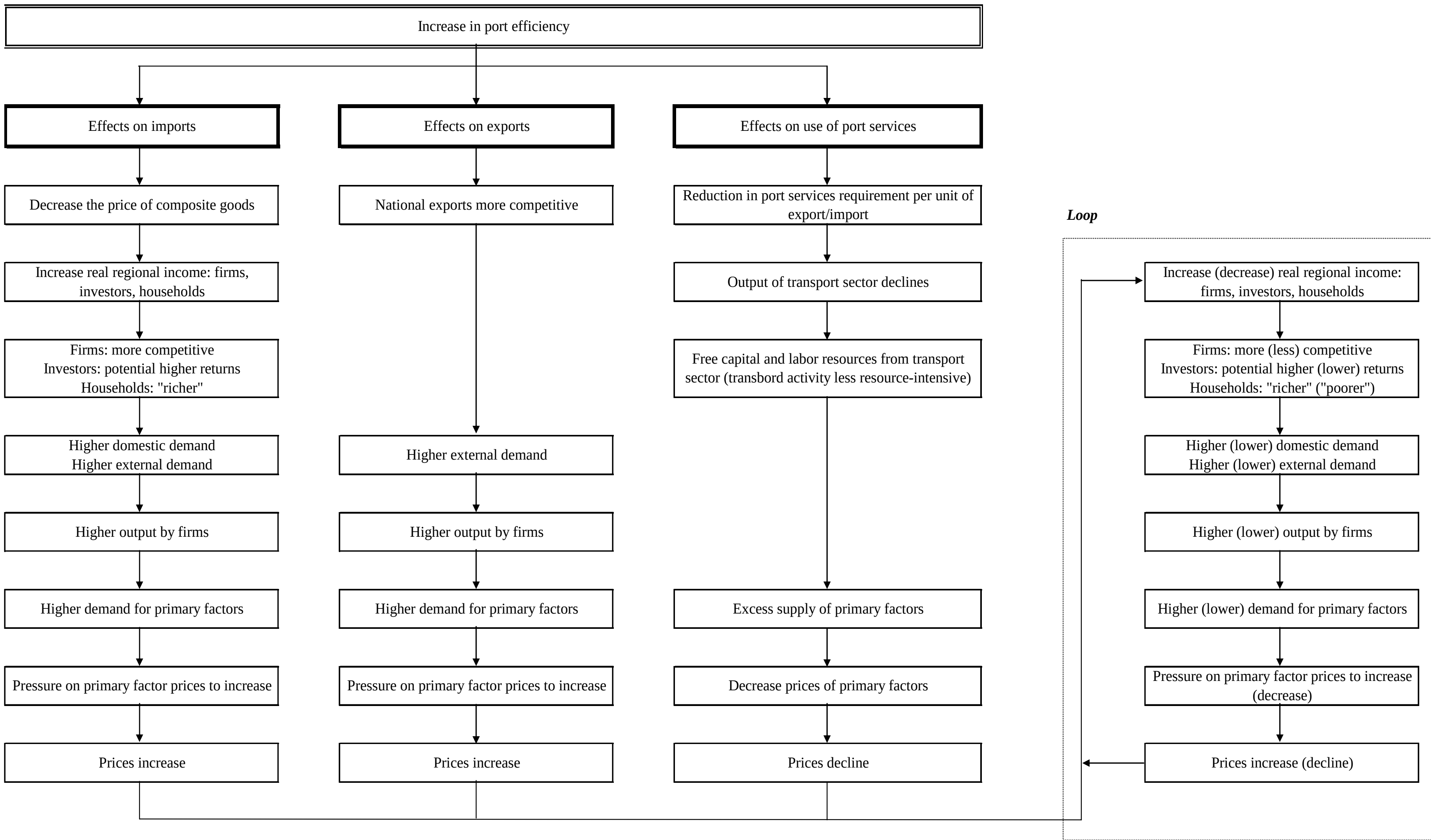
How are the increases in port efficiency entered into the model? There are three major channels through which the shocks operate: import effects, export effects, and effects relating to the use of port services. In the first case, the increase in port efficiency for import activity reduces the price of composite commodities, with positive implications for regional real income. In this cost-competitiveness approach, firms become more competitive. Production costs decline as inputs become more costly, the cost of producing capital decreases, and investors foresee potentially higher returns. There is also a concomitant increase in households' real income, which generates higher domestic demand at the same time that increases in the competitiveness of national products stimulate external demand. This creates room for increased output at the firm level, which creates additional demand for inputs and primary factors. The increasing demand puts pressure on factor markets to increase prices, resulting in added pressure for prices of domestic goods to increase. In the second case (export effects), as international competitiveness increases, higher international demand puts extra pressure on prices through the increase in export activity. Finally, in the third case, as transborder activities become less resource-intensive and the activity level in the transportation sector decreases, labor and capital are freed, resulting in an excess supply of these factors. This creates downward pressure on wages and capital rents, which are passed on in the form of lower prices.

Second-order price changes go in both directions in a loop that continues until they converge at a new equilibrium. The net effect is determined by the relative strength of these countervailing forces. Figure 4.8 summarizes the transmission mechanisms associated with major first-order and second-order effects in the adjustment process underlying the model's aggregate results.

As for the differential spatial effects, the net results are heavily dependent on the structure of the integrated interstate system. Specifically, in the long run, one mechanism becomes relevant: the "re-location" effect. As factors are free to move between regions, new investment decisions define marginal re-location of activities, in the sense that the spatial distribution of capital stocks and population changes. The main mechanism affecting regional performance is associated with capital creation. As port efficiency increases, better access to foreign capital goods increases the rate of returns in the regions. While potentially benefiting capital importing regions, this has a negative impact on the capital-good sectors in the producing regions (substitution effect).

Finally, regions might be adversely affected through re-orientation of trade flows (trade diversion), as relative accessibility changes in the system. Thus, gains in efficiency in port activities are not necessarily accompanied by overall gains in regional performance.

Figure 4.8 Functioning Mechanism of the Model under Simulations of Increases in Port Efficiency



4.6.2 Results

Increases in port efficiency, when considered as a trade liberalization process, are purported to have long run benefits derived from gains on both the production side (as there is an overall increase in the foreign exchange revenue earned by export industries or saved in import industries, per unit of labor and capital) and the consumption side (as the same basket of products can be obtained at lower cost).

Table 4.3 presents simulation results for the three scenarios. Gains in efficiency (real GDP growth) and welfare (equivalent variation) are positive. In all scenarios, positive impacts on real GDP growth are verified. The biggest impacts occur in scenario 3.[61] It should be noted that in the long run the effects on GDP are magnified. In terms of employment, in the short run there is a reduction in employment, led by the transportation and construction sectors, the latter one of which has a particularly strong employment coefficient. The labor-saving result also shows overall increase in efficiency in the short run. In terms of welfare gains, results suggest that the magnitude of the changes are equivalent in both closures, for a given scenario, ranging from US$0.4 billion (scenario 2) to US$1.0 billion (scenario 3).

Changes in the terms of trade tend to benefit Brazilian exports in all three scenarios, with the results pointing to the increased competitiveness of Brazilian products. This conclusion is reinforced by the performance of the trade balance: export volumes increase faster than import volumes. As port efficiency increases, international trade appears to increase its share in national GDP, resulting in a more open Brazilian economy. In the long run, real investments also grow faster than real GDP.

Industry activity results show that, in general, tradable sectors benefit the most from the increase in port efficiency, while transportation and other services tend to lose. Explanations for specific sector results should consider structural and parametric aspects of the database. Sectors that present higher increases in their output tend to have a high share of imports in their cost structure, and greater export demand elasticity (in the case of traditional exports). On the other hand, sectors with high import substitution elasticities, high import shares in their domestic markets, and a high percentage of changes in their tariff rates are more likely to be harmed by the policy change.

The transshipment cost reduction stimulates the export sectors in different ways. To a great extent, these sectors benefit from reductions in the cost of production. Imported intermediate inputs, which have import duties levied upon them, experience a relatively sharp reduction in their cost. It has been noted elsewhere (Agénor and Montiel, 1996) that imported intermediate goods play a prominent role in economic activity in the developing world, and this is the case for Brazil as well, especially in the center-south regions of the country. In addition, the general price level decreases with the tariff cut and, through indexation mechanisms, the cost of primary factors of production also decreases.

[61] In aggregate terms, the three scenarios point to the same direction. Relative magnitudes are different though, with a consistent hierarchy going from scenario 3 (best results) to scenario 2 (worst results); scenario 1 achieves an intermediary performance.

Agriculture and manufacturing are examples of tradable sectors that gain from the increased competitiveness in international markets associated with more efficient practices in port activity. Still, import-competing industries/regions may be adversely affected by substitution away from regionally produced goods and towards imports. To better understand spatial outcomes, it is important to consider the geographic distribution of sectoral activity within Brazil. The chemical producing and related product industries in Bahia, for example, face a relatively high level of competition from foreign products. Similarly, when interregional feedback effects are considered, the electronic industries of the Amazonas also face relatively high international competition. They, however, can reverse adverse effects from international competition by increasing their sales to markets in Brazil's other regions, especially in the country's center-south.

As expected, at the sectoral level there is a decrease in the production of transportation services. Because resources are scarce, the reduction in the production of port services as transborder activities become less resource-intensive, results in gains to other sectoral output, especially in sectors producing tradable goods, which face stronger competition from foreign products.

To summarize, in aggregate terms the simulation results suggest that increases in port efficiency lead to a faster-growing, more competitive, and more open Brazilian economy.

Table 4.3 Aggregate Results: Selected Variables (in percentage change)

	Scenario 1		*Scenario 2*		*Scenario 3*	
	SR	*LR*	*SR*	*LR*	*SR*	*LR*
Aggregates						
Real GDP	0.036	0.092	0.026	0.061	0.053	0.130
Aggregate employment, wage bill weights	(0.016)	0.033	(0.011)	0.026	(0.024)	0.047
Equivalent variation – total (change in $ 1,000,000)	693.9	623.5	460.9	428.6	1,010.2	1,005.4
Economy-wide terms of trade	(0.266)	(0.304)	(0.193)	(0.216)	(0.399)	(0.447)
GDP price index, expenditure side	0.012	0.017	(0.016)	0.006	0.001	0.003
GDP components						
Real household consumption	0.025	0.056	0.017	0.039	0.036	0.082
Real aggregate investment	-	0.119	-	0.066	-	0.152
Real aggregate regional government demand	-	0.075	-	0.051	-	0.103
Real aggregate federal government demand	-	0.056	-	0.039	-	0.082
International export volume	0.550	0.672	0.396	0.458	0.825	0.981
International import volume	0.229	0.309	0.159	0.201	0.339	0.445
Activity level						
Agriculture	0.022	0.098	0.015	0.056	0.033	0.133
Manufacturing	0.034	0.125	0.025	0.086	0.052	0.179
Utilities	0.009	0.051	0.006	0.036	0.013	0.073
Construction	(0.001)	0.064	(0.001)	0.045	(0.002)	0.089
Trade	0.011	0.059	0.007	0.036	0.016	0.081
Financial institutions	0.041	0.098	0.029	0.059	0.061	0.136
Public administration	0.005	0.062	0.004	0.043	0.008	0.089
Transportation and other services	(0.077)	(0.064)	(0.053)	(0.047)	(0.114)	(0.099)

Source: Data based on author's calculations

Spatial (Regional) Impacts

Spatial effects are presented in Table 4.4 and Figures 4.9a, 4.9b and 4.9c. In all three scenarios real GDP increases in the long-run in all the macro-regions except for the center-west, which is landlocked. It is also important to note that in the long-run, under all three scenarios, three groups of states exhibit relatively weak performance. These are the landlocked states of Minas Gerais, Goiás, Tocantins; the northeastern states of Ceará, Bahia, Rio Grande do Norte and Paraíba; and the southern states of Paraná and Rio Grande do Sul.

Figure 4.9a presents the spatial results for the first scenario in terms of GDP growth. Under this scenario, it is clear that in the short -run there are three spatial regimes in the Brazilian economy. The first of these is associated with "primary exporters", and is one in which the transportation infrastructure is sparse and the main links and nodes are easily associated with specific and scattered export activities. This area encompasses the states of Amazonas, Pará and Mato Grosso—benefits from lower costs associated with its export activities. In the case of the Amazonas, a relevant indirect effect also occurs through the improved efficiency of import transshipments, as the interstate exports from the "Zona Franca de Manaus" become more competitive. The second is an "intermediate space", which acts as the interface of the Brazilian interregional system with the world economy, and is more integrated with the domestic markets. The third and last one is a denser economic space, more integrated with the world economy, where port efficiency plays a crucial role in determining overall competitiveness. This third group includes Brazilian "global traders" located in the more developed regions of the southeast and south. Short-run results for scenario 3 (Figure 4.9c) also reveal similar spatial regimes.

In the second scenario, short run results reveal the nature of the shocks (Figure 4.9b). Decentralization, as designed, would follow a clear north-south pattern. As seen in Table 4.1, more efficient regionally controlled ports are concentrated in the south of the country (Rio Grande do Sul, Santa Catarina and Paraná). Therefore, as decentralization benefits ports located elsewhere, relative efficiency increases for those ports whose inland regions are in the other portion of the country. In other words, the effects on imports and exports are most sensitive outside the south region.

Table 4.4 Spatial Results: Real Gross State Product (in percentage change)

	Scenario 1		*Scenario 2*		*Scenario 3*	
	SR	*LR*	*SR*	*LR*	*SR*	*LR*
Region						
North	*0.037*	*0.112*	*0.032*	*0.039*	*0.055*	*0.136*
AC	0.010	0.039	0.005	0.154	0.013	0.208
AP	0.046	0.067	0.041	0.086	0.071	0.120
AM	0.041	0.152	0.036	0.046	0.066	0.181
PA	0.037	0.098	0.034	0.040	0.050	0.113
RO	0.021	(0.004)	0.013	(0.016)	0.032	(0.001)
RR	0.010	0.114	0.005	(0.083)	0.014	0.046
TO	0.023	(0.038)	0.017	(0.032)	0.034	(0.051)
Northeast	*0.028*	*0.041*	*0.023*	*0.000*	*0.045*	*0.058*
AL	0.040	0.274	0.033	0.300	0.063	0.315
BA	0.030	0.030	0.024	0.039	0.056	0.082
CE	0.023	(0.389)	0.021	(0.441)	0.029	(0.576)
MA	0.091	0.336	0.083	0.307	0.147	0.540
PB	0.037	(0.074)	0.026	(0.141)	0.051	(0.072)
PE	0.014	0.196	0.008	0.059	0.018	0.232
PI	0.033	0.716	0.029	0.750	0.045	0.855
RN	0.019	(0.055)	0.015	(0.019)	0.026	(0.067)
SE	0.019	0.277	0.013	0.098	0.028	0.399
Southeast	*0.034*	*0.121*	*0.029*	*0.068*	*0.053*	*0.160*
ES	0.102	0.215	0.095	0.186	0.152	0.317
MG	0.041	(0.111)	0.034	(0.103)	0.063	(0.181)
RJ	0.020	0.047	0.017	0.017	0.034	0.058
SP	0.033	0.192	0.028	0.116	0.052	0.261
South	*0.043*	*0.011*	*0.008*	*0.057*	*0.049*	*0.040*
PR	0.040	0.073	0.008	0.027	0.053	0.047
SC	0.049	0.011	0.009	0.130	0.048	0.140
RS	0.042	(0.034)	0.009	0.048	0.046	(0.010)
Center-West	*0.013*	*(0.012)*	*0.007*	*(0.039)*	*0.017*	*(0.023)*
DF	(0.011)	0.059	(0.008)	0.044	(0.017)	0.086
GO	0.023	(0.525)	0.017	(0.337)	0.034	(0.704)
MT	0.042	0.331	0.026	0.165	0.059	0.461
MS	0.013	0.302	0.005	0.062	0.017	0.342
Brazil	*0.036*	*0.092*	*0.026*	*0.061*	*0.053*	*0.130*

Source: Data based on author's calculations

Figure 4.9a Spatial Results: Real Gross State Product, Scenario 1.[62]

Short run *Long run*

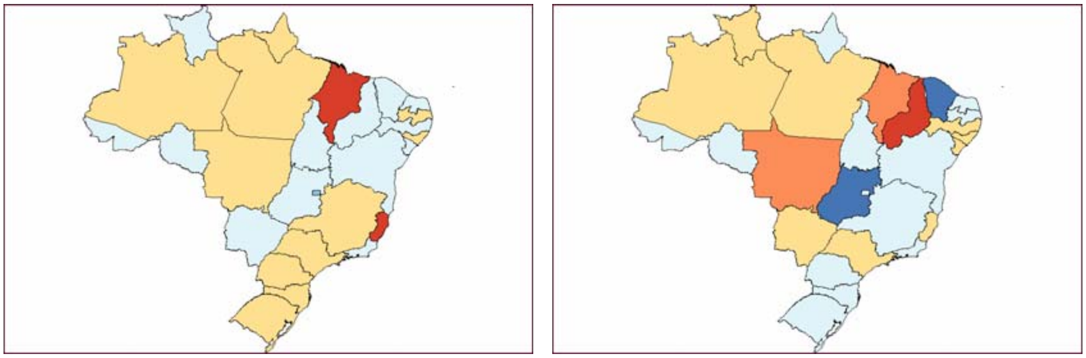


Figure 4.9b Spatial Results: Real Gross State Product, Scenario 2

Short run *Long run*

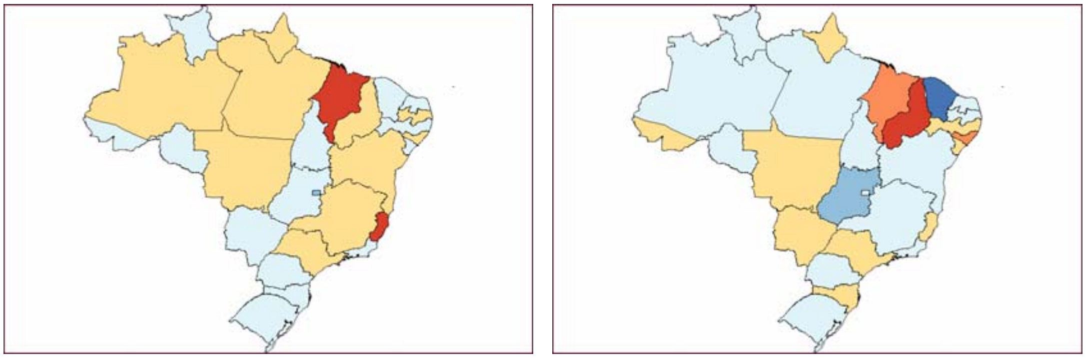
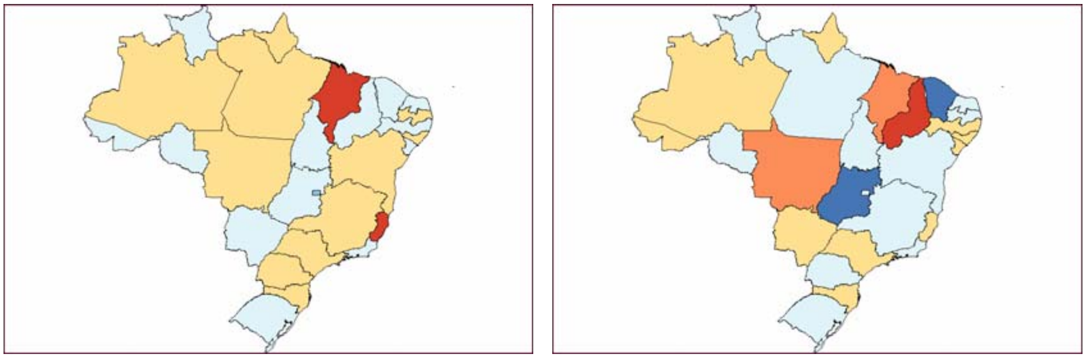


Figure 4.9c Spatial Results: Real Gross State Product, Scenario 3

Short run *Long run*



Source: Data based on author's calculations

[62] In the maps, warm colors (orange, red, and dark red) represent values above the average, in terms of standard deviations; cool colors (light blue, blue, and dark blue) represent values below the average, also in terms of standard deviations; warmer/colder (i.e. darker) colors represent outliers.

Fiscal Impacts

Table 4.5 offers a special presentation of the fiscal impacts of the simulations, including revenue and expenditure components of the fiscal (primary) budget in nominal terms. Neither Central Bank operations nor those of state enterprises are included. This special presentation provides information similar to that usually published by the Treasury.

As Figure 4.10 illustrates, (Porsse, 2005), modeling of public finances in B-MARIA follows a slightly different specification, but consolidation into the Treasury format is straightforward. Figure 4.10 describes the main characteristics of the government's budget and the fiscal linkages between the central and regional governments modeled in the B-MARIA-27 model in accordance with the Brazilian federal system. The most important source of revenue for Brazil's central government are income taxes and contributions (other indirect taxes), while the main source of revenue for the regional governments are indirect commodity taxes, i.e. excise taxes collected on goods and service transactions by the origin principle. The Brazilian constitutional rules impose a hard vertical linkage between governments, and 21.5% of the income and commodity taxes collected by the central government is transferred to the regional governments.

The simulations run for the preparation of this report closed the government accounts and assumed a balanced marginal budget for both the central government and the regional governments. In other words, the government deficit was set exogenously, allowing government expenditures to change. Given changes in total revenues, the adjustment variable was set to be "other government outlays".[63]

The following pattern emerged from the simulations. First, for all three scenarios, fiscal impacts were greater in the long run than in the short run. In the long run, federal direct tax revenues were found to play a more prominent role, positively affecting both the Federal government revenue as well as the revenue of regional government because of the Federal transfers made to each region. In the short run, with a more restricted tax base (fixed capital stocks), revenue from direct taxes was not found to perform as strongly. Indirect tax revenue tended to outperform direct tax revenue, benefiting the regional governments more than the central government. Since the revenue side sets the stage for increases in overall expenditures, assuming a balanced marginal budget at all levels of government, government outlays also followed a similar scenario. In the short-run, regional government expenditures were found to grow faster than those of the Federal government, while in the long-run, Federal expenditures outperformed regional expenditures. The bottom line of Table 4.5 presents the impacts on real budget surplus[64]: the Federal government achieves higher increases, in percentage change, in its prevailing (primary) surplus in the long run. It is noteworthy that the relative magnitudes of changes in the three scenarios follow the same hierarchy previously revealed by other relevant variables (scenario 3 > scenario 1 > scenario 2).

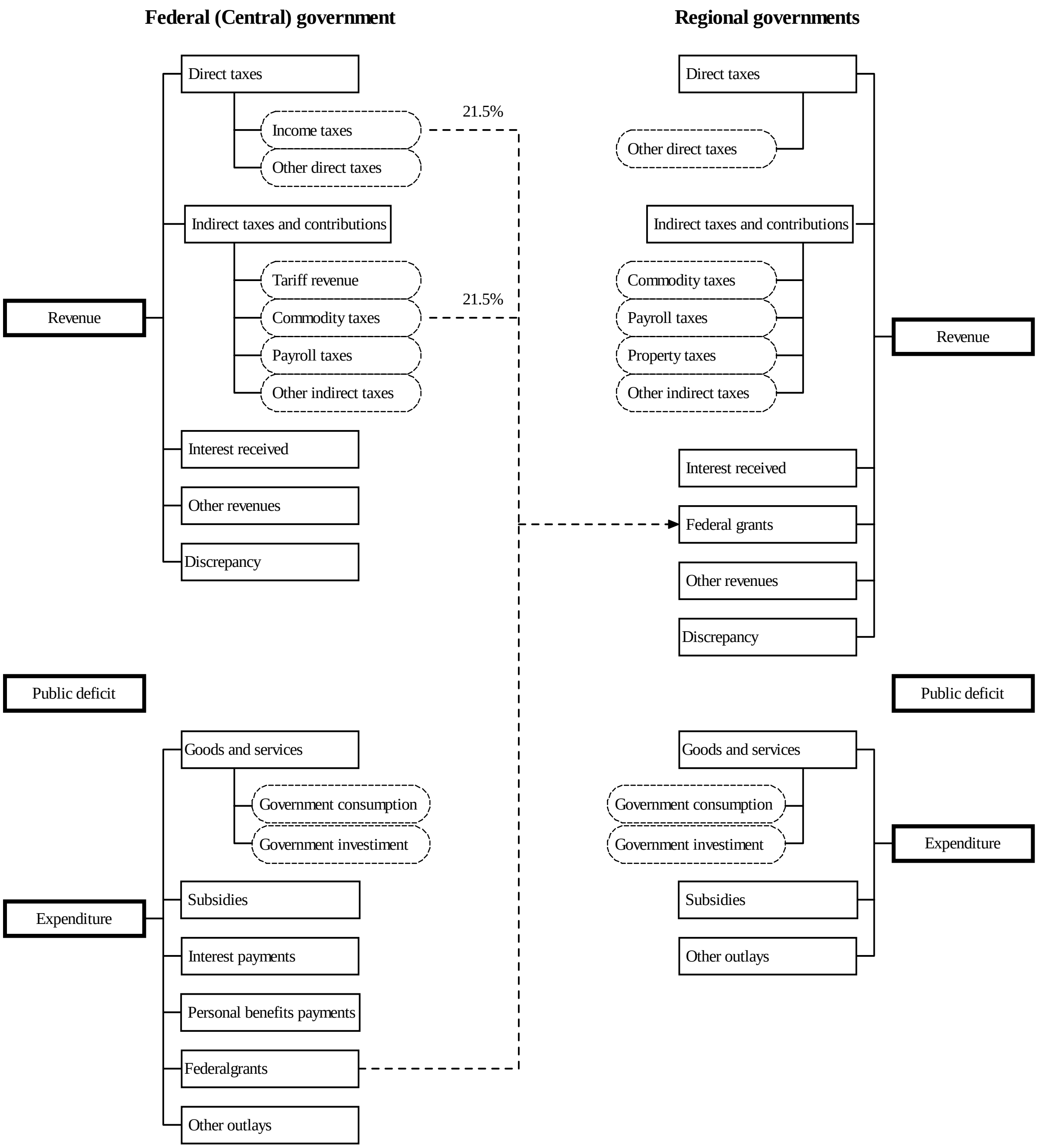
Finally, it should be noted that the adjustment variable, other outlays, showed positive changes in all scenarios, both in the short run and in the long run. It is, therefore, evident that there is room for improved fiscal performance considering other alternatives to close the government accounts. In summary, increases in port efficiency do have non-negligible fiscal impacts, enhancing the

[63] Variable "discrepancy" was turned off.

[64] In our benchmark year, 2002, both the Federal and regional governments presented a budget surplus.

performance of government accounts, mainly through economy-wide effects on economic activity and trade.

Figure 4.10 Government Budget and Fiscal Linkages between Brazilian Governments



Source: Porsse (2005)

Table 4.5 Fiscal Results

	Scenario 1				*Scenario 2*				*Scenario 3*			
	Short run		*Long run*		*Short run*		*Long run*		*Short run*		*Long run*	
	Federal	*Regional*	*Federal*	*Regional*	*Federal*	*Regional*	*Federal*	*Regional*	*Federal*	*Regional*	*Federal*	*Regional*
I. TOTAL REVENUE	0.053	0.065	0.236	0.119	0.013	0.021	0.207	0.070	0.061	0.079	0.329	0.139
I.1. Tax Revenue	0.058	0.087	0.315	0.114	0.017	0.036	0.293	0.059	0.069	0.111	0.452	0.131
I.1.1. Indirect taxes and contributions	0.083	0.094	0.124	0.119	0.036	0.041	0.073	0.061	0.107	0.122	0.148	0.137
I.1.2. Direct taxes	0.036	0.046	0.486	0.086	(0.000)	0.008	0.491	0.047	0.034	0.051	0.725	0.097
I.2. Payroll Taxes	0.045	0.021	0.093	0.091	0.006	(0.010)	0.049	0.108	0.048	0.013	0.102	0.108
I.3. Federal Transfers to Regions	-	0.030	-	0.157	-	(0.004)	-	0.092	-	0.026	-	0.187
I.4. Other Revenue	0.045	0.048	0.093	0.091	0.006	0.009	0.049	0.067	0.048	0.054	0.102	0.107
II. TOTAL OUTLAYS	0.053	0.065	0.236	0.119	0.013	0.021	0.207	0.070	0.061	0.079	0.329	0.139
II.1. Government Consumption (Personnel)	0.012	0.013	0.088	0.094	(0.015)	(0.015)	0.063	0.065	0.002	0.001	0.109	0.115
II.2. Federal Transfers to Regions	0.030	-	0.157	-	(0.004)	-	0.092	-	0.026	-	0.187	-
II.3. Personal Benefit Payments	0.105	0.023	0.032	0.053	0.045	(0.009)	0.020	0.031	0.137	0.017	0.023	0.050
II.4. Subsidies	0.117	0.091	0.126	0.131	0.056	0.044	0.072	0.050	0.154	0.122	0.152	0.140
II.5. Other Outlays	0.045	0.139	0.715	0.155	0.013	0.072	0.687	0.077	0.052	0.188	1.060	0.173
III. Government Balance	0.053	0.065	0.236	0.119	0.013	0.021	0.207	0.070	0.061	0.079	0.329	0.139
Real budget surplus	0.041	0.053	0.219	0.102	0.029	0.037	0.200	0.063	0.060	0.078	0.326	0.136

Source: Data base on author's calculations

4.7 Conclusions

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 the case in Brazil and much of Latin America—it becomes important to separate out link and node costs. This separation is even more important from a policy perspective, as Brazil faces the complex and daunting challenge of identifying the most critical elements of its infrastructure to upgrade. The choice of ports for government investment will have significant implications on the hinterlands serving those ports as well as on 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 the prospects for the less developed northeast to grow fast enough to reduce disparities in welfare levels. Furthermore, 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.

Chapter 5
Assessing the Economic Impacts of Lowering Transportation Costs in Brazil: An Application to Two Federal Highways

5.1 Introduction

One of the main obstacles to economic development in Brazil is the so called *custo Brasil*—the extra cost of doing business in the country. Enterprises are faced with a heavy burden that many competing firms in other countries do not confront, and which hampers their competitiveness. This cost includes different components that represent distortions in the relationship between the public and the private sectors, reflecting inadequate legislation and inadequate provision of public goods. An ongoing debate centers on the contributions of different sectors, including labor costs, transportation infrastructure, the tax system, and the regulatory system, to the *custo Brasil*.

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

More than ten years after the aforementioned World Bank study, the situation in the transportation sector remains the same. Brazil's transportation infrastructure is rapidly deteriorating because of a lack of investment and maintenance, and it is showing an increased number of critical points, or bottlenecks, in most of the corridors. Decay in the transportation system curtails economic growth by hampering competitiveness both in domestic and international markets. The deterioration of Brazil's transportation network in recent years has contributed to high operational costs, and has prevented the country's competitive integration into the world economy.

Due to the low quality of infrastructure services, particularly in transportation, inventory levels for final goods are estimated to be twice as high in Brazil as they are in the U.S., and three times as high for raw materials. Considering Brazil's relatively high interest rates, the cost to the Brazilian economy of the additional inventory holdings is estimated at 4 percent of GDP.

The low quality of transportation services, explains most of the high inventory levels in Brazil (Castro 2004). In addition to the low quality of road infrastructure, the lack of well developed multimodal transportation in Brazil, has also negatively impacted the country's competitiveness. A summary breakdown of soybean production and export costs show that Brazil loses its production cost advantage over the U.S. due to higher transport and export costs (including customs administration).

Table 5.1 Estimated Soybean Export Costs: Brazil and U.S.
(US$/metric ton; 1st quarter 2006)

To Germany (Hamburg)	Brazil (Mato Grosso)	U.S. (Iowa)	Brazil/US cost ratio
Production cost	157.86	204.78	0.77
Transport cost to export port	84.65	30.84	2.74
Freight cost to Hamburg	38.51	19.53	1.97
Final cost in Hamburg	281.02	255.15	1.10

To China (Shanghai)	Brazil (Goias)	U.S. (Minneapolis)	Brazil/US cost ratio
Production cost	180.71	202.34	0.89
Transport cost to export port	42.49	34.80	1.22
Freight cost to Shanghai	50.13	35.71	1.40
Final cost in Shanghai	273.33	272.85	1.002

Source: U.S. Department of Agriculture, Brazil Soybean Transportation, Aug. 2006

As shown in Table 5.1 above, in the U.S. transportation costs from the place of production to an international port represent about 7.7 to 12.8 of the final cost of soybeans, whereas in Brazil the cost represents between 15.5 and 30.1 percent. As a result, Brazil loses its cost advantage in production, due largely to high domestic transportation costs. In other words, Brazilian domestic transport costs from the farm gate to port are 122-274 percent of the equivalent costs in the U.S., while freight costs range from 140-197 percent of U.S. costs.

Recent government initiatives to promote investments in infrastructure include the Programa de Aceleração do Crescimento (PAC, growth acceleration program) which was unveiled at the end of January 2007.[65] Investments in logistic infrastructure are estimated at US$58.3 billion in the four-year period from 2007-2010, of which US$33.4 billion or 57.3% of the total will go toward improving road infrastructure.[66]

One important aspect of macroeconomic management in Brazil with potential effects on the public provision of infrastructure is the Projeto Piloto de Investimento (PPI, pilot project for investment), which permits the government to reduce the primary surplus by an equivalent amount to an increase in infrastructure expenditure. PPI will probably be increased from 0.2% of GDP to 0.5% of GDP beginning this year. Since the government has formally maintained the 4.25% of GDP primary fiscal target[67] in 2007, this will put the effective primary surplus closer to

[65] The PAC aims to increase average annual GDP growth to 5% per year (almost double the country's long-term average), principally through increased investment in infrastructure, which will be fostered in part through targeted tax breaks (EIU, February 2007).
[66] www.brasil.gov.br (Programa de Aceleração do Crescimento 2007-2010).
[67] The primary balance of the non-financial public sector (NFPS) equals the fiscal balance excluding interest payments.

3.75% of GDP.[68] This could represent an additional US$3 billion to be invested in infrastructure projects.

Concomitantly to the four-year PAC program, the federal government has also signaled its intention to revive long-term transportation planning. The design of an ambitious Plano Nacional de Logística e Transportes (PNLT, national plan of logistics and transportation) has been initiated. The plan includes a variety of stakeholders and aims at supporting decision makers in attaining economic objectives through policy initiatives related to both public and private infrastructure and organization of the transportation sector.[69]

At the state level, few initiatives have taken place in the realm of transportation planning. States such as Bahia, Rio Grande do Sul and Minas Gerais have all developed thorough diagnostics of the sector, including forward-looking exercises with a long term view of the available possibilities for policy intervention within their respective state borders.[70] As a recent report by the World Road Association (2003) points out, there is a growing need for economic and socioeconomic models to help improve road management. In a context where public administrations experience a stronger demand for social programs and where road budgets tend to be tightened or even scaled back, the economic evaluation and optimization of road investment actions and/or policy becomes almost imperative.

This chapter represents an attempt to address this need. In doing so, it uses a fully operational interregional CGE model designed for the Brazilian economy and based on previous work by Haddad and Hewings (2005), to assess the likely economic effects of recent road transportation policy changes in Brazil. Among the features embedded in this framework, modeling of external scale economies and transportation costs provides an innovative way of dealing explicitly with theoretical issues related to integrated regional systems. The explicit modeling of transportation costs built into the interregional CGE model based on origin-destination flows, takes into account the spatial structure of the Brazilian economy and creates the capability of integrating the interstate CGE model with a geo-coded transportation network model. This enhances the potential of the framework for understanding the role of infrastructure in regional development. The transportation model used is the so-called Highway Development and Management Model, which was developed by the World Bank and implemented using the TransCAD software. Further extensions of the current model specification for integrating other features of transportation planning in a continental industrializing country like Brazil are discussed with the goal of building a bridge between conventional transportation planning practices and the innovative use of CGE models. In order to illustrate the analytical power of the integrated system, a set of simulations that evaluate the economic impacts of physical/qualitative changes in the Brazilian road network (e.g. a highway improvement) are presented, in accordance with recent policy developments in Brazil. Rather than providing a critical evaluation of this debate, the likely structural impacts of such policies are emphasized. It is expected that the results will reinforce the need to better specify spatial interactions in interregional CGE models.

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[68] EIU (2007).

[69] www.centran.eb.br (Programa Nacional de Logística e Transportes).

[70] 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.

The remainder of this chapter is organized as follows. After the discussion of relevant modeling issues focusing on the treatment of transportation costs in CGE models in the next section, section 5.3 presents an overview of the CGE model used in the simulations, focusing on its general features. Section 5.4 discusses the modeling integration approach. After that, the simulation experiments are designed and implemented, and the main results are discussed in section 5.5. In the conclusions, the main findings are evaluated and put in perspective taking into account their applicability and limitations.

5.2 Modeling Issues

In the last fifteen years, the development of regional and interregional CGE modeling has experienced an upsurge in interest from academics and policy makers. Different models have been built for different regions of the world. Research groups located in Australia, Brazil, Canada, Germany, Scotland, and the U.S., as well as individual researchers, have 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 to interregional CGE modelers in particular.[71] Experimentation with the introduction of scale economies, market imperfections, and transportation costs is expected to provide innovative ways of dealing explicitly with theoretical issues related to integrated regional systems.

The potential uses of interregional CGE models include the analysis of transportation planning policies with ranging effects on regional and national economies (including common markets such as the European Union, MERCOSUR or NAFTA). National and/or statewide transportation system planning is a widely institutionalized process in several countries. The use of model-based analytical procedures is common in infrastructure planning. This includes the application of conventional input-output methods for forecasting freight movements. Nevertheless, the feedback impact of transportation 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 transportation and economics research fields in the USA (e.g. Friez et al. 1998) and the EU (e.g. Bröcker 2002), along with similar efforts in several Asian countries (e.g. Miyagi 2001) and Brazil (e.g. 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. The expansion and improvement of transportation facilities can be used as a means of reducing firms' transaction costs and expanding the economic opportunities in a region or country, since doing so may help to increase income and improve the standard of living of the local population.

As reported in Weisbrod and Treyz (1998), studies that attempt to identify the national implications of investments in transportation infrastructure tend to focus the analysis on productivity gains, which are defined, in general terms, as the ratio between output and primary factors. From a regional perspective, income generation due to the expansion of existing plants or the arrival of new firms has always been perceived as a benefit to be pursued by the local

[71] See, for instance, Fujita et al. (1999) and Fujita and Thisse (2002).

government. However, from a national perspective, if productivity is accepted as being the main driver of economic growth, the relocation of firms inside the national economic space can only be seen as a benefit if the underlying productivity element associated with this movement is sufficient to exceed the cost of relocation.

In addition to their impact on systemic productivity, investments in transportation can have differential impacts across economic spaces. Spatially localized interventions could increase regional competitiveness. External scale economies and accessibility effects could result in 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 relationships (both complementary and competitive) associated with the regional agents in the relevant economic spaces.

The modeling procedure developed in this chapter represents an attempt to address some of these issues in the context of a unified approach, while giving proper treatment to the role of transportation infrastructure in the allocation of a given economy's resources. The explicit modeling of transportation costs in an interregional CGE model integrated in a geo-coded transportation network infrastructure model allows for the assessment, under a macro-spatial perspective, of the economic effects of specific transportation projects and programs.

5.2.1 Treatment of Transportation Costs

It has been noted elsewhere (Haddad 2004) that current CGE models are not without their limitations in representing spatial phenomena. Isard's vision of integrated modeling, 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). If adequately coped, interregional CGE models are the main candidates to provide the core subsystem in a fully integrated system.

Spatial infrastructure and spatial socioeconomic phenomena are key elements that shape and improve our understanding of economic spaces. In one of its relevant dimensions, a framework incorporating the explicit modeling of transportation costs based on the capability of integrating the interregional CGE model with a geo-coded transportation network model enhances the potential of the integrated system to improve our understanding of the role infrastructure plays in regional development. Initial attempts to link a transportation network model with an interregional CGE model are documented in Kim and Hewings (2002, 2003), with encouraging results for regional planners.

The embedding of spatial trade flows into economic modeling, especially those related to interregional trade linkages, should go hand-in-hand with the specification of transportation services. Given existing interregional CGE models, one can identify at least three approaches for introducing the representation of transportation, all of which take into account the fact that transportation is a resource-demanding activity. This basic assumption is essential if one intends to properly model an interregional CGE framework, and the model's results would not be valid if it is not properly accounted for (see Isard et al. 1998).

First, it is possible to specify transportation technology by adopting the iceberg transportation cost hypothesis based on the work of Samuelson (1952). It is assumed that a certain percentage of the transported commodity itself is used up during transportation. Analytically, one possible way to introduce iceberg costs is to consider the transport rate $\eta^i > 0$ to be the share of commodity i lost per unit of distance, where z_{rs} is the distance from **r** to **s**. The amount arriving in **s**—if one unit of output i is sent from **r** to **s**—is $\exp(-\eta^i z_{rs})$, which is less than unity if z_{rs} is positive (Bröcker 1998a). To calibrate the model, it is assumed that the transport rates η^i for each sector are known in the form of data on transportation cost per unit of distance expressed as percentages of the respective commodity values. The z_{rs} variable potentially provides the linkage for the integration with a geo-coded transportation model. Models using this transportation technology framework include Bröcker (1998a, 1998b, 2002), Kilkenny (1998), Hu (2002), and Almeida et al. (2007).

Second, one can assume transportation services to be produced by a special optimizing transportation sector. A fully specified production possibilities frontier (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), even though it makes the model structure rather complicated in practice (Bröcker 1998b). The model can be calibrated by taking into account the specific transportation cost structure of each commodity flow providing for spatial price differentiation, which indirectly addresses the issue related to regional transportation infrastructure efficiency. In this sense, space plays a major role.[72] Examples can be found in Haddad (1999, 2004), and Haddad and Hewings (2001, 2005).

Finally, a third approach to the introduction of transportation into CGE models consists of the development of a satellite module for the transportation system. The transportation subsystem is usually exogenously modeled, generating transportation inputs that feed the production functions in the CGE model. In this case, there is no micro-foundation behind the satellite model, as is the case with the behavioral equations in the interregional CGE core. Roson (1994) and Kim and Hewings (2002, 2003) provide some examples of this approach.

5.3 The Interregional CGE Model

As in Chapter 4, the departure point is the B-MARIA model, developed by Haddad (1999). The B-MARIA model and its extensions have been widely used for assessing the regional impacts of economic policies in Brazil. Since the publishing of the reference text, various studies have been

[72] A direct link between the stock of capital associated with the transportation sector and the transportation infrastructure network can be derived. However, identification problems emerge as one cannot properly identify the magnitudes for the aforementioned link with the public stock of transportation infrastructure. This limits analytical possibilities with a geo-coded information system.

undertaken using variations of the original model as their basic analytical tool.[73] 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).

Studies using the B-MARIA model and its extensions benefit from the modeling flexibility that allows users to deal with the differentiated impacts of policies across regions and sectors in the interregional Brazilian system. Departing from its basic structure, variations in the general characteristics (regional and sectoral settings, benchmark year, etc.) have been implemented together with methodological extensions (e.g. treatment of the external sector, finer disaggregation of public sector accounts). Some examples of applications include: prospective studies on the Brazilian regional dynamics (Baer et al. 1998; Haddad et al. 1999); evaluations of the trade liberalization process in the early 1990s (Haddad and Hewings 2000; Haddad and Azzoni 2001); an assessment of the impacts of investments in the automobile sector (Haddad and Hewings 1999); evaluations of transportation policies (Haddad and Hewings 2001, 2005; Haddad and Perobelli 2005); a methodological evaluation of structural coefficients and behavioral parameters of the model (Haddad et al. 2002); an assessment of regional impacts of trade agreements (Domingues 2002); methodological developments for the study of tax competition in Brazil (Domingues and Haddad 2003; Porsse 2005); and, finally, the analysis of trade interactions among Brazilian states (Perobelli 2004).

The theoretical structure of the B-MARIA model is well documented. In addition to the reference readings provided in Haddad (1999) and Haddad and Hewings (1997), which present the model in detail, Domingues (2002), Perobelli (2004), Haddad (2004), Haddad and Hewings (2005), and Porsse (2005) also present extended versions of the model, focusing on some of its new developments and calibration procedures.

In this chapter, a version of the B-MARIA model is developed specifically to evaluate transportation policies in the state of Minas Gerais. The approach is similar to the one used by Haddad (2004) and Haddad and Hewings (2005) in integrating the interregional CGE model with a geo-coded transportation network infrastructure model. Instead of using a simpler transportation network model based on only one attribute of the links to deal with accessibility (i.e. maximum speed), however, a more sophisticated model is used—the Highway Development and Management Model (HDM-4), developed by the World Bank.[74] The general features of the B-MARIA-Minas Gerais model are explained in more detail in Annex 13. The structural database for the CGE model, including detailed sectoral and regional information, as well as the behavioral parameters used and the closures are presented in Annex 11. The modeling of transportation costs to be integrated with the CGE model is detailed in Annex 14.

5.4 Transportation Infrastructure Projects

This section illustrates the analytical capability of the unified framework in the evaluation of specific transportation projects contemplated in the PAC program. The case study under consideration refers to two federal highway improvement projects, BR-262 and BR-381, in the

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[73] Among these are four doctoral dissertations: Domingues (2002), Perobelli (2004), Porsse (2005), and Ferraz (2007) , the latter at the concluding stage.

[74] http://www.worldbank.org/transport/roads/tools.htm

state of Minas Gerais. The following analysis is based on a strategy of applying the framework developed here to the evaluation of each 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 chapter. The following section assesses the impacts of these projects on national variables as well as on a broader set of socioeconomic state variables.

The characteristics of the projects, which are currently in their planning stages, are detailed in a document prepared by Fipe (2007) for the *Secretaria de Transportes e Obras Públicas* of the State of Minas Gerais (Secretariat of Transportation and Public Works). The justification of the choice to improve these specific sections of the BR-262 and BR-381 highways includes the strategic location of these network links in the national transportation system, since they constitute two of the main corridors providing access to the more dynamic regions of the country. It is hoped that their improvement will foster regional development in the State of Minas Gerais, one of the country's leading regional economies.

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 a third lane between Nova Serrana and Araxá. Total costs for the project are estimated at 554 million BRL.[75]

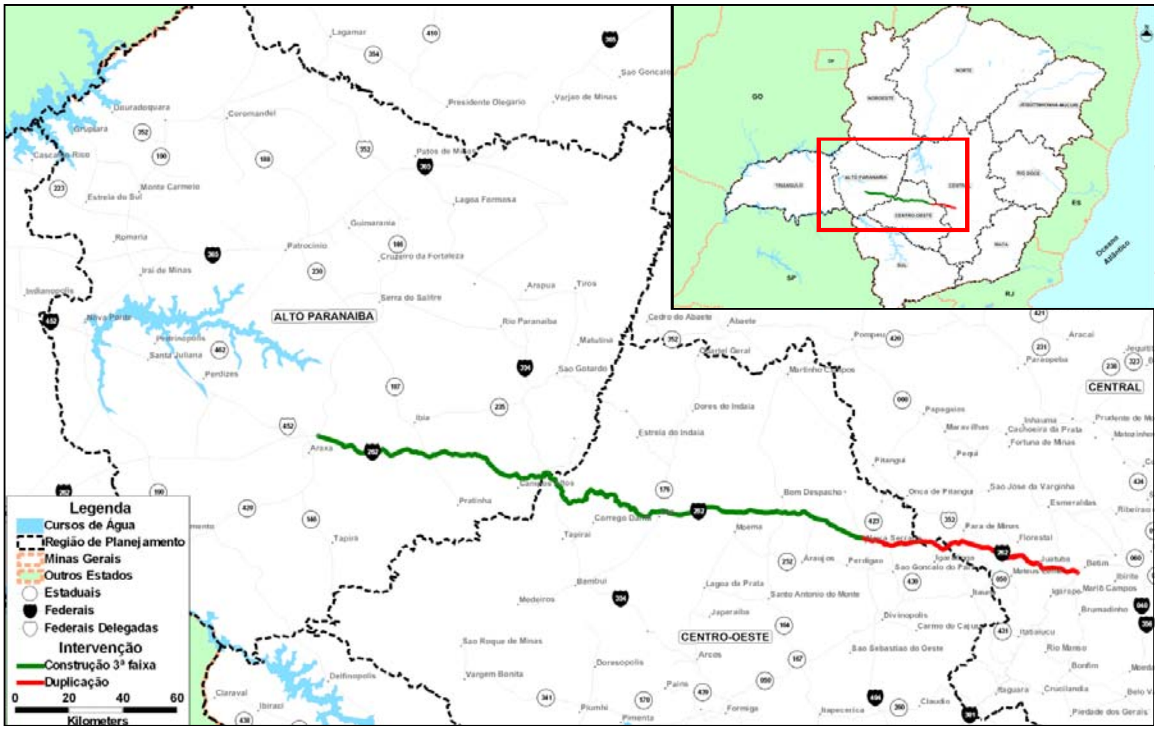
The BR-381 project involves the duplication of the track between Belo Horizonte and Governador Valadares, a total length of 304 km. Total costs of the implementation are estimated at 1,395 million BRL.

The distinction between the two projects lies in the role they play in the integration of Brazilian regions. While the BR-262 project would constitute a major improvement in the east-west integration of the country, linking the coast of the southeast to the more agricultural areas of the midwest, the BR-381 would play a strategic role in the integration of the northeast with the southeast and south of the country. The location of both roads is shown in Figure 5.1. These distinct axes of integration would have different effects on the interregional 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 specialized spaces have more prominent roles.

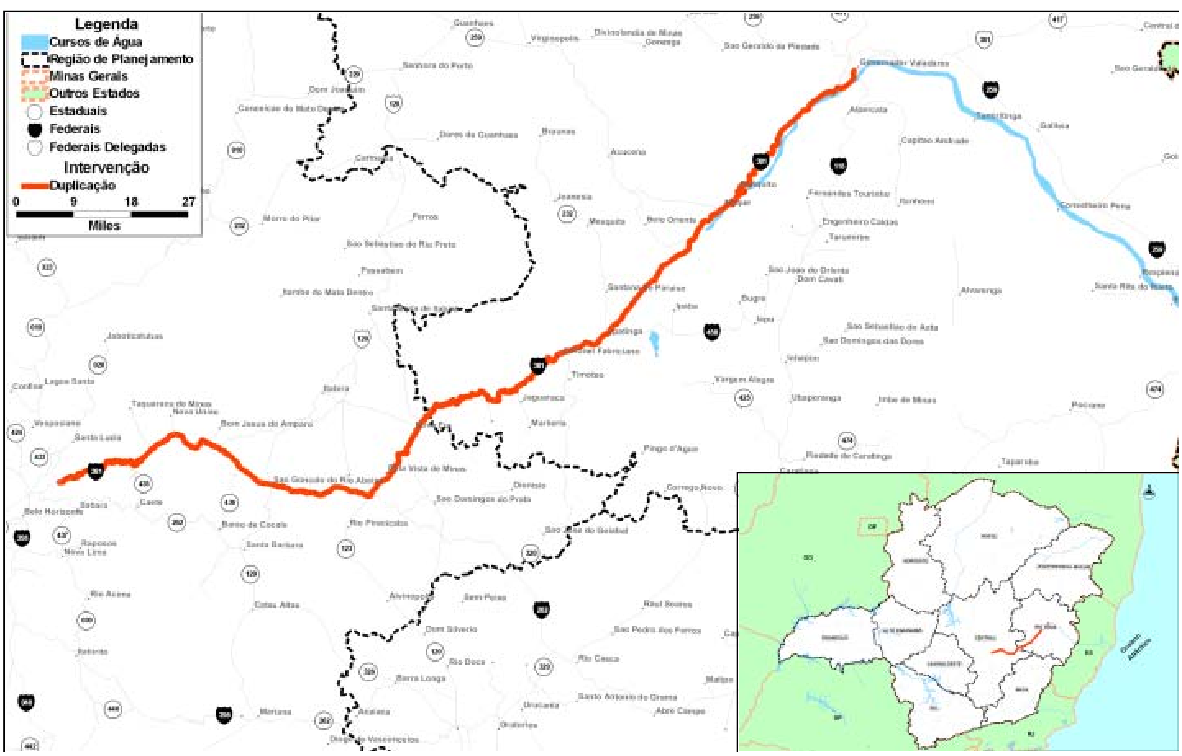
[75] Values as of December 2006.

Figure 5.1 Location of Road Improvement Projects

BR-262



BR-381



Source: Secretaria de Transportes e Obras Públicas, Minas Gerais

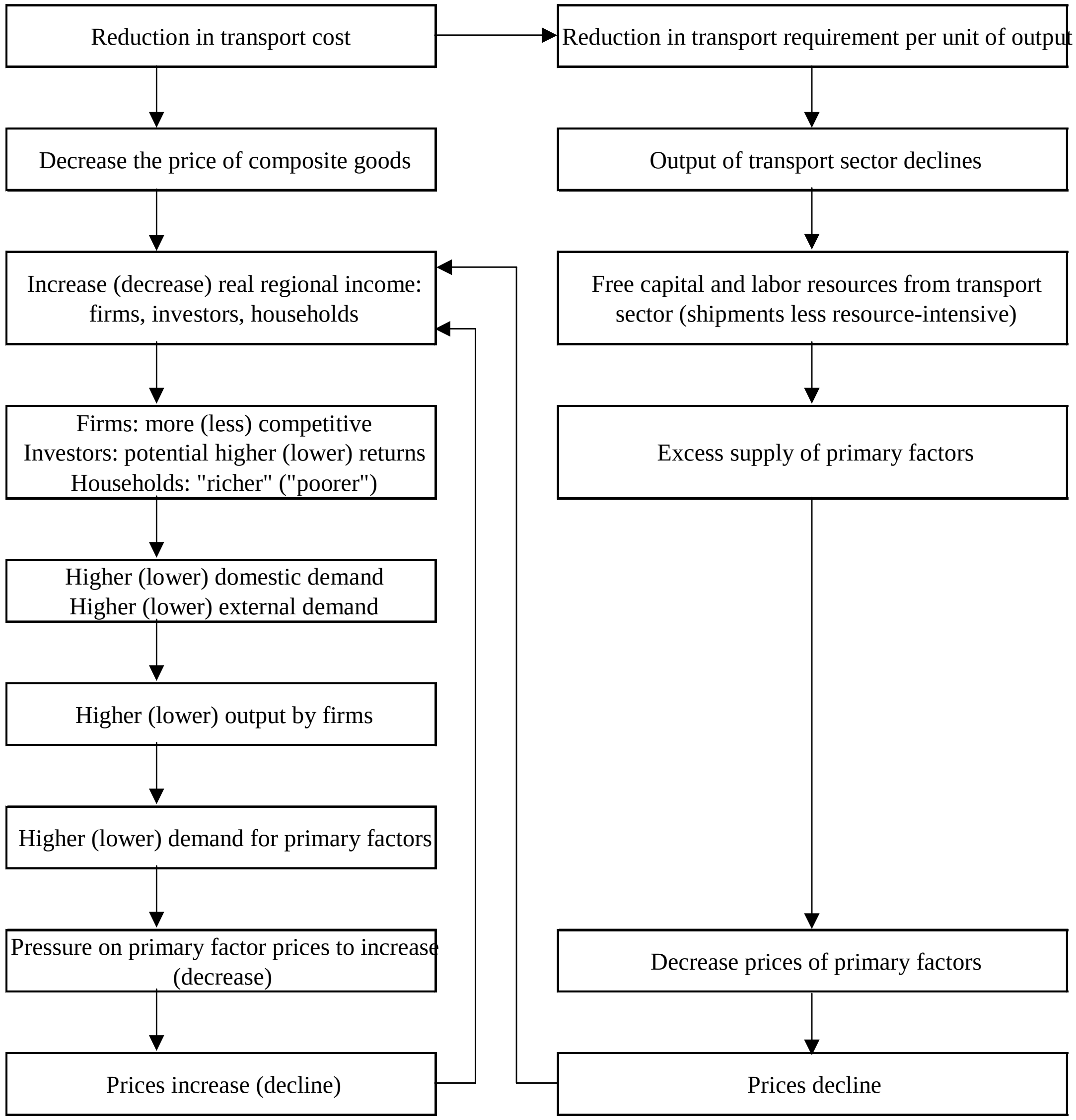
5.4.1 Functioning Mechanism

This subsection presents the main causal relationships underlying the simulation results. The simulation exercise considers the implementation of two road improvement projects in the state of Minas Gerais. According to the model structure this may represent a margin-saving change, i.e. a reduction in the use of transportation services per unit of output, implying a direct reduction in the output of the transportation sector. As shipments become less resource-intensive, labor and capital are freed, thereby generating excess supply of primary factors in the economic system. This creates downward pressure on wages and capital rents, which are passed on to consumers in the form of lower prices.

As with to the functioning mechanism presented for the model presented in Chapter 4, the reduction in transportation 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 decrease (inputs are less costly), and because the cost of producing capital also declines investors foresee potential higher returns. Meanwhile, households increase their real income, envisioning higher consumption possibilities. Higher incomes generate higher domestic demand, while increases in the competitiveness of national products stimulate external demand. This creates room for increasing firms' output in both domestic and international markets, leading to a higher demand for inputs and primary factors. Increasing demand puts pressure on the factor markets to increase prices, and entails a corresponding expectation that the prices of domestic goods will increase.

Second-order price changes go in both directions, and their net effect is determined by the relative strength of the countervailing forces. Figure 5.2 summarizes the transmission mechanisms associated with major first-order and second-order effects in the adjustment process underlying the model's aggregate results.

Figure 5.2 Causal Relationships in the Simulation



As for the differential spatial effects, three major forces operate in the short-run—two price (substitution) effects and one income effect—and the net result depends heavily on the structure of the integrated interstate system. In the case of regional performance, two substitution mechanisms involving price effects are relevant in understanding the adjustment process. First, there is a direct substitution effect. Consider two trading regions, **r** and **s**, an exporter and an importer, respectively. As transportation costs between the two regions decrease, **r** will increase its exports to **s**, as it is now cheaper for consumers in **s** to buy from **r**. A substitution effect operates in the sense that consumers in **s** will directly substitute imports from **r** for either local production or imports from other regions (including foreign producers).

A second substitution effect is also operating. In order to produce more exports for **s**, producers in **r** will buy inputs from other regions. Due to the reduction in transportation costs these inputs are now cheaper: producers in region **r** become more competitive and further increase their output. This is the indirect substitution effect.

A third, countervailing force appears in the form of an income effect. With better accessibility, the demand for products from region **r** increases. The sources of higher demand for the region's output result from both a substitution effect, as prices for **r**'s products are now lower, and an income effect, as consumers' real purchasing power increases. This increase in demand causes prices to rise. The net price change will depend on whether the combined direct and indirect substitution effects will prevail over the income effect.

In the long run a fourth mechanism becomes relevant: the "relocation" effect. As factors are free to move between regions new investment decisions define marginal relocation of production activities, in the sense that the spatial distribution of capital stock and population changes. The main mechanism affecting regional performance is associated with capital creation. As transportation costs decrease, better access to non-local capital goods increases the rate of return in the regions. While this potentially benefits capital importing regions, it also has a positive impact on the capital good sectors of the producing regions.

Finally, and similarly to the model developed in Chapter 4, regions might be adversely affected through re-orientation of trade flows (trade diversion), as relative accessibility changes in the domestic trading system. Thus, overall gains in efficiency in the transportation sector are not necessarily accompanied by overall gains in welfare. This issue of trade diversion versus trade creation has been an important one in the international trade literature.

5.4.2 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 findings are discussed below.[76]

National impact*s*

Table 5.4. presents simulation results for national aggregates. Two distinct pictures emerge highlighting the specific structural differences between the two projects. In the case of the BR-262 project, the effects on regional economies largely agree with common sense expectations for this type of infrastructure project.

Gains in efficiency (real 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. It should be noted that in the long run the effects on GDP are magnified. In terms of employment, in the short run employment falls led by the transportation and construction sectors; the latter, specifically, has a strong employment coefficient. In the long run this negative effect on employment still prevails, but to a lesser degree, since activity effects partially overcome the sectoral structural effects.

Changes in terms of trade tend to benefit Brazilian exports in the short run by enhancing the competitiveness of Brazilian products. This conclusion is based on the projected effect of the BR-262 project on the international trade sector, in which export volumes increase, leading GDP

[76] Simulation results were computed using GEMPACK (Harrison and Pearson, 1994, 1996).

growth in the short run. However, international trade is the only component of GDP that improves in the short run.

In the long run, this situation is reversed. While stronger penetration of imported products is confirmed, due to the reversal of the terms of trade result, domestic absorption becomes the lead component, leading GDP growth. This result can be explained as follows: In the short run components of domestic absorption are less prone to change, while in the long run primary factors (both labor and capital) are more flexible. Pressures on primary factor prices to increase are thus less sensitive, allowing for a greater decrease in domestic costs of production. In this specific simulation, however, prices of exports tend to increase in relation to domestic prices, altering the international trade balance.[77] This fact is intrinsically related to the location of the project, which is situated on a route linking agricultural markets in the west and central parts of the country to important domestic centers of consumption in the east. Since this east-west link is not substantially associated with export corridors for agricultural products, the positive impacts of the project accrue mostly to domestic markets. Moreover, the distinct nature of the respective economic structures of the linked spaces results in very weak spatial competition among regions in the BR-262 area of influence.

In this sense, the spatial effects on GDP (Figure 5.3) reveal positive impacts in regions directly affected by the BR-262 both in the short run and in the long run. It is important to note that in the long run these positive impacts are spread over a larger area. Moreover, relocation effects tend to have the greatest impact on the agricultural regions in the west as well as the areas directly linked to the project itself within the borders of Minas Gerais.

Table 5.2 National Results: Selected Variables (in percentage change)

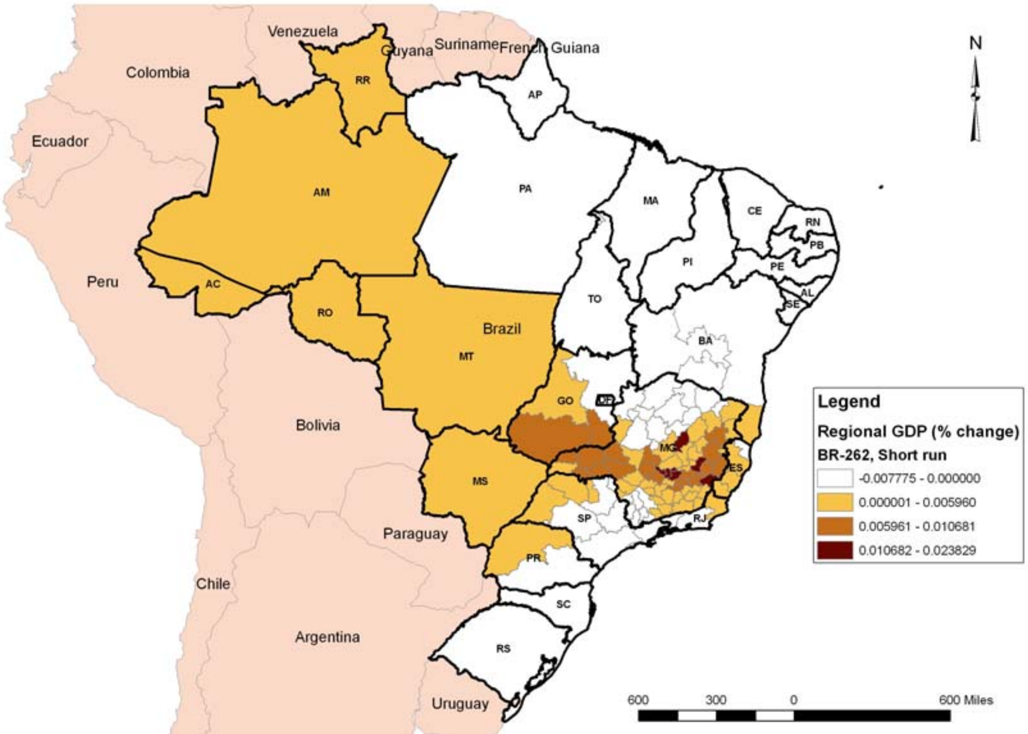
	BR-262		*BR-381*	
	SR	*LR*	*SR*	*LR*
Aggregates				
Real GDP	0.00022	0.00105	0.00018	(0.00293)
Aggregate employment, wage bill weights	(0.00131)	(0.00030)	(0.00670)	(0.00481)
Equivalent variation – total (change in $ 1,000,000)	(12.3)	58.6	(48.3)	6.4
Economy-wide terms of trade	(0.00180)	0.00040	(0.00674)	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: Data based on author's calculations

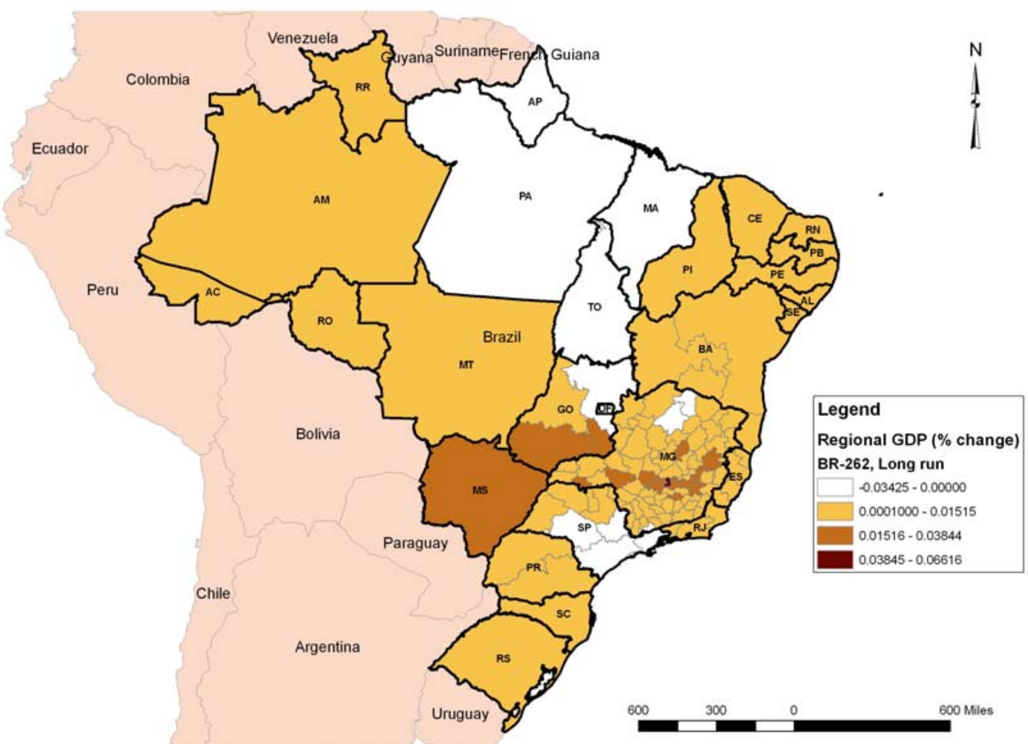
[77] The marginal trade balance is assumed to be in equilibrium in the long run.

Figure 5.3 Spatial Results: Real GDP (in percentage change)
BR-262 Project

Short run



Long run



In the case of the BR-381 project, macroeconomic short run results are qualitatively equivalent to those found in the analysis of the BR-262 project. Specifically, GDP growth is led by the international sector through improvement in the terms of trade, as well as an increase in the overall competitiveness of Brazilian products. However, another result occurs that is far more surprising from a common sense perspective: real GDP in the long run is projected to *decrease* after the duplication project is completed. To better understand the mechanisms behind this probable result, one needs to consider the following stylized situations, which are depicted in Figure 5.4.

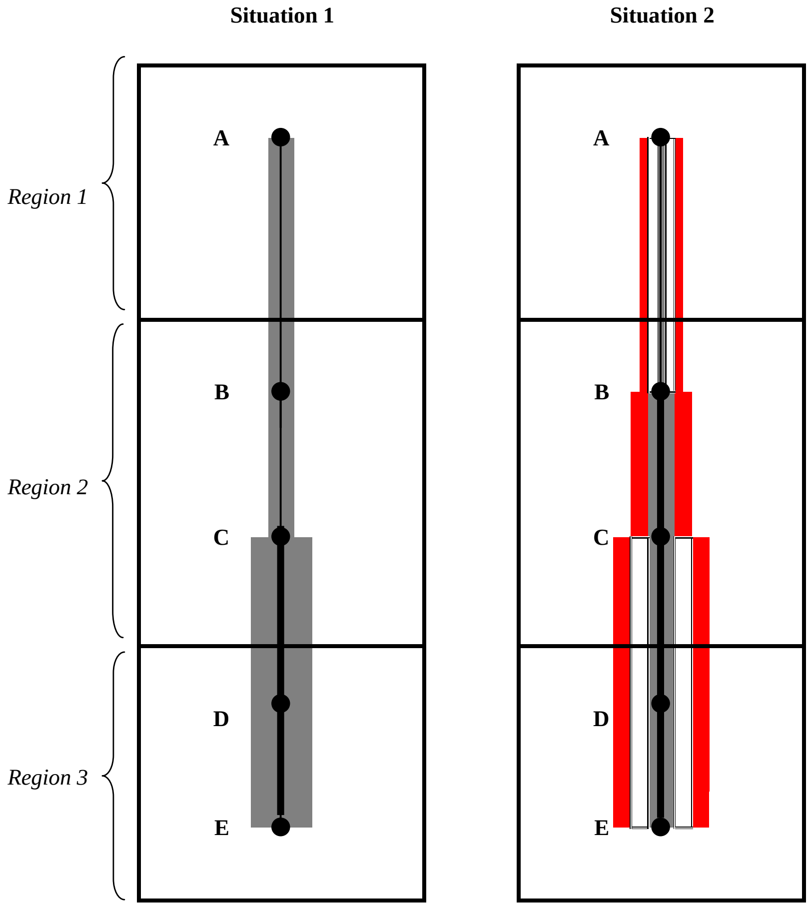
The two boxes refer to the spatial dimension associated with the project's first-order area of influence in terms of the integrated interregional system. Point A could refer to a node located northward from the northernmost node associated with the project, which is point B (Governador Valadares). The southernmost point related to the project, point C (Belo Horizonte) is also a limiting reference to this analysis. Further south, point D could be São Paulo and point E could represent Curitiba. The idea is to create a framework that will reveal possible outcomes in a context of spatial competition.

Three different regions are considered: Region 1 (northeast), encompassing point A; Region 2 (Minas Gerais), encompassing points B and C; and Region 3 (São Paulo and southern Brazil), encompassing points D and E. It should be emphasized that BR-381 is relevant to the integration of these three regions. More importantly, it is part of one of the major routes linking the northeast to the south of the country.

When the project is implemented (Situation 2), the duplication of highway section B-C considerably alters the allocation of traffic in the network. Links not explicitly tackled in the project start to receive more traffic, increasing their operational costs.[78] From the total of 11,881 links in the transport model simulation, 7,384 presented cost decreases while 3,462 presented cost increases.[79] Most of the relevant links which presented cost increases happen to be located in the more dense economic regions south of Belo Horizonte, or in terms of Figure 5.4, Region 3. This situation can have negative impacts, especially in those regions in which increases in spatial transactions costs reduce the competitiveness of their products. In the specific case of the BR-381 project, it is important to understand the hierarchical role these regions play in the Brazilian interregional system in order to interpret the final aggregate results of the simulation.

[78] Depending on the link, a wide range of OD pairs may use it. This is more common in highly dense economic areas.
[79] The remaining did not present any changes in cost.

Figure 5.4 Schematic Interpretation of the Simulation of the BR-381 Project



	Link capacity		*Economic density*	*Cost change*
	Situation 1	*Situation 2*		
A-B	Limit	Over capacity	Low	Positive
B-C	Limit	Under capacity	Low	Negative
C-D	Limit	Over capacity	High	Positive
D-E	Limit	Over capacity	High	Positive
Network effects				
A-C	-	-	-	Negative
A-D	-	-	-	Negative
A-E	-	-	-	Negative
B-D	-	-	-	Negative
B-E	-	-	-	Negative
C-E	-	-	-	Positive

Legend:
- Dual carriageway
- Single carrriageway
- Original interregional trade
- Additional interregional trade
- Interregional trade reduction

Hypothetical sites:
- **A** Salvador
- **B** Governador Valadares
- **C** Belo Horizonte
- **D** São Paulo
- **E** Curitiba

Figure 5.5 helps to clarify this issue. It presents both the short run and long run effects on GDP from a spatial perspective. Looking more closely at the results for the long run, an "accounting" explanation for the negative real GDP result emerges. Regional contributions to 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% greater than the positive one. The map indicates that negative impacts are concentrated in the whole south region, in the states of São Paulo and Rio de Janeiro. Of the total negative impact, 58% comes from the São Paulo regions and 12% from Rio de Janeiro. In the regions which demonstrate positive performance, major contributions come from the northeast, especially Salvador, Aracaju, and Fortaleza, representing 68% of the total positive impact on GDP growth.

This is clearly a situation in which spatial competition plays a prominent role. Given the favorable scenario concerning relative production costs in the northeast, in a given transport infrastructure context of systemic low quality, the relative poorer northeast region increases its spatial market area, at the expense of the richer southeast, which suffers from the network effects.

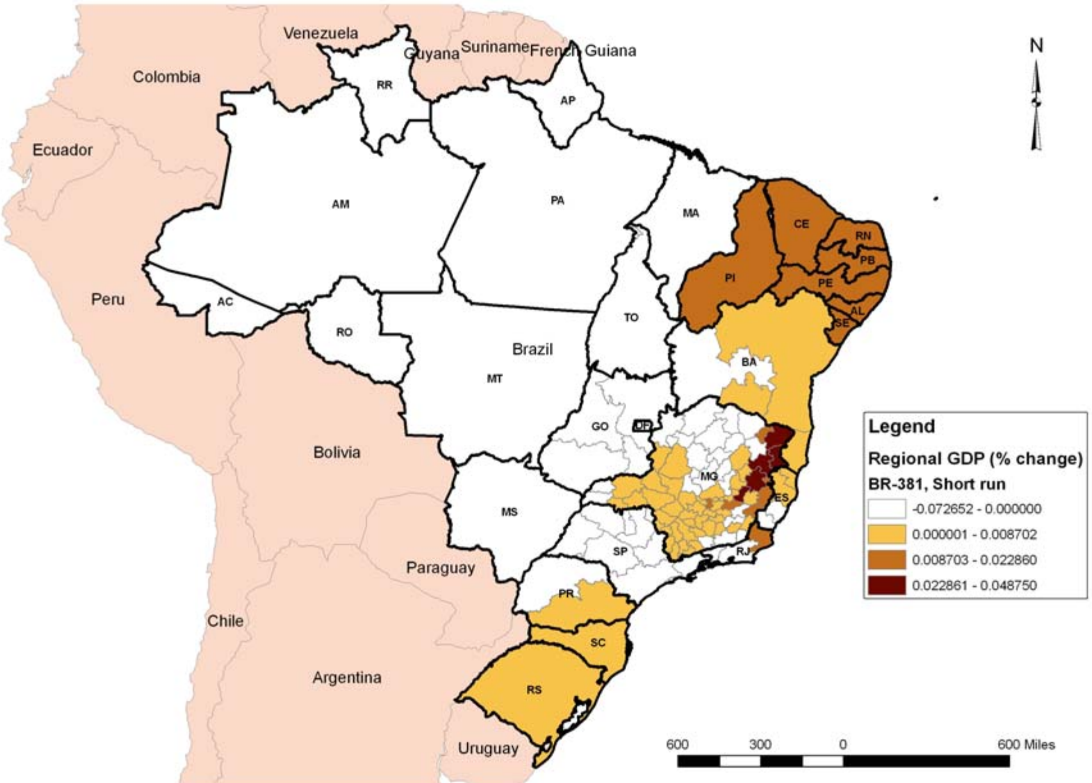
Short run results present a very different situation, one which is characterized by less flexible mechanisms of interregional transmission because the possibility of interregional factor mobility is precluded. In the case of the south (including São Paulo) there seems to be stronger competitive interdependence with Minas Gerais and the eastern economies of the northeast, particularly the more industrialized ones. The impact on real GDP, in percentage terms, makes this contrast more evident as economic growth in Minas Gerais and the northeast occurs at the expense of growth in the economies south of Minas Gerais even though the western economies of the northeast, Tocantins and Mato Grosso present negative performance. In the short run, the economy of Minas Gerais and the northeast exacerbates the effects associated with the flows of goods, widening its market area at the expense of not only the western economies of the northeast, but also the economies in the south of the country. The effect on real GDP shows that the state that receives the investments is the one that enjoys most of the benefits from it.

In the long run, behavioral parameters play an even more prominent role in the functioning of the model. Relocation effects involving capital and labor define a new geography of winners and losers. The state of Minas Gerais and the northeast become the main attractors of economic activity, competing directly with the center-south of the country. The net result is the relocation of activities towards those areas, establishing two distinct spatial regimes of potential winners and losers.

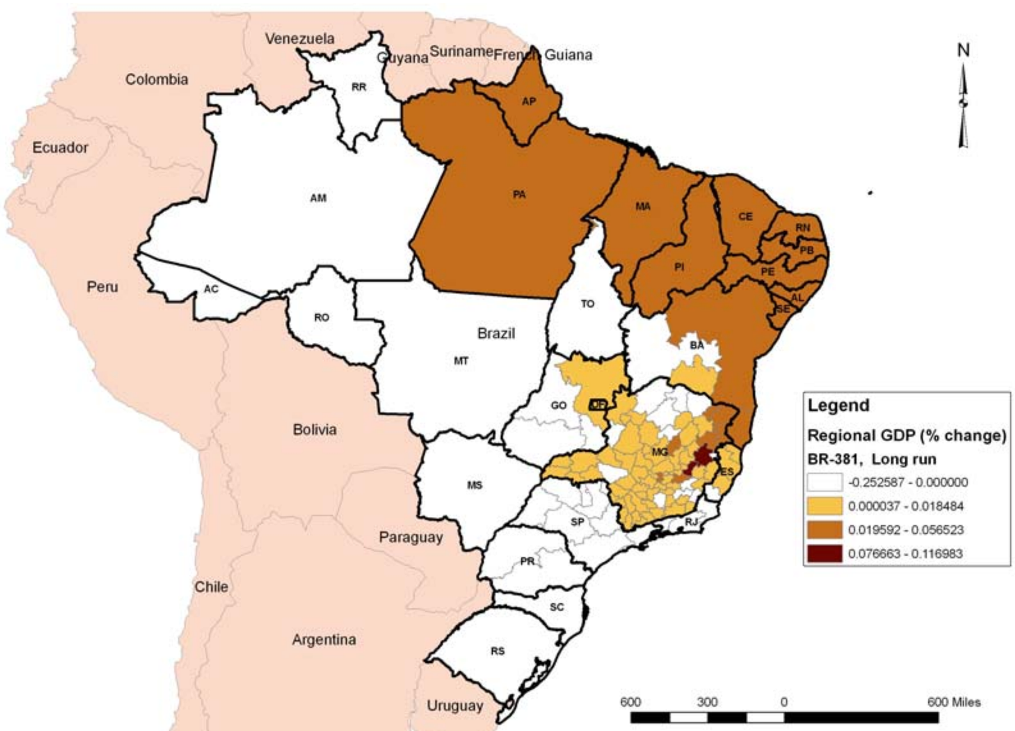
Before moving to the analysis of the specific impacts in the State of Minas Gerais, it is important to emphasize the systemic nature of the problems under analysis. As witnessed, isolated projects may promote undesirable outcomes if not considered within the context of a well-specified program of investments. Policymakers who fail to appreciate the importance of the integrated nature of transportation systems may make critical errors in program design.

Figure 5.5 Spatial Results: Real GDP (in percentage change)
BR-381 Project

Short run



Long run



Regional impacts

This subsection offers a closer look at the effects of the two proposed projects within the borders of Minas Gerais. As both projects are located in that state it is important to assess the specific local impacts. Policymakers in Minas Gerais may have special interests in these projects given their strategic role in the state transport network.

Common patterns appear relating to the aggregate effects of both projects with Minas Gerais (Table 5.5). In general, positive outcomes are stronger in the BR-262 project than in the BR-381 project. In both projects, however, most of the indicators move in the same direction. Overall gains in efficiency (real GDP growth) are positive, with bigger impacts occurring over 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. It is important to note that in the long run the effects of the BR-262 project on the terms of trade are magnified, which does not happen to the *custo Minas* in the BR-381 project. A less favorable situation also emerges in the long-run, as the overall competitiveness of Minas Gerais seems to be hampered by production cost increases associated with increases in consumer good prices, also affecting welfare as measured by the equivalent variation. This effect is related to the incidence of direct spatial competition with similar economies in the northeast.

In terms of the regional concentration of effects, the model considers the relative growth of the poorer regions of the state, the north and Jequitinhonha/Mucuri. The results reveal that both projects are pro-concentration, although to a lesser degree in the case of the BR-381 project. Finally, both projects are also pro-poor, and the model projects reductions in the headcount poverty index for the state of Minas Gerais both in the short run (in which the effect is weaker) and in the long run (in which it is stronger). In terms of poverty reduction, the BR-262 project performs better.

Table 5.3 State Results: Selected Indicators (in percentage change)

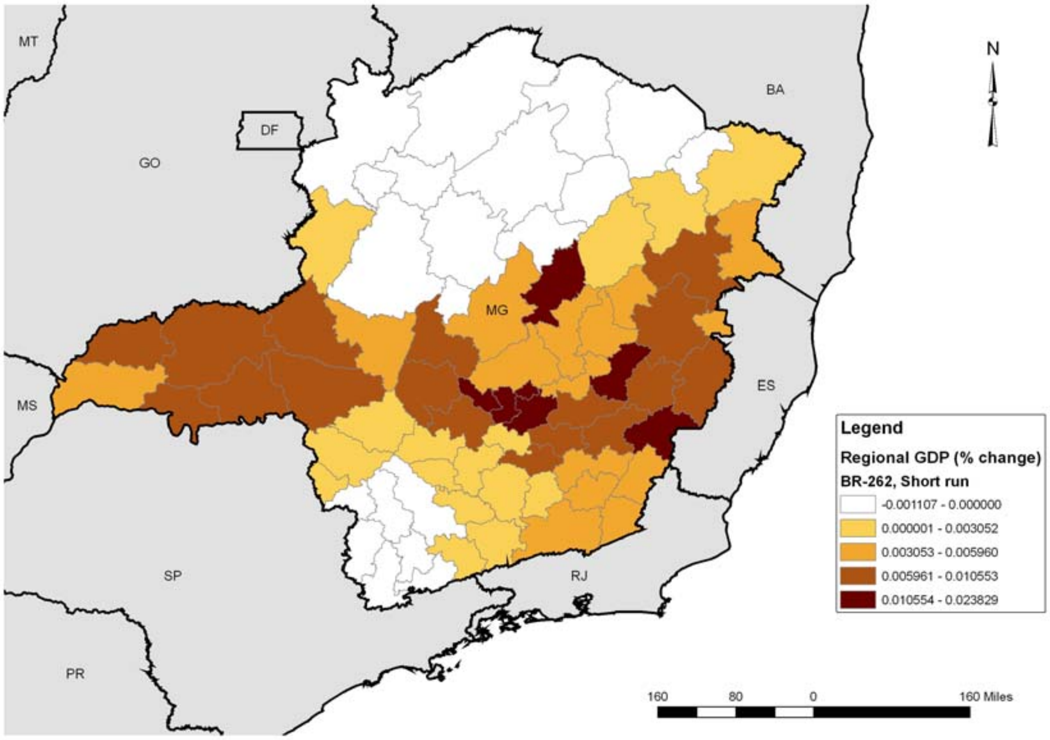
	BR-262		*BR-381*	
	SR	*LR*	*SR*	*LR*
Real GDP	0.00765	0.01554	0.00532	0.00686
Aggregate employment, wage bill weights	(0.00020)	0.00683	(0.00101)	(0.00075)
Equivalent variation – total (change in $ 1,000,000)	15.4	30.1	7.7	(7.5)
Real tax revenue	0.00269	0.01381	0.00297	0.00425
Terms of trade	(0.00024)	(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: Data based on author's calculations

Figures 5.6 and 5.7 depict the spatial GDP effects of both projects focusing on the various regions of Minas Gerais. Overall, the stronger effects on the areas closest to the projects are evident. These effects, however, tend to spread out over time, as suggested by the smaller number of regions presenting negative performance in the long run.

Figure 5.6 Spatial State Results: Real GDP (in percentage change) BR-262 Project

Short run



Long run

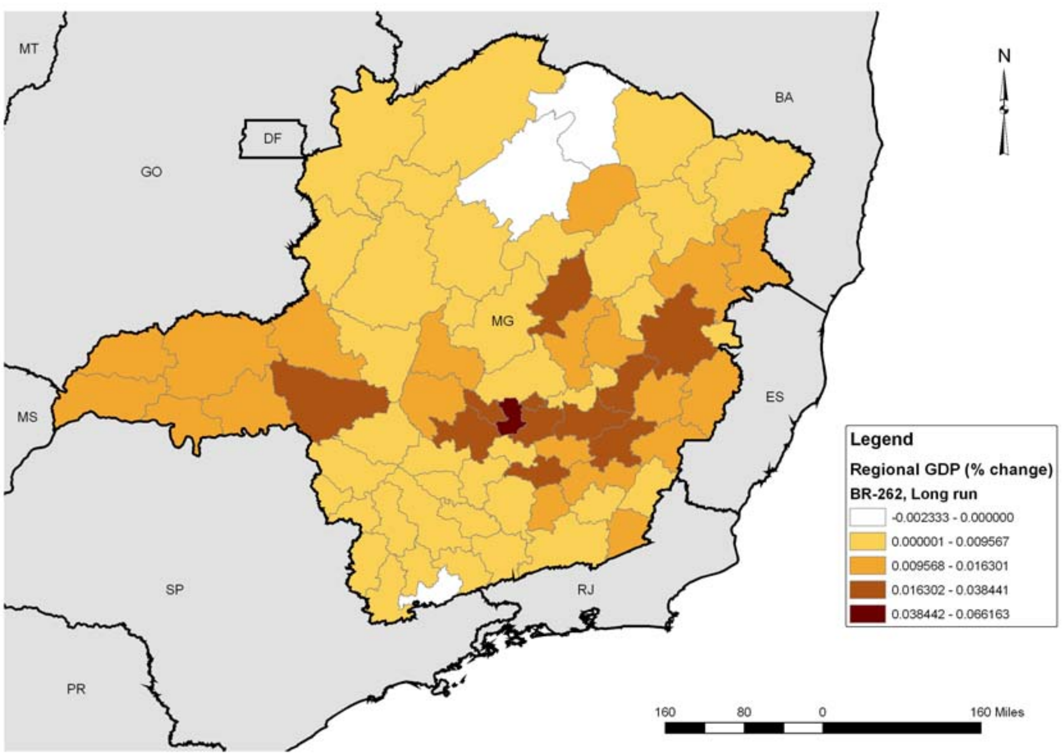
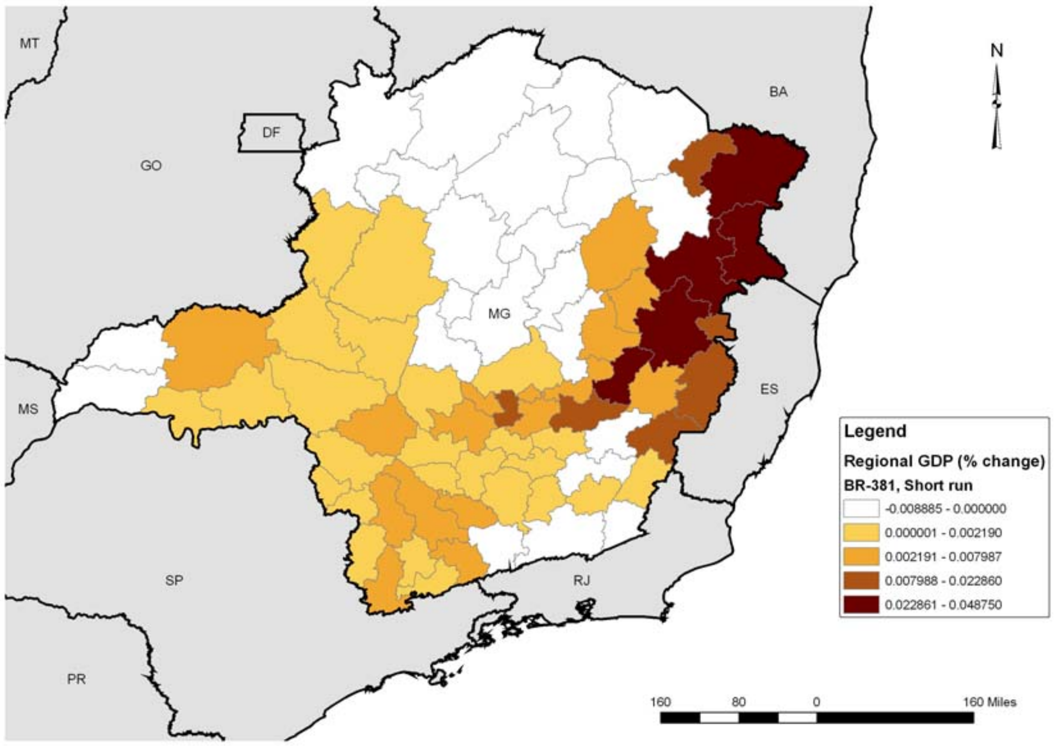
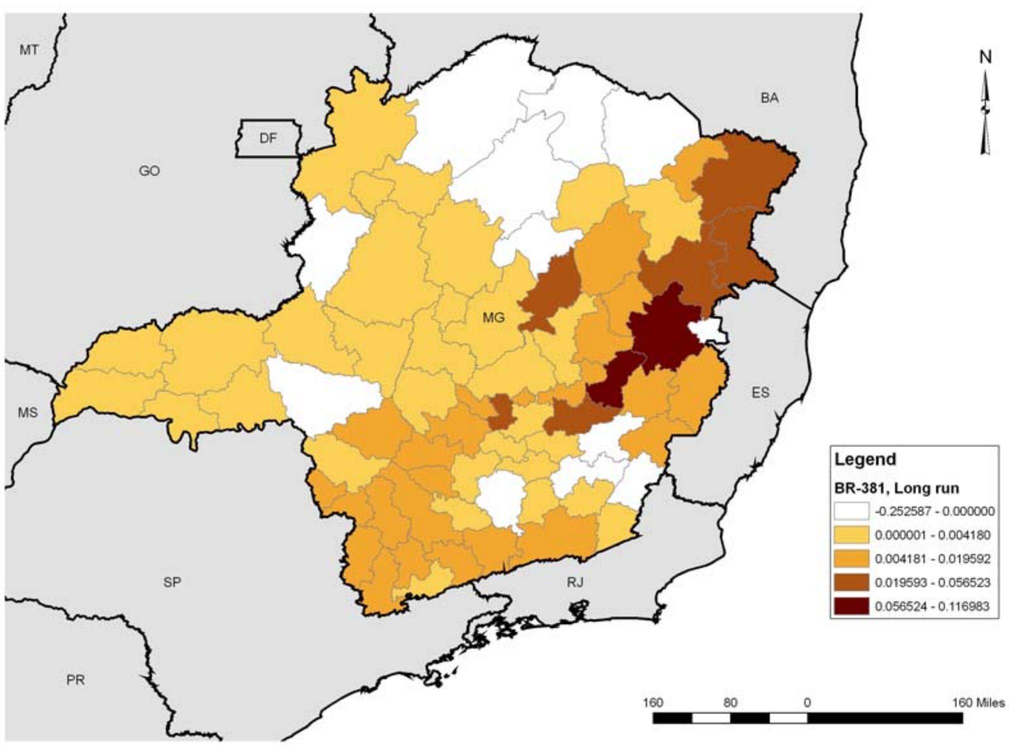


**Figure 5.7 Spatial State Results: Real GDP (in percentage change)
BR-381 Project**

Short run



Long run



5.5 Conclusions

There is clearly a need for appropriate tools for assessing the economic impacts of transportation infrastructure policies, and this chapter has attempted to tackle that issue. It has been suggested that interregional CGE models can potentially be used for the analysis of transportation policy. A way in which this potential can be realized has been illustrated but this tool is not yet a typical part of the transportation project planning process. For it to achieve broad applicability, further amendments are needed in order to cope with methodological advances both in economic and transportation modeling.

Although capable of representing the effects of transportation infrastructure in a consistent manner, the use of current versions of interregional CGE models has some drawbacks when intended to replace conventional models used in national or statewide transportation planning. Future versions of interregional CGE models should incorporate some common features of conventional models of transportation planning such as a broader multimodal view, quality and non-price attributes, congestion effects, and a finer spatial disaggregation to allow for more detailed intra-regional analysis. The integrated approach proposed here directly addresses some of these issues. More importantly, however, the results provided are encouraging in that they demonstrate that the broader issues dealt with in this chapter, while difficult, are not insurmountable.

Overall Conclusions

As the Brazilian economy continues to grow, and as international trade becomes increasingly influential in its growth pattern, the nation's transportation infrastructure will play an ever more vital role in both facilitating economic expansion and extending the benefits of growth throughout the vast regions of the country. Given the importance of transportation policy and the complexity of infrastructure improvement programs, policymakers require detailed projections capable of incorporating a broad and specific range of factors incorporating effects across regions and time periods. In this context, economy-wide models, such as Computable General Equilibrium (CGE) modeling and Social Accounting Matrixes, provide appropriate analytical tools for evaluating changes in the transportation sector and their implications for national economic development. The results of the economy-wide models used in this report describe the principal impacts on output, income distribution, and other key variables resulting from specific changes in the Brazilian transportation system.

One particularly important conclusion of this analysis is the finding that a reduction in overall transportation costs would not only increase production and contribute to lower prices, but would lead to a more equitable distribution of income as well. The cost of inefficient transportation systems are either absorbed by producers or passed on to consumers in the form of higher prices. In some cases, this cost may be so high as to limit the ability of producers to access all but the nearest markets. Moreover, not all forms of transportation are appropriate for all goods. For example, the physical constraints of trucking discourage the production of high-volume goods such as cereal grains and are particularly ill-suited to the needs of producers in the agricultural frontiers. Finally, the direct costs of using transportation services fall heaviest on poor consumers, for whom transportation costs comprise a larger share of their total income. Consequently, taxes on final consumption of these services are inherently regressive.

As public investment in transportation has decreased significantly over the last three decades, it has been shown elsewhere that reducing transportation costs and eliminating distortions to increase private sector participation would require more decisive government action both in terms of administrative reform and on regulatory issues. While the results of this, albeit limited, study do not conclusively prove that the benefits of a change in the modal composition Brazil's transportation infrastructure are sufficient to justify the investment required, excessive or incautious public expenditure on the road system may result in a host of unforeseen and undesirable consequences. These include not only the high maintenance costs associated with road construction, but also the indirect cost of restricting trade in high volume, low value added agricultural goods, particularly from the innermost regions of the country.

Diversifying the modal composition of transportation is costly, and the benefits of diversification remain unclear; however, concentrating on improvements (rather than expansions) of the road sector remains a priority for transportation policy. The findings in the last chapter show that while any specific road project may be expected to increase regional output and reduce regional income concentration and poverty, the long term impact at the national level will be affected by factor mobility, interregional trade diversion, and secondary effects on traffic flows. As new or expanded transit lanes alter the allocation of productive factors, gains to one region may come at the expense of another. New or expanded roads will also alter traffic patterns, diverting greater numbers of vehicles onto roads that may not be prepared to cope with them and straining the maintenance budget of regions not involved in the original project. While such tradeoffs are inevitable, road projects must account for these secondary effects and road planning must reflect broader goals of equitable regional development.

In addition to its broader economic effects, regional development is also a major concern in maritime transportation policy. Much like the road system, the inadequacy of Brazil's ports increases production costs, lowers overall competitiveness, and distorts producer incentives. Improving the port system will boost the position of Brazil's firms in the global economy while increasing the purchasing power of Brazilian consumers. Enhanced port efficiency will raise firm output and national welfare while improving Brazil's terms of trade and fiscal balance. Administrative decentralization, greater private sector participation and higher levels of public and private investment will all have strong positive effects on regional and national growth.

A comprehensive and detailed long-term transportation policy will be necessary in order for Brazil to effectively advance the state of its transportation infrastructure. This report shows that improvements in physical infrastructure and in the efficiency of administrative models will contribute to greater efficiency and output, as well as improving income distribution. Just as important, this report shows that economy-wide modeling could serve as standard analytical tool to address key questions regarding changes in transportation policy and evaluate their potential effects.

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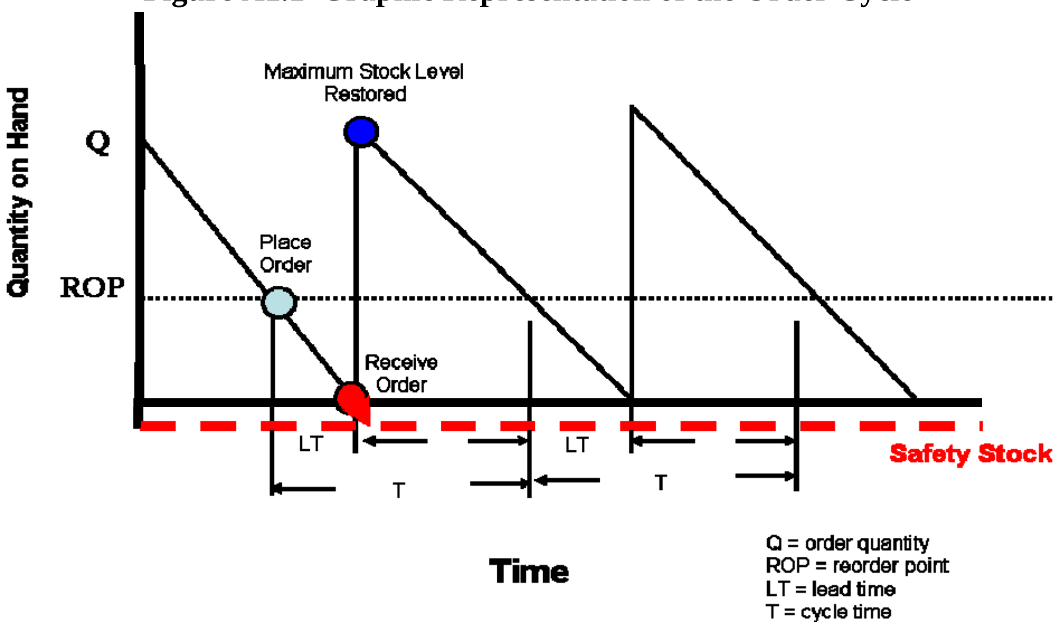
Annex 1
The Logistics Approach in Brazil

The inadequacies of the Brazilian transportation sector negatively affect the logistics function in a number of ways, the most important of which relate to company inventory levels and warehousing costs. In effect, by not working properly, the transportation component of the logistics function forces producers to increase inventory levels and incur greater warehousing costs in order to avoid disruptions in both their supply of production inputs as well as their shipments to consumers.

The effects on inventory levels can be best understood using a graphic representation of the order cycle. As illustrated in Figure A1.1, most of the relationships between clients and suppliers are based on a cyclical process of order placement, order processing, and delivery in the following sequence:

1. Inventory starts at quantity D (demand) that is supplied by the supplier at time zero and gradually consumed by the client.
2. At a certain inventory level ROP (reorder point), the client decides to place a new order while the remaining D is being consumed.
3. The supplier receives the order, processes it, and delivers it during period TR (time of replenishment).
4. The client then receives the new quantity, stocks return to their maximum level and a new cycle begins.

Figure A1.1 Graphic Representation of the Order Cycle



Source: Ballou (1992)

The order quantity (Q) can remain fixed from one order cycle to the next or it can vary. For the purposes of this discussion, the constancy of the order quantity is not relevant. What are relevant are the adverse effects that transportation inefficiencies have on inventory levels, processing costs, and the number of warehouses.

1. Customers depend on the supplier to follow the negotiated lead time. When the supplier encounters transportation inefficiencies, lead times are longer and orders go unfilled. To avoid the negative impacts of a stockout, customers come to rely on safety stocks, which represent additional logistics costs that are transferred to the product's final price. Longer lead times also lead customers to place greater numbers of orders, which further negatively impact the logistics function by increasing order processing and delivery costs. Finally, customers' inability to trust suppliers to fulfill lead times, adversely affects demand behavior and forecasting becomes inefficient in the whole supply chain.

As already referenced, Brazil's poor transportation conditions also negatively impact warehousing costs. Companies have two basic strategies to deliver their product—they can either use a *push system* under which they produce and push inventory to warehouses near the demand sites, or they can employ a *pull system* under which they wait for the customers' orders to deliver the products. The first strategy is highly dependent on warehousing costs, while the second strategy is mostly dependent on rapid and reliable transportation. Both strategies involve tradeoffs, but because of Brazil's poor transport conditions companies are more or less obliged to use push systems because the transportation variable of the logistics function is not reliable. As illustrated by Figure A1.2, once companies adopt the push system, the number of warehouses in the supply chain increases, resulting in a further increase in logistics costs for a variety of reasons:

- Since there is typically a high concentration of demand in metropolitan areas, the cost of land is very high, and the higher the number of warehouses, the higher the logistics costs.
- For every warehouse in the system, inventories need to be maintained, and the proportion of inventories in relation to the number of warehouses is quadratic.
- The more warehouses there are in the supply chain, the higher the inventory transfer costs.
- Finally, order processing costs also rise, contributing to the increase in total logistics costs.

Figure A1.2 Logistics Costs as Related to the Number of Warehouse Facilities

Source: Ballou (1992)

In summary, inefficiencies in Brazil's transportation sector lead to the adoption of strategies that result in inventory increases, increase order processing costs, and result in increases in the number of warehouses and longer lead times, affecting the competitiveness of companies operating in Brazil. In order to alleviate the additional costs incurred as a result of this system, the government must make further investments in infrastructure and adopt service plans designed to improve the efficiency and reliability of the transportation system.

While there are different estimates of logistics costs in the Brazilian economy in relation to its GDP, the bottom line is that even the lower of these estimates doesn't compare favorably with U.S. logistics costs, which are estimated at only 8.26% of GDP. Castro (2004) estimates total logistics costs in Brazil to be 16.9% of GDP, while Lima (2006) estimates them to be 12.6%.

Annex 2
Methodological Aspects of Chapter 2: A Leontief-Miyazawa Model

In order to analyze the impacts of changes in the modal composition of cargo transportation in Brazil, a Leontief-Miyazawa type of model was estimated. The input-output relationships were considered, as were the sectoral distribution of income to households in different income brackets, and the sectoral allocation of consumption expenditures by households.

A2.1 The Static Model

The intersectoral flows present in a given economy and determined by both technological and economic factors, can be described by a system of simultaneous equations represented by

$$X = AX + Y \qquad (1)$$

where X is a (n x 1) vector with the total output of each sector, Y is a (n x 1) vector of final demand for each sector, and A is a (n x n) matrix of technical coefficients of production (Leontief, 1951). The sectoral final demands are usually treated as exogenous to the system and therefore the output vector is uniquely determined given the final demand vector, that is,

$$X = (I - A)^{-1}Y \qquad (2)$$

where I is the (n x n) identity matrix and $(I - A)^{-1}$ is the (n x n) Leontief inverse matrix.

The vector of final demand, however, is the sum of a vector of consumption demands and a vector of exogenous demands (i.e., government expenditure, investment, and exports):

$$Y = Y^c + Y^e \qquad (3)$$

where Y^c is the (n x 1) vector of consumption demand and Y^e is the(n x 1) vector of exogenous demand.

Considering that consumption demand is related to income, in the tradition of Keynes and Kalecki (see Miyazawa, 1960, 1963, and 1976, Keynes, 1936, and Kalecki, 1968 and 1971), the multisectoral consumption function is defined as

$$Y^c = CQ \qquad (4)$$

where C is a (n x r) matrix with the consumption coefficients, and Q is a (r x 1) vector with the total income of each income group.

Let E be a matrix whose elements e_{ik} represent the total amount of the i^{th} commodity consumed by the k^{th} income group, and c_{ik} is defined as

$$c_{ik} = \frac{e_{ik}}{q_k} \qquad (5)$$

Since “(...) the consumption structure generally depends on the structure of income distribution” (Miyazawa, 1976, p. 1), it is necessary to include the way income is distributed by sector. The income-distribution structure can be represented by the simultaneous equations

$$Q = VX \qquad (6)$$

where V is a (r x n) matrix with the value-added ratios. The simultaneous equations (6) represent the fact that the productive structure prevailing in a country is associated with a corresponding structure of income distribution.

Let R be a matrix whose elements r_{kj} represent the income of the k^{th} group earned from the j^{th} sector. Then, v_{kj} is given by

$$v_{kj} = \frac{r_{kj}}{x_j} \qquad (7)$$

To solve the static model we start by substituting (3), (4), and (6) into (1), getting

$$X = AX + CVX + Y^e \qquad (8)$$

whose solution is $X = (I - A - CV)^{-1} Y^e \qquad (9)$

Moreover, it is convenient to express the matrix in (9) as the product of $B = (I - A)^{-1}$ - which reflects the production flows - and another matrix reflecting the endogenous consumption flows, that is,

$$X = B(I - CVB)^{-1} Y^e \qquad (10)$$

Finally, substituting (10) into (6), the multisectoral income multiplier is given by

$$Q = VB(I - CVB)^{-1} Y^e \qquad (11)$$

which shows that the income for each group (and, of course, the aggregate income) will have different values depending on the sectors' shares in the exogenous final demand (Miyazawa, 1963 and 1976).

A2.2 The Dynamic Model

The model derived in the previous sub-section does not take into account time lags. To make the model more realistic, one must account for the fact that changes in sectoral output levels do not cause changes in consumption (through changes in the different income groups) immediately, but only after a certain period of time, that is,

$$Y_k^c = CVX_{k-1} \qquad (12)$$

where *k* represents a time period, and *k-1* denotes the previous time period. Equation (8) then becomes

$$X_k = AX_k + CVX_{k-1} + Y^e \qquad (13) \qquad \text{or} \qquad X_k - BCVX_{K-1} = BY^e \qquad (14)$$

which is a non-homogeneous system of first-order linear difference equations with constant coefficients.

Given the one-period lag between production and consumption in equation (12), equation (14) can be used to analyze the dynamic behavior of the model and, in particular, the convergence of the system to the steady-state solution presented in equation (8). The solution of equation (14) is given by the sum of the complementary solution, i.e. the solution of the homogeneous system, and a particular solution, i.e. a solution for the complete system (see Goldberg, 1958). The homogeneous version of (14) is

$$X_k - BCVX_{K-1} = 0 \qquad (15)$$

and its solution is given by

$$X_k = \left(BCV\right)^k G \qquad (16)$$

where the (n x 1) vector *G* will be determined by the initial condition.
A particular solution can be found by making $X_k = X_{k-1} = X$, i.e.

$$X - BCVX = BY^e \qquad (17)$$

The solution being

$$X = \left(I - BCV\right)^{-1} BY^e \qquad (18)$$

The final solution is then given by the sum of (16) and (18), i.e.

$$X_k = \left(BCV\right)^k G + \left(I - BCV\right)^{-1} BY^e \qquad (19)$$

Given the initial condition X_0, vector *G* can be found by solving the system for $k = 0$, that is,

$$G = X_0 - \left(I - BCV\right)^{-1} BY^e \qquad (20)$$

Moreover, the steady-state solution of the model is given by equation (18), and is identical to the solution of the static model in equation (10)[80].

By the theory of eigenvalues and eigenvectors (Strang 1980), matrix $\left(BCV\right)^k$ can be expressed as

$$\left(BCV\right)^k = S^k \Lambda S^{-1} \qquad (21)$$

where S is a (n x n) matrix whose columns (linearly independent by hypothesis) are eigenvectors of $\left(BCV\right)$, and Λ is a (n x n) diagonal matrix with the eigenvalues of $\left(BCV\right)$.

Substituting (21) into the homogeneous solution (16) gives:

$$X_k = S^k \Lambda S^{-1} G \qquad (22)$$

As k approaches infinity, the system will converge to the steady-state solution (18) if $\left(BCV\right)^k$ goes to zero. The sufficient condition for the system to converge is that the eigenvalues of $\left(BCV\right)$, γ_i, must be in the interval $0 \le \left|\gamma_i\right| < 1$, for all i.

[80] The fact that equations (10) and (18) are identical can be seen by an algebraic manipulation of the matrices in equation (8):

$$B\left(I - BCV\right)^{-1} = \left[\left(I - CVB\right)B^{-1}\right]^{-1}$$

$$= \left[B^{-1} - CV\right]^{-1}$$

$$= \left[B^{-1}\left(I - BCV\right)\right]^{-1}$$

$$= \left(I - BCV\right)^{-1} B$$

Annex 3
Description of the Model of Chapter 3

The model used in Chapter 3 of this study employs a multi-country and multi-sectoral approach, covering 12 regions of the world and 25 sectors. Although it is not fundamental to the analysis, the model preserves the multiregional characteristic of the Harrison et al. model, but reduces the 16 regions used in that model to 12, in an effort to scale down and reduce computational time. The multiregional presentation is used to simulate a scenario where transportation improvements are combined with trade policy, in order to investigate the complementariness between them. In the model's sectoral component, the number of sectors is expanded from the 22 used in the original model to 25, by disaggregating transportation into three categories representing, land, air, and water services. Land transportation refers to urban transportation and includes services provided by roads and rail, while water transportation refers to maritime transport services on rivers and seas. Table A4.1 in Annex 4 shows the regions and sectors in the current version of the model.

The model is static and assumes constant returns to scale[81]. Constant elasticity of substitution (CES) production functions combine intermediate inputs and primary factors to generate some level of output. Primary factors include capital, unskilled labor, skilled labor, land and natural resources. Factors are mobile across sectors only within a given region. Value added is combined through a CES function. Intermediates and value added composite are added through a Leontief structure. The output is a constant elasticity of transformation (CET) function of domestic output and exports.

The model uses 20 households, ten rural and ten urban, distinguished by income level[82]. Nested CES utility functions define the demand for each agent. At the top level, a Cobb-Douglas function combines the composite Armington aggregate[83] of each and every good and service in the economy. At the intermediary level, domestic production and aggregate imports are chosen through a CES function. At the lower level, the imports from different regions are combined in a CES function. The demand function assumes a multi-stage budgeting structure. First, consumers choose the amount of each Armington aggregate good to buy. The elasticity of demand at this level is determined by the expenditure shares of each household in the benchmark. Based on the decision of how much income to spend on a given good, the consumers allocate the expenses on aggregate imports and domestic goods. Finally, consumers decide how much will be spent across imports from the 11 other regions. It is important to note that the elasticities of demand with respect to prices differ across households, since the initial expenditure shares are not equal amongst them.

[81] Imperfect competition and increasing returns to scale are not addressed, although endogenous growth is explored through endogenous increases in the total factor productivity (TFP). The assumption is that the perfect competition and returns to scale approach allows a better understanding of the links between the provision of transportation services and income distribution in a general equilibrium.

[82] Harrison, Rutherford and Tarr (1997) present a discussion of the demand structure and elasticities important to this kind of disaggregated household formulation in CGE models.

[83] The Armington assumption is often used in CGE models as a means of combining domestic production and imports of a given good through a CES function. The assumption here is that varieties of the same good coming from different countries are considered to be imperfect substitutes.

The model is formulated as a mixed complementary problem, and solved using the GAMS-MPSGE software developed by Rutherford (1999). MPSGE uses the PATH algorithm of Ferris and Munson (2000).

The model uses the same database used in Harrison et al. (2004), the GTAP5 dataset (Hertel, 1997; Dimaranan and McDougall, 2002), preserving the many changes they made to better capture aspects of the Brazilian economy[84]. These changes include a departure from the GTAP5 dataset to use the 1996 updated version of the Brazilian input-output table instead of the 1985 version of the table that GTAP was based on. Other changes include the use of new, corrected estimates of the factor shares for some Brazilian industries and the protection data for Brazil; and the inclusion of a household expenditure survey for Brazil in an effort to construct information on multiple households.[85] Apart from these changes to the original model, the household factor income and expenditure shares were improved to take into account the transportation sub-sectors and better represent their attributes in the Brazilian economy.

[84] The data used comes from the most recent Brazilian IO table (1996) produced by IBGE. As documented by Ferreira Filho (2006), the GTAP6 model uses the same 1996 IO table. This means that the coefficients in the GTAP6 database for Brazil are close to those used in this study since they come from the same source and year.
[85] All the changes made to the GTAP5 database to build the model in Harrison et al. (2003) can be found in the Appendices of their paper.

Annex 4
Tables from Chapter 3

Table A4.1 List of Commodities, Regions and Factors.

Commodities

PDR	Paddy rice
GRO	Cereal grains
OSD	Oil seeds
AGR	other agriculture
OCR	Other crops*
CMT	Bovine meat products
OMT	Other meat products
MIL	Dairy products
PCR	Processed rice
SGR	Sugar
OFD	Other food products
ENR	Energy and mining
TEX	Textiles
WAP	Wearing apparel
LEA	Leather products
LUM	Wood products
MAN	Other manufacturing
I_S	Iron and steel
FMP	Other metal products
MVH	Motor vehicles and parts
SER	Services
OTP	Land transportation
ATP	Air transportation
WTP	Water transportation
CGD	Savings good
DWE	Dwellings

Regions

BRA	Brazil
ARG	Argentina
URY	Uruguay
CHL	Chile
COL	Columbia
PER	Peru
VEN	Venezuela
XAP	Rest of Andean Pact
MEX	Mexico
XCM	Central America and Caribbean
XSM	Rest of South America
CAN	Canada
USA	United States of America
E_U	European Union 15
JPN	Japan
ROW	Rest of World

Factors

CAP	Capital
LAB	Unskilled labor
LND	Land
RES	Natural resources
SKL	Skilled labor

*Note: "Other crops" is an aggregate of the following sectors from the full GTAP dataset: wheat, vegetables and fruits, fiber based plants, wool, forestry, fishing and the GTAP category “other crops”.

Table A4.2 Household Income Shares (percent) from Factors of Production and Transfers

	Income Shares						
Household*	Unskilled labor	Skilled labor	Rent from Capital	Rent from Land	Rent from Nat. Res.	Transfers	Sum
Rhhd1	74.3	2.0	0.4	1.1	0.0	22.2	100%
Rhhd2	81.8	5.8	1.1		0.0	11.3	100%
Rhhd3	85.7	10.8	1.1	1.7	0.0	0.7	100%
Rhhd4	65.3	7.6	2.9	2.0	0.0	22.2	100%
Rhhd5	81.6	4.6	13.7		0.1		100%
Rhhd6	76.1	7.5	16.2		0.1		100%
Rhhd7	73.3	8.8	16.9	0.3	0.6		100%
Rhhd8	65.7	13.2	18.8	2.1	0.2		100%
Rhhd9	65.9	11.7	19.9	1.9	0.5		100%
Rhhd10	64.8	11.0	21.3	2.7	0.2		100%
Uhhd1	70.4	0.6	0.2	0.4	0.0	28.4	100%
Uhhd2	76.3	8.9	0.6	0.3	0.0	13.9	100%
Uhhd3	68.8	14.5	2.9	0.2	0.0	13.6	100%
Uhhd4	67.0	14.1	8.5	0.3	0.0	10.1	100%
Uhhd5	56.5	27.4	15.8		0.0	0.1	100%
Uhhd6	52.2	28.2	19.5		0.1		100%
Uhhd7	30.1	29.3	40.5		0.1		100%
Uhhd8	27.6	29.2	43.0		0.1		100%
Uhhd9	20.7	29.6	49.5		0.2		100%
Uhhd10	14.5	16.5	68.8		0.2		100%

*Households are defined in Table 3.2 of Chapter 3.

Source: Authors' calculations based on the LSMS survey data for Brazil, 1996.

Table A4.3 Household Expenditure Shares (percent) on Commodities

Household	Cereal grains	Other agri-culture	Other crops	Energy & mining	Bovine meat products	Other meat products	Dairy products	Processed rice	Sugar	Other food	Textiles	Wearing apparel
Rhhd1	0.3	4.4	10.5	2.3	6.6	3.6	5.5	2.3	1.6	19.5	1.6	4.2
Rhhd2	0.2	4.1	9.0	2.5	6.1	3.4	5.1	2.1	1.5	19.7	1.7	4.5
Rhhd3	0.2	4.1	9.7	2.5	6.1	3.3	5.0	2.1	1.5	19.5	1.7	4.5
Rhhd4	0.2	3.3	7.1	2.5	4.9	2.7	4.1	1.7	1.2	14.5	1.7	4.5
Rhhd5	0.2	3.1	6.4	2.7	4.6	2.5	3.8	1.6	1.1	13.1	1.8	4.9
Rhhd6	0.2	2.9	7.8	3.8	4.2	2.3	3.5	1.5	1.0	13.2	2.6	5.5
Rhhd7	0.1	2.2	7.7	3.8	3.2	1.8	2.7	1.1	0.8	11.6	2.0	3.5
Rhhd8	0.1	2.5	6.2	2.5	3.7	2.0	3.1	1.3	0.9	23.0	1.7	4.5
Rhhd9	0.1	0.9	13.4	0.9	1.3	0.7	1.1	0.5	0.3	23.3	0.6	1.7
Rhhd10	0.2	4.0	9.0	2.2	5.9	3.3	4.9	2.1	1.4	18.5	1.5	4.0
Uhhd1	0.3	4.3	11.4	2.1	6.4	3.5	5.3	2.2	1.5	22.0	1.4	3.8
Uhhd2	0.3	4.3	11.4	2.4	6.4	3.5	5.3	2.2	1.5	21.9	1.6	4.4
Uhhd3	0.2	3.9	10.3	2.1	5.8	3.2	4.8	2.0	1.4	19.6	1.4	3.8
Uhhd4	0.2	2.8	6.6	2.6	4.1	2.3	3.4	1.4	1.0	14.4	1.8	4.8
Uhhd5	0.2	2.8	7.4	2.1	4.2	2.3	3.4	1.5	1.0	11.9	1.4	3.8
Uhhd6	0.1	2.1	5.6	2.2	3.1	1.7	2.6	1.1	0.8	9.4	1.5	4.0
Uhhd7	0.1	1.8	4.8	2.3	2.7	1.5	2.2	0.9	0.7	8.7	1.6	4.2
Uhhd8	0.1	1.3	3.5	1.8	2.0	1.1	1.6	0.7	0.5	7.1	1.2	3.3
Uhhd9	0.0	0.6	1.7	0.7	0.9	0.5	0.8	0.3	0.2	5.2	0.5	1.3
Uhhd10	0.1	0.9	2.7	1.8	1.4	0.8	1.2	0.5	0.3	5.4	1.3	3.4

Household	Leather products	Wood products	Other manufacturing	Other metal products	Motor vehicles % parts	Land trans-port	Air trans-port	Water trans-port	Services	Dwellings	Total
Rhhd1	1.3	1.8	13.6	0.7	1.5	10.3	0.1	0.0	8.2		100
Rhhd2	1.4	1.9	14.5	0.7	2.2	8.6	0.1	0.1	10.4		100
Rhhd3	1.4	2.0	13.9	0.7	3.2	7.5	0.1	0.1	10.7		100
Rhhd4	1.4	2.0	14.7	0.7	4.7	7.6	0.2	0.1	20.1		100
Rhhd5	1.6	2.1	15.8	0.8	5.1	7.9	0.3	0.1	20.7		100
Rhhd6	2.2	3.0	20.8	1.1	7.2	7.0	0.1	0.1	10.0		100
Rhhd7	1.6	3.0	19.7	1.1	7.1	7.9	0.2	0.1	12.6	6.2	100
Rhhd8	1.4	2.0	14.6	0.7	4.7	7.3	0.4	0.2	17.2		100
Rhhd9	0.5	0.7	12.6	0.3	1.7	6.3	0.9	0.4	32.0		100
Rhhd10	1.3	1.7	12.9	0.6	4.2	6.4	0.2	0.1	15.7		100
Uhhd1	1.2	1.7	9.6	0.6	1.8	8.1	0.2	0.1	12.4		100
Uhhd2	1.4	1.9	12.6	0.7	1.9	7.0	0.1	0.0	9.2		100
Uhhd3	1.2	1.7	11.4	0.6	1.9	6.3	0.2	0.1	13.7	4.5	100
Uhhd4	1.5	2.1	14.9	0.8	2.7	6.2	0.2	0.1	17.7	8.5	100
Uhhd5	1.2	1.6	12.3	0.6	3.9	6.2	0.2	0.1	15.7	16.1	100
Uhhd6	1.3	1.7	12.8	0.6	4.1	5.6	0.2	0.1	19.0	20.5	100
Uhhd7	1.3	1.8	13.6	0.7	4.3	5.6	0.3	0.1	23.7	16.9	100
Uhhd8	1.0	1.4	10.8	0.5	3.4	5.1	0.6	0.3	52.1	0.4	100
Uhhd9	0.4	0.6	4.6	0.2	2.1	4.5	0.9	0.4	73.1	0.4	100
Uhhd10	1.1	1.4	10.7	0.5	3.5	4.5	0.7	0.3	57.2	0.3	100

Source: Author's calculations

Annex 5

Data on Household Consumption

The household data in the model was constructed using information from the Living Standards and Measurement Survey (LSMS) for Brazil, undertaken by the Instituto Brasileiro de Geografia e Estatística (IBGE). The survey is called Pesquisa sobre Padrões de Vida and covers the northeast and southeast regions of Brazil. This survey was chosen because it includes detailed information on the consumption patterns and income level of each household. A detailed description of how the data from the LSMS was incorporated in the model can be found in Harrison et al (2003).[86]

The original work from Harrison et al. (2003) does not disaggregate transportation sectors and services from other services. Consequently, it was necessary to disaggregate the consumption shares of transportation services from other services. Since the data concerning transportation services as a share of total household expenses is crucial to the research, a careful breakdown of service-related expenses was undertaken in an effort to better capture the poorest households' expenses on land transportation.

The first step in disaggregating household expenses on transportation from other expenses was to make assumptions about which services consumed by families should be captured. Land transportation expenses were considered to be those most related to urban public transportation and travel by roads, while any expenses relating to the acquisition and maintenance of vehicles or the cost of fuel were removed from consideration. The information used came from the LSMS survey and from the Pesquisa de Orçamentos Familiares (POF), for 1996/1997 and 2002/2003.

The total expenses on transportation services in Brazilian household surveys usually include expenses on the types of services used most frequently by the poorest families as well as those services used mostly by the richest families. Figure A5.1 below shows the categories and shares of transportation services in the POF survey for 2002-2003. The data indicates that the most important transportation-related expense for poorer families in the survey is urban transportation, whereas for richer families it is automobile purchases. The data also suggests that higher income families usually spend a larger share of their income on total transportation services than poorer families, but most of those expenses relate to automobile purchases and use. Since the focus of this investigation was on the types of transportation services mostly used by poorer households, expenses on automobiles (purchase price, fuel, and maintenance) were not taken into account when disaggregating land transportation services from other services consumed by households. Automobile purchases were part of the expenses included in the commodity MVH (motor vehicles and parts), while fuel (gasoline and ethanol) was accounted for in ENE (energy), and auto maintenance was distributed between MVH and SER (services). As a result, household expenditure on transportation services in the resulting data should reflect expenses on urban transportation, travel, and other transportation expenses.

[86] Briefly, the household data on income and expenditure were incorporated in the IO data through an optimization problem, which combines the two datasets keeping as close as possible to the original income and expenditure shares of the LSMS survey.

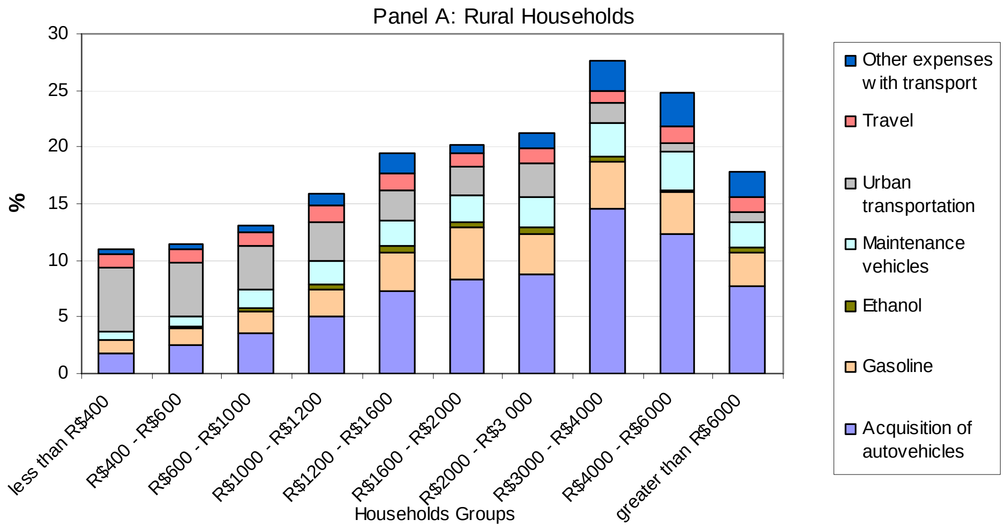
Another important assumption that was made had to do with poorer urban households' expenses on transportation services. Gomide et al. (2006) have shown that the prices for urban transportation services represent a heavy burden on low income families in urban areas. To illustrate this, they built an index to represent several characteristics of urban transportation services in the metropolitan area of Belo Horizonte, Brazil's third largest city. To measure affordability, Gomide et al. estimated that poorer individuals would spend anywhere from 9% (in the case of those whose income is equal to or lower than 2.5 times the minimum wage) to 50% (in the case of those whose income is equal to or lower than 0.5 times the minimum wage) of their total monthly income in order to use urban transportation twice a day, even when subsidies (travel passes) given from employers and assured by law were taken into account. As a result, many poor families are excluded from the use of transportation services, even though their importance to them is considerable. The authors make it clear that the share of potential or effective expenses on transportation by poor families is much larger than it is for others. In an effort to capture these findings, the present study adjusted the share of urban poor families' expenses on transportation services upwards.

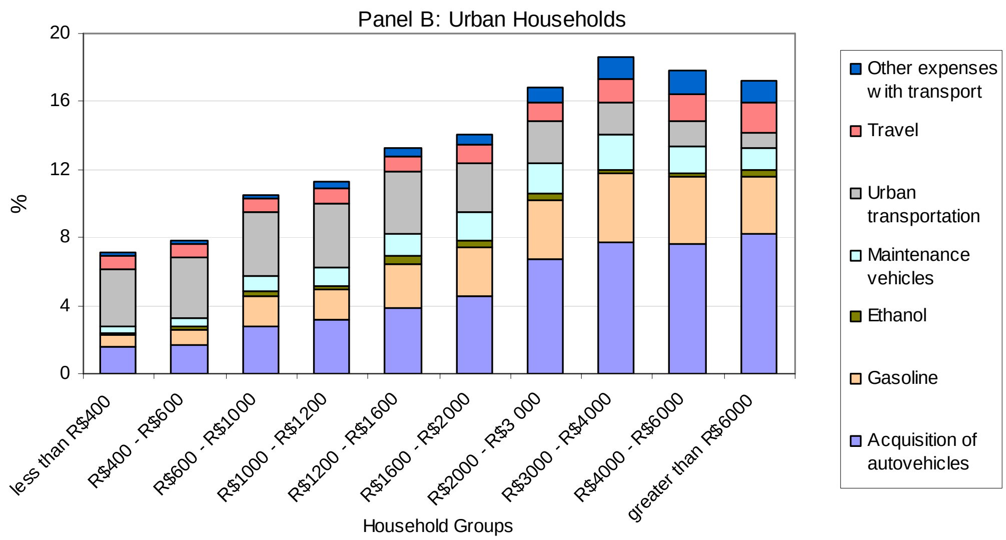
Figure A5.2 presents expenses on land transportation as a share of household income after adjustments (adj.). For comparison purposes, the shares of transportation expenses that relate to urban transportation, travel and other are provided in the POF survey for 2001/2002. The adjusted shares closely follow the shares at POF, being parallel and higher by almost two percentage points. The exceptions are the two poorest urban categories for which, as discussed above, the adjusted share was increased. It is important to point out that the adjusted shares must be bigger than the POF shares, since the sum of the household expenditures on land transportation services must be equal to the total consumption of land transportation services in the IO table. Then, the total expenses on transportation services in the economy were distributed among households in a consistent way in order to represent those transportation service expenses most important to poor families in the Brazilian economy. The present model used the adjusted shares shown in Figure A5.2. Annex 6, illustrates a simulation as part of which these shares were not adjusted, in an effort to identify the results under a scenario where the share of transportation services used by poorer families was not adequately represented.

The other two categories of transportation, i.e. air and water transportation, were also disaggregated from the original data base used by Harrison et al. (2004). For these two categories, however, the expenditure shares were retained since they are generated from the optimization problem used to adjust the household data to the IO table. Other reasons for retaining them includes the fact that there is no additional information from household surveys about them and because they seem to be a reasonable reflection of what one could expect to observe in reality[87].

[87] For example, the expenditure share of air transportation shown in Table A5.1 increases with the income of the household group. In other words, air transportation expenses account for a bigger share of richer households' expenses than poorer households' expenses. This seems to be reasonable in Brazil, where individuals from poor income groups rarely, if ever, use this kind of transportation service.

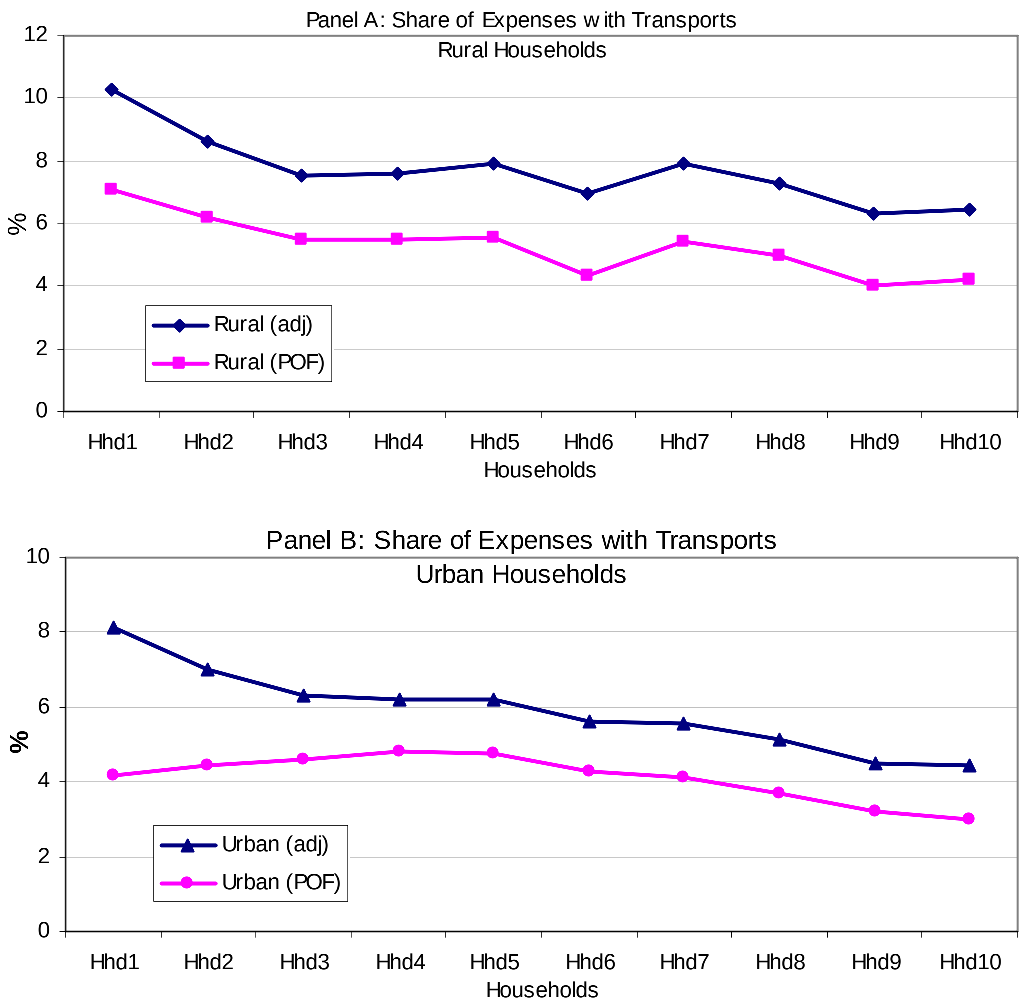
Figure A5.1 Share of Expenses with Transports by Households Categories





Source: POF – IBGE (2004)

Figure A5.2 Share of Expenses with Land Transports by Household Categories – Comparison Between Adjusted Shares (adj) and POF.



Source: Estimations from POF – IBGE (2004).

Annex 6
Full Scenarios of Improvements in Efficiency, Tax Cuts, and Interactions between Transportation and International Trade

A total of five alternative tax cut scenarios were performed. These scenarios were used to study the effect of cost reductions in the production and use of transportation services. Each scenario removed some type of *ad-valorem* tax. Under scenario TIT taxes on intermediate inputs used by the land transportation sector were removed. Scenario TII removed taxes on the use of transportation services as intermediate inputs by other sectors. Scenario TPT removed the taxes on the final demand for transportation services while scenario TYT removed taxes on the production of transportation services. Finally, for the purposes of a comparative exercise, under scenario TTT all taxes were simultaneously removed. Table A6.1 presents the taxes on intermediate inputs in the database. The taxes on final demand for land transportation services were 5.8% and taxes on production were 1.1%[88].

Table A6.1 Taxes on Intermediate Inputs Used by or from Land Transportation (percent)

	Taxes on inputs used by transport sector	Taxes on inputs from transport sector
PDR		
GRO		3.5
OSD		3.5
AGR		1.4
OCR	3.9	3.4
ENR	8.0	1.6
CMT	13.7	0.6
OMT		0.9
MIL	16.3	1.1
PCR		
SGR		0.3
OFD	14.4	0.4
TEX	18.0	0.5
WAP		0.7
LEA		0.6
LUM	16.0	0.4
MAN	34.6	0.6
I_S		0.2
FMP	33.7	0.4
MVH	33.0	0.6
OTP	5.7	5.7
ATP	5.7	
WTP	5.7	
SER	3.6	4.6
DWE		3.2

Source: Author's calculation based on GTAP5 database and 1996 Brazilian IO table from IBGE

[88] Some care is necessary in analyzing the tax numbers from an input-output table. It is not possible to relate the tax rates to a particular tax applied in the economy. In other words, the *ad-valorem* tax rates of the model were constructed from total tax revenues reported at some aggregated level. For example, the ICMS, considered as a value-added tax in Brazil, and presented in the IO table is part of both the taxes on intermediate inputs as well as final demand. The same is true for the IPI. For this reason, it is not possible to conclude with any certainty whether the results specifically reflect cuts in ICMS or IPI.

Table A6.2 presents the impacts of tax reduction scenarios in terms of some aggregate variables. An overall welfare improvement was observed in all scenarios, since they simulate a reduction in price distortions in the economy. For example, looking at scenario TYT, we can see that the removal of the 1.1% production tax from the land transportation sector promotes a 0.1% increase in aggregate welfare. From the table we can also observe that higher welfare gains can be obtained when taxes on inputs used by the transportation sector are removed (scenario TIT), as well as when all taxes are removed (TTT), since those mean deeper tax cuts compared to other scenarios. Although the TIT scenario is not really a practical tax policy since it means exempting just one sector from paying taxes in the use of inputs from other sectors, this serves to clarify the point that lowering the cost of producing transportation services leads to reasonable welfare improvements.

Table A6.2 Change in Aggregate Variables from Scenarios of Tax Cuts

	Scenarios				
Variables	TYT	TIT	TII	TPT	TTT
Welfare (%)	0.10	0.49	0.10	0.27	0.93
Welfare (US$bi)	0.51	2.59	0.54	1.45	4.94
GDP (%)	0.09	0.43	0.08	-0.01	0.56
Tax Revenue (%)	0.07	0.36	0.01	-0.01	0.42
Price of Sk.Labor (%)	0.07	0.33	0.06	-0.07	0.36
Price of Unsk.Labor(%)	0.09	0.48	0.09	0.04	0.67
Price of Capital (%)	0.09	0.44	0.08	-0.01	0.57
Price of Land (%)	0.09	0.46	0.12	0.04	0.68

*Source: Author's calculation*s

With few exceptions, the percentage changes in GDP resulting from tax cuts follow the changes in welfare. The removal of transportation taxes on final consumption (TPT) causes a very small reduction in GDP, although it increases welfare more than the removal of taxes on production. The improvement in welfare in the TPT scenario comes from increased consumption since cheaper relative transportation costs increase demand by inducing consumers to substitute transportation for other goods, (a "substitution effect"), and also allow for overall increases in consumption by reducing the total expense of transportation services, (an "income effect"). The results suggest that the "substitution effect" dominates the "income effect" since the returns to unskilled labor, which is used more intensively in the land transportation sector, increases while returns to capital and skilled labor are reduced. As a result of the decrease in the returns to capital and skilled labor GDP falls by 0.01%.

Although tax cuts were simulated, the resulting changes in tax revenues were not negative, except in the TPT scenario. Since the tax cuts promote an increase in economic activity, increasing both consumption and production, the government could expect increases in tax collection.

Table A6.3 shows changes in prices and production in Brazil. As expected, there were two results—more pronounced decreases in the price of land transportation services and increases in its production. The air and water transportation sectors also benefited most from tax cuts on land transportation, since the interdependence among transportation sectors is more pronounced than it is between other economic sectors. This means that cheaper prices for land transportation have a greater impact than price changes for other forms of transportation, due mostly to the relatively large share of land transportation inputs in the total intermediate demand expenses of air and water transports. The changes in production also confirmed the changes in factor income prices and GDP discussed above. Since land transportation uses unskilled labor more intensively, unskilled labor prices usually increase more than prices of other factors. When there is a strong increase in the production of capital intensive goods or services, such as air transportation services, the price of capital increases. However, if the output of land transportation services increases much more than that of other sectors, as in the TPT scenario, only the price of unskilled labor rises.

Table A6.3 Changes in Production and Prices from Tax Cuts (percent)

	Scenarios									
	tyt		tit		tii		tpt		Ttt	
Sectors	Output	Price	Output	Price	Output	Price	Output	Price	Output	Price
PDR	0.03		0.16		0.05		0.02		0.25	
GRO	-0.04	0.01	-0.21	0.06	-0.01	0.01	0.01	0.00	-0.24	0.08
OSD	-0.05		-0.23		-0.01		0.04		-0.23	
AGR	0.03	0.01	0.14	0.06	0.04	0.01	0.02	0.00	0.22	0.07
OCR	0.02	0.01	0.08	0.07	0.07	-0.01	0.00	0.01	0.15	0.08
ENR	0.15	-0.02	0.78	-0.10	0.16	-0.04	0.35	-0.01	1.43	-0.16
CMT	0.06	-0.01	0.30	-0.04	0.08	0.00	0.02	-0.01	0.44	-0.06
OMT	0.05	0.00	0.26	-0.02	0.09	0.00	0.01	-0.01	0.39	-0.03
MIL	0.03	0.01	0.17	0.03	0.07	0.01	0.00	-0.01	0.26	0.03
PCR	0.03	0.01	0.16	0.05	0.09	0.00	0.01	-0.01	0.28	0.04
SGR	0.06	-0.01	0.32	-0.05	0.06	0.00	0.05	-0.02	0.48	-0.07
OFD	0.05	0.00	0.23	-0.02	0.06	0.00	0.02	-0.01	0.34	-0.03
TEX	0.05	0.00	0.24	0.01	0.05	0.01	0.09	-0.01	0.42	0.00
WAP	0.05	0.00	0.23	0.01	0.07	0.01	0.01	-0.01	0.34	0.01
LEA	0.05	0.00	0.25	0.00	0.05	0.01	0.07	-0.02	0.41	-0.01
LUM	0.03	0.00	0.13	-0.01	0.03	0.01	-0.02	-0.01	0.15	-0.02
MAN	0.05	0.00	0.26	-0.02	0.00	0.01	0.10	-0.01	0.41	-0.03
I_S	0.15		0.74		0.05		0.11		1.01	
FMP	0.05	-0.01	0.24	-0.04	0.01	0.01	0.06	-0.01	0.35	-0.05
MVH	0.08	0.00	0.42	-0.02	0.04	0.01	0.15	-0.01	0.68	-0.02
SER	-0.05	0.01	-0.25	0.07	-0.03	-0.01	-0.15	-0.02	-0.48	0.06
OTP	0.66	-1.05	3.44	-5.27	0.20	-0.24	3.20	0.00	7.59	-6.24
ATP	0.75	-0.05	3.83	-0.24	0.12	0.00	0.23	-0.01	4.76	-0.29
WTP	0.31	-0.03	1.57	-0.14	0.14	-0.01	0.17	-0.01	2.11	-0.18
DWE	0.03	0.01	0.15	0.05	0.07	0.00	-0.01	-0.01	0.24	0.05

Source: Author's calculations

Table A6.4 presents the changes in welfare for the 20 households, and the change in the Gini coefficient. The table repeats the aggregate welfare results for Brazil. The tax cuts promoted an overall increase in welfare, with stronger effects on poorer rural households (Rhhd1). Most households experienced welfare changes higher than the average welfare increase in the economy.

Table A6.4 Changes in Welfare and in Gini Coefficient from Tax Cuts (percent)

Household types	Scenarios				
	tyt	tit	tii	tpt	ttt
BRA	0.10	0.49	0.10	0.27	0.93
Rhh1	0.14	0.70	0.08	0.56	1.44
Rhh2	0.12	0.63	0.08	0.47	1.28
Rhh3	0.12	0.59	0.09	0.41	1.18
Rhh4	0.11	0.55	0.08	0.42	1.13
Rhh5	0.12	0.62	0.09	0.44	1.25
Rhh6	0.11	0.58	0.09	0.38	1.13
Rhh7	0.12	0.62	0.09	0.44	1.24
Rhh8	0.13	0.66	0.12	0.40	1.28
Rhh9	0.11	0.57	0.10	0.36	1.11
Rhh10	0.12	0.62	0.12	0.36	1.19
Uhh1	0.11	0.57	0.07	0.45	1.18
Uhh2	0.11	0.55	0.08	0.39	1.09
Uhh3	0.10	0.50	0.08	0.35	0.99
Uhh4	0.10	0.50	0.08	0.34	0.99
Uhh5	0.10	0.50	0.08	0.33	0.98
Uhh6	0.10	0.51	0.10	0.30	0.97
Uhh7	0.09	0.46	0.08	0.28	0.89
Uhh8	0.09	0.44	0.09	0.27	0.85
Uhh9	0.08	0.38	0.08	0.24	0.75
Uhh10	0.10	0.50	0.12	0.23	0.91
Gini	-0.0011	-0.0067	0.0108	-0.0364	-0.0354

Source: Author's calculations

The Gini coefficient improved in almost all scenarios. Cuts in taxes related to final demand produced the best result in terms of income distribution. This was the result of two effects. The first of these relates to increases in consumption of land transportation services by poorer households because of cheaper final prices and the higher shares of transportation in the total expenses of lower income families. The second relates to the increase in poorer households' income as a result of increases in the price of unskilled labor. The improvements in income distribution in the TYT and TIT scenarios were much lower since richer households, such as Rhh8, Rhhd10 and Uhhd10, also benefited from these policies. This is because prices for capital and land increased almost as much as the price of unskilled labor due to strong increases in production of capital intensive sectors such as air and water transportation.

When tax cuts were implemented on the intermediate use of transportation services by other sectors (TII) there was a negative impact on income distribution. This happened because poorer households increased their welfare by less than the average of the economy and by less than richer households. Cheaper land transportation inputs benefit production in several sectors such as energy, water, air transportation and agriculture, resulting in increases in returns to capital and land by as much or more than the increase in unskilled labor prices. As a result, the impacts on the income of richer households are more visible than on the income of poorer households.

Improvement in the efficiency of transport services

Another way to address the importance of transportation services in the Brazilian economy is to investigate the role of efficiency improvements in this sector. Here, different shocks were performed by reducing the amount of inputs necessary to produce a unit of service of land transportation. This can be thought of as a decrease in the input-output coefficient. Four different scenarios were used: an improvement in the efficiency in the use of all primary factors and intermediate inputs used by the land transportation sector (scenario TEC); an improvement in the efficiency of labor (TCF); an improvement in the efficiency of capital (TCK); and an improvement in the efficiency of intermediate inputs (TCI)[89]. In all four cases the overall cost of production was reduced by 5%.

Table A6.5 presents the impacts on aggregate variables. The changes in welfare were very similar for all cases, since the overall increase in efficiency in terms of costs was the same in all scenarios. These changes suggest that the economy would experience an aggregate increase in welfare of about 0.44% if land transportation services could be provided in a more efficient way that would reduce production costs by 5%. The gains to GDP were somewhat similar to the gains in welfare. However, improvements in the use of labor had a greater benefit in terms of GDP than improvements in the use of capital, just because of the differences in the changes in prices of primary factors. Tax revenues grew by around 0.35% when costs in the transportation sector dropped by 5%.

Table A6.5 Change in Aggregate Variables from Improvements in Efficiency

	Scenarios			
Variables	TEC	TCF	TCK	TCI
Welfare (%)	0.44	0.44	0.44	0.43
Welfare (US$bi)	2.33	2.36	2.36	2.32
GDP (%)	0.39	0.50	0.29	0.38
Tax Revenue (%)	0.34	0.36	0.33	0.33
Price of Sk.Labor (%)	0.39	0.33	0.65	0.35
Price of Unsk.Labor(%)	0.35	-0.11	0.71	0.43
Price of Capital (%)	0.41	0.72	0.10	0.37
Price of Land (%)	0.39	0.58	0.39	0.32

Source: Author's calculations

The biggest differences in the overall impacts of the different scenarios regarding improvements in the efficiency of transportation services were observed in the prices of primary factors. As each scenario considered reduction in different components of cost, the effects on factor prices were also differentiated. In this way, the increased efficiency in the use of labor (scenario TCF) meant lower demand for it to produce transportation services, leading to an overall decrease in its price. However, this was not observed with capital when an increase in its efficiency (TCK) was simulated. To understand these differences one needs to remember that the transportation sector is more labor intensive and less capital intensive relative to other economic sectors. Less use of a particular factor to produce a specific amount of transportation services means an overall increase in the availability of that factor for other sectors. Since the rest of the economy is relatively more capital intensive and less labor intensive, the demand for "extra" capital is greater than the demand for "extra" labor, and then the changes in relative prices are more

[89] The shocks implemented were related to technological change. To the extent they change the frontier of production and/or the output/input ratio, it is necessary to use some caution in interpreting them. When the use of one factor is reduced the relative intensity of it in the output is also decreased. For example, an increase in the efficiency of capital means the transportation sector will become more labor intensive than before. This may not be an ideal path for technological change and this report is not necessarily recommending it. The notion here is to simply use alternative ways of decreasing costs in the supply of transportation services and avoid the complication and details of technological change models and theories.

favorable to the former. The impacts on factor prices when improvements were simulated in the use of all factors (scenario TEC) or only intermediate inputs (scenario TCI) followed the same logic regarding relative factor usage, where the factor used more intensively by land transportation (labor) suffered from a lower increase in relative prices.

As one might expect, improvements in efficiency were reflected in lower prices and an increase in the production of transportation services (Table A6.6). Consequently, several sectors benefit from cheaper transportation, decreasing prices and increasing outputs. These results clarified the importance of transportation services to other sectors and to overall economic growth and highlight the benefits from efficiency improvements on transportation.

Table A6.6 Changes in Production and Prices from Improvements in Efficiency (percent)

Sectors	Scenarios							
	TEC		TCF		TCK		TCI	
	Output	Price	Output	Price	Output	Price	Output	Price
PDR	0.13		0.34		0.12		0.06	
GRO	-0.14	0.04	0.73	-0.06	-0.65	0.12	-0.35	0.06
OSD	-0.20		0.19		-0.32		-0.31	
AGR	0.13	0.04	0.37	-0.13	0.06	0.15	0.05	0.07
OCR	0.11	0.03	0.60	-0.26	-0.15	0.25	-0.01	0.09
ENR	0.16	-0.09	0.50	0.01	1.16	-0.18	-0.24	-0.10
CMT	0.25	-0.04	0.32	-0.13	0.31	0.01	0.21	-0.02
OMT	0.22	-0.01	0.23	-0.10	0.26	0.03	0.21	0.01
MIL	0.15	0.03	0.10	-0.02	0.26	0.04	0.14	0.04
PCR	0.13	0.04	0.11	-0.03	0.16	0.09	0.13	0.06
SGR	0.27	-0.04	0.48	-0.15	0.22	0.03	0.19	-0.01
OFD	0.19	-0.02	0.31	-0.10	0.24	0.02	0.14	0.00
TEX	0.10	0.01	0.15	0.02	0.36	-0.01	0.01	0.02
WAP	0.19	0.02	0.17	0.00	0.25	0.01	0.19	0.03
LEA	0.18	0.01	0.36	-0.03	0.16	0.02	0.12	0.02
LUM	0.16	-0.01	0.26	-0.07	0.20	0.01	0.10	0.01
MAN	0.13	-0.01	0.15	0.01	0.51	-0.04	0.02	-0.01
I_S	0.55		0.57		1.00		0.43	
FMP	0.16	-0.03	0.29	-0.05	0.45	-0.03	0.02	-0.02
MVH	0.16	-0.02	0.15	0.04	0.62	-0.06	0.04	-0.03
SER	0.01	0.08	0.20	0.06	0.17	0.09	-0.10	0.09
OTP	2.80	-4.70	3.19	-4.86	3.22	-4.72	2.53	-4.63
ATP	3.16	-0.21	3.45	-0.21	3.60	-0.22	2.92	-0.21
WTP	1.23	-0.11	1.39	-0.11	1.48	-0.13	1.11	-0.11
DWE	0.14	0.05	0.05	-0.05	0.25	0.11	0.15	0.07

Source: Author's calculations

The impacts on households and income distribution are presented in Table A6.7. The welfare gains to the poorest families were generally higher than the average aggregate gains in Brazil. Nonetheless, richer rural and urban families also experienced above average gains in almost all scenarios. Consequently, the Gini coefficient decreased in some scenarios and increased in others. It decreased when the efficiency improvement occurred in the use of capital and intermediate inputs, since it promotes relatively larger increases in the returns to labor. The Gini coefficient increased in the scenarios where labor is used more efficiently, since its relative price declines or doesn't increase as much as the price of other factors. This underscores the point that the model captures the income distribution effects of efficiency improvements in transportation through household income. Since poorer households receive most of their income from unskilled labor, positive impacts on income distribution were observed if its price increased relatively more than the price of other factors[90].

Table A6.7 Changes in Welfare and in Gini Coefficient from Improvements in Efficiency (Percent)

	Scenarios			
Household types	TEC	TCF	TCK	TCI
BRA	0.44	0.44	0.44	0.43
Rhh1	0.57	0.26	0.83	0.62
Rhh2	0.51	0.16	0.81	0.57
Rhh3	0.48	0.10	0.80	0.54
Rhh4	0.45	0.16	0.70	0.50
Rhh5	0.50	0.16	0.78	0.56
Rhh6	0.47	0.14	0.73	0.53
Rhh7	0.51	0.22	0.76	0.56
Rhh8	0.54	0.16	0.87	0.60
Rhh9	0.46	0.18	0.70	0.51
Rhh10	0.50	0.16	0.79	0.56
Uhh1	0.46	0.18	0.70	0.51
Uhh2	0.44	0.10	0.73	0.50
Uhh3	0.41	0.12	0.67	0.46
Uhh4	0.41	0.13	0.66	0.46
Uhh5	0.44	0.22	0.66	0.46
Uhh6	0.44	0.20	0.69	0.47
Uhh7	0.43	0.40	0.48	0.42
Uhh8	0.41	0.38	0.46	0.40
Uhh9	0.36	0.39	0.36	0.35
Uhh10	0.46	0.66	0.28	0.43
Gini	0.0044	0.1255	-0.1059	-0.0134

Source: Author's calculations

Transportation and International Trade

Infrastructure provision is an important theme in other areas besides growth and income distribution. Calderón and Servén (1994) have discussed the role of infrastructure as a necessary ingredient in increasing efficiency in resource allocation and export growth from trade liberalization. The work of Araújo Júnior and Ramos (2006) was used to investigate the importance of improved transportation services in complementing trade openness policies, and several scenarios were analyzed under which trade barriers were removed with and without improvements in transportation. To represent such a policy the analysis considers 50% unilateral cuts in Brazilian *ad valorem* import tariffs. These cuts were performed in four different scenarios: trade openness without improvement in transportation services (scenario TRD); a cut

[90] Some caution is necessary when analyzing the results about improvements in labor efficiency from a CGE model of this type. A misleading conclusion one could formulate about the results would be to think that improvements in the efficiency of labor would hurt the poorest families. Here the negative impacts on the poor from such improvements are due to the specificities of the modeling exercise. Higher labor productivity could improve the income of households receiving revenue from it, since the amount of output per unit of labor should increase. The way improvements in the use of labor were implemented here implies a lower cost for it and a reduction in its demand, reducing its relative price in the economy.

in tariffs and a 10% increase in public infrastructure[91] (TRK); a cut in tariffs and an increase in the efficiency of the use of intermediate inputs in the transportation sector[92] (TRI); and a cut in tariffs and the removal of taxes on final demand for land transport services (TRT).

Table A6.8 Change in Aggregate Variables from Alternative Scenarios with Trade

Variables	Scenarios			
	TRD	TRK	TRI	TRT
Welfare (%)	0.66	0.98	1.09	0.93
Welfare (US$bi)	3.50	5.21	5.82	4.96
GDP (%)	0.35	0.49	0.73	0.34
Tax Revenue (%)	0.31	1.68	0.64	0.30
Price of Sk.Labor (%)	0.52	0.74	0.88	0.46
Price of Unsk.Labor(%)	0.94	1.25	1.38	0.99
Price of Capital (%)	0.13	0.41	0.50	0.12
Price of Land (%)	5.23	5.52	5.53	5.27

Source: Author's calculations

Table A6.8 presents the aggregate impacts of these scenarios. The cut in tariffs alone provided an increase of 0.66% in aggregate welfare and of 0.35% in GDP. These impacts were higher than the impacts observed in previous scenarios, since here cuts in distortions were promoted in practically all sectors of the economy. Taking into account that scenarios implemented previously dealt with changes in only one sector of the economy, it can be demonstrated that improvements in transportation services have a relatively strong impact on the economy. For example, in the scenario where all taxes were removed on the production of transport services (scenario TYT), the tax removal, initially at 1.1%, generated an increase in welfare of 0.1%, one seventh of the gains from the 50% tariff cuts in all sectors of the economy.

The gains from trade were expanded when improvements in transportation services were simulated together with cuts in tariffs. The increase in transportation infrastructure added 0.29 percentage points to gains in welfare from trade, while cuts in taxes on final demand for transportation services added 0.27 percentage points. More impressively, the reduction in the cost of intermediate inputs added 0.43 percentage points to the welfare gains from trade. These results confirmed the notion that trade gains can be magnified by improving the supply of transportation services.

Changes in prices of primary factors show that trade openness favors sectors intensive in land and unskilled labor. Table A6.9 confirms this by presenting the effects on sectoral production and prices. The results follow the study of Harrison et al. (2004), since the model and database are very similar. As noted by those authors, the tariff structure in the Brazilian economy is relatively more protective in capital intensive and industrial sectors. Consequently, tariff cuts will benefit sectors such as agriculture and food industry that were less protected before the opening.

[91] In this scenario the share of 20% of total capital in the land transportation sector was considered part of infrastructure and it was also assumed that zero elasticity of substitution existed between it and value-added.
[92] As in the previous scenarios, the overall costs in the production of transportation services fell by 5%.

Table A6.9 Changes in Production and Prices Alternative Scenarios with Trade (percent)

	Scenarios							
	TRD		TRK		TRI		TRT	
Sectors	Output	Price	Output	Price	Output	Price	Output	Price
PDR	0.24		0.34		0.28		0.26	
GRO	5.57	-1.56	5.42	-1.52	5.20	-1.49	5.58	-1.56
OSD	10.06		9.86		9.67		10.10	
AGR	2.60	-2.56	2.68	-2.52	2.63	-2.49	2.62	-2.56
OCR	1.49	-2.38	1.52	-2.33	1.45	-2.29	1.48	-2.37
ENR	1.42	-2.65	1.93	-2.71	1.16	-2.75	1.78	-2.66
CMT	2.25	-2.45	2.45	-2.47	2.46	-2.46	2.27	-2.46
OMT	3.57	-2.92	3.74	-2.93	3.78	-2.91	3.58	-2.93
MIL	-2.35	-2.72	-2.25	-2.70	-2.24	-2.67	-2.34	-2.73
PCR	0.91	-2.43	1.01	-2.40	1.03	-2.37	0.92	-2.44
SGR	9.35	-4.03	9.57	-4.06	9.54	-4.04	9.40	-4.05
OFD	-0.39	-2.75	-0.24	-2.76	-0.26	-2.74	-0.37	-2.76
TEX	-7.43	-3.48	-7.30	-3.48	-7.46	-3.47	-7.33	-3.49
WAP	-3.67	-2.94	-3.53	-2.93	-3.51	-2.92	-3.65	-2.95
LEA	7.80	-3.94	7.94	-3.94	7.86	-3.92	7.89	-3.96
LUM	-0.42	-2.98	-0.34	-2.99	-0.33	-2.98	-0.43	-2.99
MAN	-7.79	-3.52	-7.63	-3.53	-7.77	-3.52	-7.69	-3.53
I_S	-0.47		0.07		0.05		-0.35	
FMP	-5.31	-3.77	-5.15	-3.79	-5.28	-3.78	-5.25	-3.78
MVH	4.38	-2.98	4.66	-2.99	4.43	-3.00	4.53	-2.99
SER	0.59	-2.27	0.44	-2.22	0.50	-2.18	0.44	-2.29
OTP	0.07	-2.11	2.25	-5.41	2.60	-6.62	3.28	-2.11
ATP	23.03	-1.77	25.72	-1.94	26.11	-2.01	23.30	-1.78
WTP	20.40	-2.29	21.54	-2.38	21.58	-2.41	20.60	-2.30
DWE	0.37	-2.29	0.47	-2.25	0.52	-2.22	0.36	-2.30

Source: Author's calculations

The impacts on households and income distribution are presented in Table A6.10. Because of the changes in the relative price of unskilled labor and the overall decrease in prices for consumer goods, cuts in tariffs promoted more significant welfare gains for the poorest families. Several rural households showed pronounced welfare gains because of their possession of land. The Gini coefficient improved, falling by 0.15%. When trade liberalization was accompanied by improvements in land transportation services the positive impacts on income distribution were magnified. The most substantial reduction in the Gini coefficient was observed when trade liberalization is followed by cuts in consumption taxes on the use of transportation services. Since the changes in prices of primary factors were similar under scenarios of trade openness with and without cuts in taxes on consumption, the incremental benefit in income distribution from adding tax cuts was due to expenditure effects. In the case of the scenarios where infrastructure and use of intermediate inputs were improved, the additional benefits were due to income effects, since the price of unskilled labor increases more when those improvements were included.

Table A6.10 Changes in Welfare and in Gini Coefficient from Alternative Scenarios with Trade (percent)

	Scenarios			
Household types	TRD	TRK	TRI	TRT
BRA	0.66	0.98	1.09	0.93
Rhh1	1.57	2.02	2.19	2.14
Rhh2	1.30	1.71	1.87	1.78
Rhh3	1.20	1.58	1.74	1.62
Rhh4	1.59	1.94	2.08	2.01
Rhh5	1.03	1.43	1.59	1.47
Rhh6	1.14	1.52	1.67	1.52
Rhh7	1.05	1.45	1.61	1.49
Rhh8	1.47	1.90	2.07	1.88
Rhh9	1.08	1.45	1.58	1.44
Rhh10	1.48	1.88	2.04	1.84
Uhh1	1.58	1.95	2.09	2.03
Uhh2	1.39	1.75	1.89	1.78
Uhh3	1.26	1.58	1.72	1.61
Uhh4	1.19	1.51	1.64	1.53
Uhh5	0.83	1.15	1.29	1.16
Uhh6	0.94	1.27	1.41	1.24
Uhh7	0.61	0.92	1.04	0.90
Uhh8	0.53	0.82	0.93	0.80
Uhh9	0.26	0.51	0.60	0.49
Uhh10	0.51	0.84	0.94	0.74
Gini	-0.1541	-0.1564	-0.1666	-0.1907

Source: Author's calculations

Annex 7
Alternative Simulations

Additional simulations were performed in an effort to explore the importance of the assumptions made about factor intensity and consumption of land transportation services and their impacts in the short run. Furthermore, an alternative approach was tested to account for increases in the total factor productivity (TFP).

The alternative runs were performed under two of the scenarios simulated previously: tax cuts on final demand of land transport services and efficiency improvement in the use of intermediate inputs. The conclusions from the alternative runs under these two scenarios can be extended to the other scenarios. To test the TFP formulation the scenario of improvements in transportation infrastructure was used since the TFP is assumed to be linked to the increase in infrastructure.

Table A7.1 presents some of the results of the alternative runs. The first and fifth columns present the results from the scenarios without changes, as presented before. The second and sixth columns show the results under the assumption that the transportation sector is capital intensive[93] (using the suffix _kl to represent it). The third and seventh columns assume that richer families expend a bigger share of their income on transportation services than poor families[94] (suffix _c). Finally, in the fourth and final columns we present results from a short run formulation of the model[95] (suffix _sr).

The results show that under changes in factor shares or in consumption shares the positive impacts on welfare for poor households decrease, while for richer households they increase. Those changes were much greater in the case of alternative consumption shares, leading to an increase in the Gini index. Those results suggest that the most critical information necessary to address the impacts on poor families related to the consumption shares of land transportation services. Since the scenarios stimulated shocks in only one sector, the consumption effects seem to be more important than the income effects. This occurs because the effects on factor prices resulting from improvements in transportation were small, but the effects on the price of transportation services for final consumers were relatively large.

The short term approach demonstrates impacts that are slightly less favorable to the economy and to poor households, making it clear that the full positive impacts depend on and should occur after some time for adjustments among sectors. This means that income distribution effects will be lower, as many frictions and factor mobility constraints exist in the economy. This is particularly important in the case of the Brazilian economy, where there are several costs associated with changes in the employment of labor and capital.

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[93] As discussed in the description of the database, the labor and capital intensity information originally used were taken from the 1996 Brazilian IO. In that case, the share of unskilled labor in the value added was 47% and the share of capital was 40%. Here, the shares were changed to reflect 56% of capital and 27% of unskilled labor.

[94] In this case, richer families expend twice as much on land transportation services than poor families.

[95] The model is originally built to represent the long run. The short run is simulated by considering capital as a sector specific factor and elasticities reduced by half. This is not a full representation of the short run, since there are still no unemployment and other frictions common to short periods. What is illustrated is the direction that results could change in if lower mobility of factors was considered.

Table A7.1 Changes in Selected Indicators from Scenarios with Alternative Formulation (percent)

Indicators	Scenarios							
	tpt	tpt_kl	tpt_c	tpt_sr	tci	tci_kl	tci_c	tci_sr
GDP	-0.01	0.00	-0.01	-0.02	0.38	0.38	0.38	0.29
Price of Sk.Labor (%)	-0.07	-0.05	-0.07	-0.16	0.35	0.37	0.35	0.33
Price of Unsk.Labor(%)	0.04	-0.01	0.04	0.05	0.43	0.39	0.43	0.47
Price of Capital (%)	-0.01	0.02	-0.01	0.03	0.37	0.39	0.37	0.13
Price of Land (%)	0.04	0.05	0.04	0.17	0.32	0.33	0.32	0.40
Welfare	0.27	0.27	0.27	0.23	0.43	0.43	0.43	0.43
Rhh1	0.56	0.53	0.08	0.47	0.62	0.59	0.21	0.56
Rhh2	0.47	0.43	0.09	0.38	0.57	0.54	0.24	0.53
Rhh3	0.41	0.37	0.09	0.33	0.54	0.51	0.27	0.52
Rhh4	0.42	0.39	0.14	0.36	0.50	0.47	0.26	0.47
Rhh5	0.44	0.40	0.15	0.37	0.56	0.53	0.32	0.55
Rhh6	0.38	0.34	0.08	0.29	0.53	0.50	0.27	0.52
Rhh7	0.44	0.40	0.10	0.34	0.56	0.53	0.27	0.54
Rhh8	0.40	0.36	0.21	0.34	0.60	0.57	0.43	0.61
Rhh9	0.36	0.33	0.45	0.32	0.51	0.48	0.56	0.50
Rhh10	0.36	0.32	0.12	0.31	0.56	0.53	0.36	0.57
Uhh1	0.45	0.42	0.10	0.38	0.51	0.48	0.22	0.45
Uhh2	0.39	0.35	0.08	0.31	0.50	0.47	0.24	0.46
Uhh3	0.35	0.32	0.10	0.27	0.46	0.43	0.24	0.41
Uhh4	0.34	0.31	0.12	0.27	0.46	0.43	0.27	0.42
Uhh5	0.33	0.31	0.09	0.24	0.46	0.45	0.26	0.42
Uhh6	0.30	0.28	0.11	0.22	0.47	0.46	0.31	0.44
Uhh7	0.28	0.29	0.13	0.19	0.42	0.42	0.29	0.37
Uhh8	0.27	0.27	0.30	0.22	0.40	0.40	0.43	0.39
Uhh9	0.24	0.24	0.44	0.23	0.35	0.35	0.52	0.34
Uhh10	0.23	0.25	0.33	0.21	0.43	0.45	0.52	0.44
Gini coefficient	-0.0364	-0.0247	0.0616	-0.0187	-0.0134	-0.0026	0.0714	0.0012

Source: Author's calculations

Table A7.2 presents the results for the TFP approach. Two different groups of cases were considered. The first of these assumes an overall increase in the TFP—in other words, all primary factors increase their productivity in the same proportion. The second assumes that there is only an increase in the productivity of unskilled labor only. The role of elasticity of substitution among factors was also explored, with default values of 1 and 4. These different assumptions are discussed in the presentation of the results shown in Table A7.2.

In the second column of Table A7.2 we observe that impacts on GDP and aggregate welfare are around 3 times greater under the TFP approach in comparison with the traditional approach (results in the first column). It shows the potential gains to the economy when increases in productivity from improvements in infrastructure are accounted for. Since all factors increase in the same proportion, the changes in their relative prices are almost the same, with or without increases in TFP. However, the increases in household welfare are much higher for rich families and there is a negative impact on income distribution. This occurs because the database shows capital as 51% of the aggregate value added in the economy, while unskilled labor accounts for only 29% (Table 3.1 in Chapter 3). The same increase in the productivity of all factors means a bigger absolute increase in capital than in other factors. Since capital is more important in determining the income of richer households, while unskilled labor is the most important factor in determining the income of the poor, the income distribution becomes more stratified.

Table A7.2 Changes in Selected Indicators from Scenarios with Alternative Formulation about Infrastructure and TFP (percent)

Indicators	Scenarios			
	KP2_00	TPF for all factor	TPF for labor	TPF for labor (higher elasticities)
GDP	0.14	0.53	0.70	0.54
Price of Sk.Labor (%)	0.21	0.20	0.77	0.37
Price of Unsk.Labor(%)	0.30	0.31	-0.98	-0.07
Price of Capital (%)	0.29	0.28	0.84	0.41
Price of Land (%)	0.30	0.32	1.31	0.32
Welfare	0.32	0.84	1.07	1.05
Rhh1	0.44	0.77	1.06	1.68
Rhh2	0.40	0.76	1.05	1.73
Rhh3	0.38	0.78	1.09	1.78
Rhh4	0.35	0.68	0.92	1.46
Rhh5	0.40	0.81	1.07	1.76
Rhh6	0.37	0.79	1.05	1.68
Rhh7	0.40	0.81	1.06	1.62
Rhh8	0.43	1.03	1.37	2.06
Rhh9	0.36	0.86	1.19	1.72
Rhh10	0.40	1.00	1.37	2.01
Uhh1	0.36	0.66	0.95	1.53
Uhh2	0.35	0.71	1.02	1.66
Uhh3	0.32	0.67	0.97	1.49
Uhh4	0.32	0.69	0.95	1.46
Uhh5	0.32	0.73	1.01	1.32
Uhh6	0.32	0.83	1.12	1.47
Uhh7	0.30	0.72	0.95	0.92
Uhh8	0.29	0.73	0.92	0.89
Uhh9	0.25	0.67	0.82	0.71
Uhh10	0.33	0.98	1.19	0.89
Gini coefficient	-0.0013	0.0727	0.0568	-0.1377

Source: Author's calculations

As an alternative way to consider improvements in TFP, it is assumed that the increase in infrastructure brings improvements only in the productivity of unskilled labor. Although it is unreasonable to believe that only one factor benefits from infrastructure, it is reasonable to assume that not all factors benefit the same. Consequently, the simulation concerning improvement in the productivity of labor can be thought of as the limit to the spillover from infrastructure biased to favor one factor. The aggregate impacts of such biased increase in factor productivity are bigger than the overall TFP increase. This happens because unskilled labor is used by all sectors in the economy, while land and natural resources are specific to a very limited number of sectors. The increase in productivity of those factors is not as beneficial to the economy as the increase in unskilled labor productivity. The increase in labor productivity, however, only makes its relative price lower, since the way the model simulates increases in labor productivity implies a greater supply of it. As the other factors become relatively scarce, their relative prices increase. As a result of changes in prices of primary factors, welfare impacts on households are more favorable for richer families, stratifying income distribution and increasing the Gini index. Poor families have greater increases in welfare than in the scenario without improvements in productivity, but they are still lower than the average welfare gains for the economy.

The last column of Table A7.2 represents the results of a final approach regarding the increase in factor productivity. The elasticity of substitution of primary value added factors was increased at the same time that improvements take place in the productivity of unskilled labor. The purpose of this was to observe what would happen if more productive labor could provide a better substitute for other resources. Under this approach, the price of unskilled labor does not drop as much as in the previous scenario, and the other resources experience lower increases in prices. As a result, the welfare impacts were favorable to the poorest households and the Gini index dropped much more than in the scenario without productivity improvements. This confirms that the negative impact on income distribution in the previous scenario was due to unfavorable changes in the price of factors for the poor. Although the favorable income distribution impacts seem to be "forced" by extreme assumptions, they still suggest that improvements in transportation infrastructure can bring larger gains to the poor if they increase the productivity of labor and enhance its capability to substitute for other factors in the economy.

Annex 8
Brief Literature Review on the Integration of CGE Models and Transportation Networks

The initial research that allowed CGE models to be applied in analyses of transportation networks was the development of spatial CGE models, first by Roson (1994) and then subsequently by Bröcker (1998a) and Bröcker and Schneider (2002). Earlier work by Buckley (1992) considered the impacts of transportation systems on the spatial economy, but transportation systems were not represented as a network. 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 synergistic effects resulting from the simultaneous development of key network links, which generated greater impacts than the sum of the impacts arising from sequential development. Sohn et al. (2003) provided a conceptually similar linkage between CGE modeling and transportation network analysis, 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 also detail about bridges on the links. The objective of this integration was to evaluate the impacts of a massive earthquake in the Midwestern United States on commodity flows, production and income and thus to assign some sense of priority to the retrofitting of existing infrastructure.

Earlier analysis by Haddad and Hewings (2005) using the model employed in chapter 4 provided the methodology for integrating a multi-region CGE model with a transportation network in such a way that the role of both economies of scale 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 the motivation for chapter 4 of this report, which attempts 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 smaller component of total production costs in the U.S. than in Brazil, there are still some major issues at transfer nodes – both internally and at the nexus between interstate and international trade. It would appear that serious congestion still occurs at these transfer points, and the analysis presented in Clark et al. (2004) confirms this for seaports. The absence of direct rail-to-rail connections in the U.S. (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 tends to be of much shorter duration, and typically dissipates within a few hours.

Thus, the modeling of a nodal congestion function that also considers issues of regulation and spatial competition (such as the problem of competing destinations/origins/transfer for the shipment of goods, especially those sourced outside the country or produced within the country for export) presents a major challenge. 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 efficiency of the transfer nodes.

As Clark et al. (2004) noted in their analysis, the impacts of port inefficiency are not trivial; improving port efficiency in Latin American countries from the 25th to the 75th percentile would reduce shipping costs by 12%. 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.[96] These problems were further compounded by delays in customs clearance that were among the highest in the world.

The key problem with port inefficiency in Latin America lies in determining 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 not only to the port's inefficiency but also to increasing total transportation costs?

[96] Figures from the *The Global Competitiveness Report*, various years (1996-2000), *apud* Clark *et al*. (2004).

Annex 9
Estimation of Port Efficiency in Brazil[97]

A9.1 Methodology

In order to quantify efficiency in a set of Brazilian ports, we estimated the following model was estimated:

$$lnic_{rijk} = \alpha + \beta_1 lnkg_{rijk} + \beta_2 lnvolume_{ij} + \beta_3 sqlnvolume_{ij} + \beta_4 lnunitval_{rijk} + \beta_5 lndist\_uf_{ri} + \beta_6 sqlndist\_uf_{ri} + \beta_7 lndist\_part_{ij} + \beta_8 sqlndist\_part_{ij} + \beta_9 dumport_i + \beta_{10} dumprod_k + \varepsilon_{ijk} \quad (1)$$

where:

- $lnic_{rijk}$ is the natural logarithm of import charges on the import flow of product *k* shipped from country *j* to Brazilian port *i* to be consumed in state *r*;
- α is the constant term;
- $lnkg_{rijk}$ is the natural logarithm of the weight of the import flow of product *k* shipped from country *j* to Brazilian port *i* to be consumed in state *r*;
- $lnvolume_{ij}$ is the natural logarithm of the total volume of shipments from country *j* to Brazilian port *i*;
- $sqlnvolume_{ij}$ is the square of the natural logarithm of the total volume of shipments from country *j* to Brazilian port *i*;
- $lnunitval_{rijk}$ is the natural logarithm of the U.S. dollar value of the specific shipment of product *k* shipped from country *j* to Brazilian port *i* to be consumed in state *r* divided by its weight in kilos;
- $lndist\_uf_{ri}$ is the natural logarithm of the distance between port *i* and destination state *r*;
- $sqlndist\_uf_{ri}$ is the square of the natural logarithm of the distance between port *i* and destination state *r*;
- $lndist\_part_{ij}$ is the natural logarithm of the distance between port *i* and origin country *j*;
- $sqlndist\_part_{ij}$ is the square of the natural logarithm of the distance between port *i* and origin country *j*;
- $dumport_i$ is the set of dummy variables for each Brazilian port; and,
- ε_{ijk} is the error term.

β_1 was expected to be positive, since the weight should be directly correlated with freight charges. Because of the potential for economies of scale due to the existence of fixed costs in shipping, and congestion due to scale, β_2 was expected to be negative and β_3 to be positive. The cost function for maritime transport includes both fixed and variable costs. Fixed costs include capital costs (i.e. payment by the armor to acquire the vessel) and fixed expenditures, such as payments to the crew, maintenance and insurance. Variable costs include fuel and scale expenditures (cost of port operations)[98]. The variables $lndist\_part_{ij}$ and $sqlndist\_part_{ij}$ were included in order to capture the variable share of maritime transportation costs. It was expected that such a quadratic form with β_7 positive and β_8 negative would represent a positive relationship between distance and freight costs in the presence of long-haul economies. In order

[97] This Annex draws on Santos (2007).
[98] Vieira (2003, pp. 83-84).

to deal explicitly with the infrastructure in the hinterland, the variable $lndist\_uf_{ri}$ and its quadratic form were included, while long-haul economies in the shipment of the imported product from the port of entry to the place of consumption were also considered likely. Consequently, β_5 was expected to be positive and β_6 was expected to be negative. Importantly these variables attempted to capture proximity externalities: for instance, stronger bargaining power tends to accrue to traders that are closer to port facilities. The last control, $lnunitval_{rijk}$, was expected to have a positive parameter, as higher insurance costs were imposed on more valuable commodities increasing total freight.[99]

The set of dummy variables for Brazilian ports were expected to capture the cost differential specific to each port or, in other words, differences in port efficiency. In the estimation, the dummy for the Port of Santos was dropped so that the interpretation of the results of the coefficients of the port dummy variables would be relative to the Port of Santos' effect on import charges, which is zero by construction. Since the dependent variable was in logarithm form, the coefficients β_9 approximately equal the percentage difference (in decimal form) in the port's effect on import charges relative to the Port of Santos effect, after controlling for all other factors. More precisely, a Port Efficiency Index (PEI_i) could be calculated based on these coefficients with the formula:

$$PEI_i = \exp(\beta_9^i) \qquad (2)$$

where:

PEI_i is the port efficiency index of port *i*;
β_9^i is the estimated coefficient of the dummy variable associated with port *i*.

The *PEI* for the Port of Santos was equal to one by construction. The index for the remaining ports reflected the extent to which port costs differed from those in Santos expressed as a percentage change. Ports that presented index values smaller than one are considered to be more efficient than Santos, while those that present values greater than one are less efficient.

A9.2 Data

Two main sources of data, were relied on as provided by the Brazilian Ministry of Development (ALICEWEB) and the United Nations (COMTRADE). Detailed information was assembled on state imports by product (six-digit HS code) by port of entry by country of origin for the year 2002 (the benchmark year). This information was taken from the ALICEWEB, and revealed, for each flow, its FOB price in U.S. dollar and its weight in kilos. Each flow was matched with its specific counterpart in the COMTRADE database, which does not identify either the state destination or the port of entry. Information in the COMTRADE database provides records for Brazilian imports, also using the six-digit HS code, in CIF prices in U.S. dollars, and identifies the country of origin as well. This matching procedure reduced the sample from around 100,000 records to 71,223 observations. Import charges were then calculated by subtracting the FOB

[99] Dummy variables for different products were also included, in lien with the chapter aggregation of the *Nomenclatura Comum do Mercosul* (NCM). The idea was to control for the effects of port specialization as well as the differences in transportation costs associated with particular characteristics of specific products.

values from the corresponding CIF values. Distance measures were obtained through geo-processing with the software TransCAD.

A9.3 Results

The model (1) was estimated using the method of instrumental variables to correct for endogeneity. The endogenous variables are $lnkg_{rijk}$, $lnvolume_{ij}$, $sqlnvolume_{ij}$ and $lnunitval_{rijk}$. The instruments used (all in logarithms) were the GRP (Gross Regional Product) of the destination state in Brazil, both in level and squared; the GDP of the foreign country, also in level and squared; the region's population and its squared size. The results of the estimation are presented in Table A9.1.[100] The fit of the model to the data is quite high, with R^2 of 0.91. Overall, the control coefficients had the expected signs and they were all significant at the 1% level.[101]

Table A9.1 Econometric Results

Variable	*Coefficient*	*Standard error*	*t-statistics*	*p-value*
lnkg	0.8195	0.0310	26.4000	0.0000
lnvolume	-0.1417	0.0374	-3.7900	0.0000
sqlnvolume	0.0055	0.0012	4.5800	0.0000
lnvaloru	0.5241	0.0338	15.5100	0.0000
lndist_uf	0.1027	0.0199	5.1500	0.0000
sqlndist_uf	-0.0140	0.0028	-4.9300	0.0000
lndist_parceiro	2.1650	0.1671	12.9600	0.0000
sqlndist_parceiro	-0.1032	0.0095	-10.8700	0.0000
ditajai	-0.1402	0.0379	-3.7000	0.0000
dparanagua	-0.0676	0.0217	-3.1100	0.0020
drio_de_janeiro	-0.0235	0.0196	-1.2000	0.2290
dsepetiba	0.1184	0.1468	0.8100	0.4200
drio_grande	-0.1699	0.0323	-5.2600	0.0000
dsalvador	-0.0795	0.0518	-1.5300	0.1250
dsao_fco_sul	-0.3279	0.0595	-5.5100	0.0000
dvitoria	-0.0430	0.0235	-1.8300	0.0670
daratu	0.4133	0.2011	2.0600	0.0400
dsuape	-0.2232	0.0521	-4.2800	0.0000
dfortaleza	-0.1243	0.0605	-2.0500	0.0400
dbelem	-0.2818	0.1514	-1.8600	0.0630

Source: Author's calculations

[100] For convenience, the estimated coefficients for the product dummies were omitted.
[101] For a detailed discussion of the results, refer to Santos (2007).

Annex 10
General Features of B-MARIA-27 Model

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. 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 of values in order to introduce non-constant returns to scale. Changes in the production functions of the manufacturing sectors[102] in each 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. The hierarchy of the nested CES structure of production was retained since it was convenient for the purpose of calibration (Bröcker, 1998a), but the hypotheses on parameters' values were modified, leading to a more general form. This modeling technique allows for the introduction of non-constant returns to scale by exploring local properties of the CES function. Care should be taken to keep local convexity properties of the functional forms in order to guarantee, from the theoretical point of view, the 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, the solution for which 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. At the subsequent upper-level substitution occurs between domestic composite and imported goods.

Equations for other elements in the 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's 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 of the private sector. Thus, government entrepreneurial behavior is dictated by the same cost minimization assumptions adopted by the private sector.

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

A unique feature of B-MARIA-27 is the explicit modeling of transportation services and the costs of moving products based on origin-destination pairs. The calibration of the model takes into account the specific transportation structure cost of each commodity flow and provides spatial price differentiation, which indirectly addresses the issue of regional transportation infrastructure efficiency. This structure is physically constrained by the available transportation network modeled in a geo-coded transportation module.[103] 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.

Government Finance Module

The government finance module incorporates equations determining the gross regional product (GRP) on both the 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 according to its main sources and their 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 determines the required relationship on the basis of the requirements of the specific simulation.[104]

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. To summarize, trade deficits are financed by increases in external debt.

Labor Market and Regional Migration Module

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

[103] See Haddad and Hewing (2005), for more details.

[104] 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).

Annex 11
The Structural Database, Behavioral Parameters and Closure of the B-MARIA-27

A11.1 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 social accounting matrix, updated to 2002. Previous work in this area has been successfully implemented in interregional CGE models for Brazil (e.g. Haddad, 1999, Domingues, 2002, Perobelli, 2004; Haddad and Hewings, 2005).

A11.2 Behavioral Parameters

Experience with the B-MARIA framework has suggested that interregional substitution is the key mechanism that drives the 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, which is of direct interest to our exercise, interregional trade flows should be incorporated into the model. Interregional 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 modelers frequently face is the lack of accurate information on trade elasticities at the regional level. The "rule of thumb" 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 to the proper estimation of key parameters. As a result, an extra effort was undertaken to estimate model-consistent regional trade elasticities for Brazil to be used in the B-MARIA-27 model. Estimates are presented in Table A11.1.

Table A11.1 Trade Elasticities in the B-MARIA-27 Model

	International	*Regional*
Agriculture	0.343	1.570
Manufacturing	1.278	2.079
Utilities	0.011	1.159
Construction	0.002	0.002
Trade	0.694	0.001
Financial institutions	0.137	1.385
Public administration	0.070	0.001
Transportation and other services	1.465	0.001

Source: Author's calculations

Other key behavioral parameters were properly estimated. These include econometric estimates for scale economies (Haddad, 2004); econometric estimates for export demand elasticities

(Perobelli, 2004); and 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 goods and services.

A11.3 Closures

In order to capture the effects of increases in port efficiency the simulations were carried out under two standard closures, the short-run and the long-run. The 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 assumptions of interindustry and interregional immobility of capital, the short-run closure would include fixed regional population and labor supply, fixed regional wage differentials, and a fixed national real wage. Regional employment is driven by the assumptions regarding wage rates, which indirectly determine regional unemployment rates. On the demand side, investment expenditures are fixed exogenously; that is, firms cannot reevaluate their investment decisions in the short-run. Household consumption corresponds with household disposable income, and real government consumption is fixed, at both regional and federal levels (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 in which capital is mobile across regions and industries is also used. Capital and investment are generally assumed to grow at the same rate. The main differences from the short-run are found in the labor market and the capital formation settings. In the first case, aggregate employment is determined by population growth, labor force participation rates, and the natural rate of unemployment. The distribution of the labor force across regions and sectors is fully determined endogenously. Labor is attracted to more competitive industries in more favored geographical areas, keeping regional wage differentials constant. Similarly, capital is oriented towards more attractive industries. This movement keeps rates of return at their initial levels.

Annex 12
Modeling Port Costs

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 account for transfer costs in a broad sense.[105] 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. In the case of imported goods, the implicit transportation margin refers to the costs at the port of entry, while for exports it refers to costs at the port of exit.

The general functional form used for the equations of different users' margin demand for imported goods[106] is presented below. It can be interpreted as the demand for port services related to import activity.[107]

$$XMARG(i,"foreign",q) = AMARG(i,"foreign",q)*[\eta(i,"foreign",q)*X(i,"foreign",q)^{\theta(i,"foreign",q)}] \quad (1)$$

where *XMARG(i,"foreign",q)* is the transportation margin on the flow of commodity *i*, produced abroad ("foreign") and consumed in region *q*; *AMARG(i,"foreign",q)* is a technology variable related to commodity-specific flows, which also enters the relevant purchasers' prices equations; $\eta(i,"foreign",q)$ is the margin rate on specific basic import flows; *X(i,"foreign",q)* is the flow of imported commodity *i* consumed in region *q*; and $\theta(i,"foreign",q)$ is a parameter reflecting scale economies for port activity related to imports.

In a similar fashion, the general functional form used for the equations of margin demand for exported goods is presented below. It can be interpreted as the demand for port services related to export activity.

$$X4MARG(i,s) = A4MARG(i,s)*[\eta 4(i,s)*X4(i,s)^{\theta 4(i,s)}] \quad (2)$$

where *X4MARG(i,s)* is the transportation margin on the flow of commodity *i*, produced in region *s* and consumed abroad; *A4MARG(i,s)* is a technology variable related to commodity-specific flows, which also enters the relevant purchasers' prices equations; $\eta 4(i,s)$ is the margin rate on specific basic export flows; *X4(i,s)* is the flow of exported commodity *i* produced in region *s*; and $\theta 4(i,s)$ is a parameter reflecting scale economies to port activity related to exports.

Calibration of equations (1) and (2) requires information on the transport margins related to each commodity flow. Aggregated information for margins on imported flows associated with

[105] Hereafter, transportation services and margins will be used interchangeably.
[106] Intermediate consumption, investment consumption, household consumption.
[107] Port services are produced within a regional resource-demanding optimizing transportation sector. A fully specified production possibility frontier (PPF) has to be introduced for the transportation sector, which produces not only services consumed directly by users but also services consumed to facilitate trade, such as port services.

intersectoral transactions, capital creation, household consumption, and exports are available at the national level. However, the problem remains as to how to disaggregate information concerning previous spatial disaggregation of commodity flows in the generation of the interstate social accounting matrix. Thus, given the available information—international trade commodity flows by states, port efficiency indices by ports, mapping of international transactions for each state by port of entry (imports) and port of exit (exports), and national aggregates for specific margins—the strategy adopted considered the following:

In the calibration of equation (1), *AMARG(i,"foreign",q)* was set equal to port efficiency indices calculated for each state *q*, PEI_q, invariable across commodities. To do that, state imports were first mapped by port of entry, as presented in Table A12.1. With the estimates of PEI_i for every port *i* (see section 4.3)[108], the PEI_q was built as weighted averages of the PEI_is using the share of each port in the total imports of a given state as the weights. Similar assumptions were used for equation (2).[109] The results are presented in Figure 4.7 (Chapter 4) for both import and export activities. The estimates for Brazil as a whole suggest that in the case of imports the port mix of the country's international trade would be 1.3% less costly had all the imports entered the country through the Port of Santos. Similarly, in the case of exports the national port mix is also more efficient (4% less costly) than a hypothetical concentration in Santos.[110]

Finally, both $\theta(i,"foreign",q)$ and $\theta 4(i,s)$ were set to one, for every flow.

[108] PEI_i for *i = other ports and other modes*, was set equal to one.
[109] In this case, the PEI estimates from section 4.3, based on import charges, were assumed to be valid for export activities as well.
[110] PEI_q for *q = total*, equals 0.987 and 0.960 for imports and exports, respectively.

Table A12.1 Port and Mode Distribution of State Imports and Exports, Brazil, 2002

(A) Imports

		State Destination																										
		AC	AP	AM	PA	RO	RR	TO	AL	BA	CE	MA	PB	PE	PI	RN	SE	ES	MG	RJ	SP	PR	SC	RS	DF	GO	MT	MS	Total
	Maritime	0.8117	0.8745	0.5260	0.9427	0.9160	0.2144	0.8307	0.5855	0.9035	0.9458	0.9882	0.9051	0.9197	0.8151	0.8948	0.7972	0.8296	0.8100	0.7543	0.6047	0.7644	0.6755	0.7559	0.2754	0.7987	0.7180	0.2949	0.6895
Port of Entry	Itajai	-	-	0.0000	-	-	-	-	-	0.0001	0.0001	-	-	0.0001	-	-	-	0.0021	0.0058	0.0007	0.0026	0.0108	0.3877	0.0048	0.0013	0.0049	0.0014	0.0035	0.0104
	Paranaguá	0.6991	-	0.0012	-	0.0032	-	0.0000	0.0020	0.0002	0.0000	-	-	0.0024	-	-	-	0.0007	0.0050	0.0026	0.0050	0.5903	0.0358	0.0028	0.0168	0.1384	0.4126	0.0257	0.0488
	Rio de Janeiro	-	0.0020	0.0012	0.0081	-	-	0.0194	0.0051	0.0036	0.0002	0.0005	-	0.0025	0.0039	0.0024	0.0244	0.0391	0.2781	0.3259	0.0085	0.0020	0.0055	0.0039	0.0516	0.0199	0.0030	0.0057	0.0591
	Sepetiba	-	-	0.0003	0.0009	0.0713	-	-	-	0.0002	-	-	-	-	-	0.0002	0.0053	0.0008	0.0401	0.3277	0.0011	0.0002	-	-	0.0067	0.0002	-	0.0037	0.0404
	Rio Grande	-	-	-	0.0013	-	-	-	-	0.0004	0.0012	-	0.0059	0.0001	-	-	-	-	0.0004	0.0005	0.0005	0.0050	0.0103	0.3709	0.0025	0.0003	0.0760	-	0.0290
	Salvador	-	-	-	0.0019	-	-	-	0.0190	0.4468	0.0001	-	0.0030	0.0022	0.2999	0.0299	0.2286	0.0016	0.0021	0.0000	0.0002	0.0000	0.0004	-	0.0014	0.0003	-	-	0.0188
	São Francisco do Sul	-	-	0.0002	0.0001	0.0011	-	-	-	0.0001	-	-	-	-	-	-	-	0.0005	0.0001	0.0000	0.0012	0.0970	0.1942	0.0024	0.0140	0.0064	0.0515	0.0000	0.0119
	Vitória	-	-	-	0.0005	-	-	-	0.4864	0.0120	0.0388	0.0007	0.0238	0.0014	-	0.2615	0.2268	0.7689	0.2854	0.0045	0.0022	0.0010	0.0033	0.0001	0.0063	0.2042	0.0084	0.0012	0.0546
	Aratu	-	-	-	-	-	-	-	-	0.3694	-	-	-	0.0337	-	-	-	0.0001	-	-	0.0008	-	-	-	-	-	-	-	0.0156
	Suape	-	-	-	0.0001	-	-	-	0.0117	0.0003	0.0105	0.0011	0.2415	0.6878	0.0031	0.1709	0.1070	-	0.0000	0.0001	0.0001	0.0000	-	0.0000	0.0003	0.0001	-	-	0.0136
	Fortaleza	-	-	-	0.0013	-	-	-	0.0007	0.0000	0.8898	0.0085	0.0021	0.0008	0.4169	0.0566	-	-	0.0002	0.0000	0.0000	0.0000	-	0.0000	0.0001	-	-	-	0.0125
	Belém	-	0.0824	-	0.5271	-	-	-	-	-	-	0.0413	-	0.0000	-	0.0000	-	-	0.0000	0.0000	0.0001	-	-	-	0.0025	-	-	-	0.0036
	Santos	0.0496	0.0609	0.0003	0.0079	0.0022	-	0.8112	0.0606	0.0179	0.0052	0.0001	0.0114	0.0187	-	-	0.0510	0.0157	0.1894	0.0268	0.5174	0.0510	-	0.0449	0.1720	0.4232	0.0951	0.1333	0.2468
	Other ports	0.0631	0.7292	0.5228	0.3934	0.8382	0.2144	-	-	0.0526	0.0001	0.9360	0.6174	0.1697	0.0913	0.3733	0.1540	0.0002	0.0033	0.0653	0.0647	0.0072	0.0383	0.3260	-	0.0007	0.0700	0.1219	0.1244
	Other modes	0.1883	0.1255	0.4740	0.0573	0.0840	0.7856	0.1693	0.4145	0.0965	0.0542	0.0118	0.0949	0.0803	0.1849	0.1052	0.2028	0.1704	0.1900	0.2457	0.3953	0.2356	0.3245	0.2441	0.7246	0.2013	0.2820	0.7051	0.3105
	Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

(B) Exports

		State Origin																										
		AC	AP	AM	PA	RO	RR	TO	AL	BA	CE	MA	PB	PE	PI	RN	SE	ES	MG	RJ	SP	PR	SC	RS	DF	GO	MT	MS	Total
	Maritime	0.9039	0.8289	0.3586	0.7292	0.9406	0.0529	0.9985	0.9983	0.9390	0.8959	0.9968	0.8653	0.8254	0.9171	0.9189	0.9514	0.9608	0.9180	0.8913	0.6711	0.9267	0.9022	0.8351	0.8101	0.8443	0.9553	0.8452	0.8087
Port of Exit	Itajai	0.5736	-	0.0004	0.0001	0.0916	-	-	-	0.0001	-	-	0.0000	0.0000	-	-	-	0.0000	0.0054	0.0003	0.0063	0.0892	0.4371	0.0505	0.0020	0.0533	0.0130	0.1811	0.0426
	Paranaguá	0.2431	-	0.0005	0.0016	0.6575	0.0472	0.0450	-	0.0002	-	0.0000	-	0.0000	-	-	-	0.0001	0.0073	0.0013	0.0223	0.7017	0.0740	0.0104	-	0.0706	0.1973	0.2474	0.0909
	Rio de Janeiro	-	0.0155	0.0060	0.0001	0.0182	-	-	-	0.0073	0.0004	0.0002	0.0001	0.0010	0.0004	0.0001	-	0.0107	0.2033	0.2716	0.0160	0.0024	0.0002	0.0010	0.0015	0.0013	0.0001	-	0.0455
	Sepetiba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.1007	0.3302	0.0004	0.0001	0.0000	0.0001	-	0.0000	-	-	0.0315
	Rio Grande	0.0635	-	-	0.0001	0.0004	-	0.0003	-	0.0025	0.0068	0.0029	0.0034	0.0038	-	-	0.0043	0.0000	0.0002	0.0026	0.0018	0.0050	0.0030	0.7128	-	0.0004	0.0023	0.0066	0.0789
	Salvador	-	-	0.0012	0.0000	-	-	0.0004	0.0171	0.4749	0.0002	-	0.0093	0.1096	0.0230	0.0013	0.3174	0.0009	0.0006	0.0001	0.0003	0.0000	0.0000	0.0001	-	-	-	-	0.0206
	São Francisco do Sul	0.0199	-	-	0.0001	0.0281	-	-	-	0.0002	-	-	0.0001	-	-	-	-	0.0000	0.0025	0.0004	0.0048	0.0743	0.3614	0.0158	-	0.0115	0.1216	0.1554	0.0351
	Vitória	-	-	-	0.0006	0.0146	0.0045	-	0.0001	0.0885	0.0008	-	0.0016	0.0001	-	0.0003	-	0.9466	0.4129	0.0039	0.0010	0.0002	0.0001	0.0000	0.7709	0.2946	0.0866	-	0.0968
	Aratu	-	-	-	-	-	-	-	-	0.2838	-	-	-	-	-	-	-	-	-	0.0000	0.0000	-	-	-	-	-	-	-	0.0116
	Suape	-	-	0.0002	0.0002	-	-	-	0.0229	0.0043	0.0057	0.0013	0.3517	0.3204	0.0001	0.2051	0.0143	0.0000	0.0000	0.0002	0.0001	-	-	0.0000	-	0.0000	-	-	0.0037
	Fortaleza	-	0.0042	-	0.0012	-	-	-	0.0030	0.0027	0.8167	0.0020	0.2609	0.0537	0.7172	0.3776	0.0017	-	0.0000	0.0000	0.0001	-	-	0.0025	-	-	0.0000	-	0.0109
	Belém	-	0.0558	0.0009	0.1819	0.0078	-	-	-	0.0001	0.0004	0.0222	-	0.0006	-	0.0000	-	0.0000	0.0000	0.0004	0.0002	0.0000	0.0000	0.0001	-	0.0000	0.0001	-	0.0074
	Santos	-	0.0004	0.0065	0.0026	0.0996	-	0.0604	0.0019	0.0141	0.0376	0.0008	0.0352	0.0169	0.0003	0.0019	-	0.0015	0.1841	0.0083	0.6158	0.0410	0.0058	0.0182	0.0358	0.4043	0.4429	0.2411	0.2579
	Other ports	0.0039	0.7530	0.3430	0.5407	0.0227	0.0012	0.8924	0.9533	0.0603	0.0274	0.9675	0.2028	0.3193	0.1761	0.3326	0.6137	0.0009	0.0010	0.2720	0.0020	0.0127	0.0205	0.0237	-	0.0082	0.0914	0.0136	0.0753
	Other modes	0.0961	0.1711	0.6414	0.2708	0.0594	0.9471	0.0015	0.0017	0.0610	0.1041	0.0032	0.1347	0.1746	0.0829	0.0811	0.0486	0.0392	0.0820	0.1087	0.3289	0.0733	0.0978	0.1649	0.1899	0.1557	0.0447	0.1548	0.1913
	Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Source: Author's calculations

Table A12.2 State Distribution of Imports and Exports by Ports and Modes, Brazil, 2002

(A) Imports

Port of Entry	State Destination																										
	AC	AP	AM	PA	RO	RR	TO	AL	BA	CE	MA	PB	PE	PI	RN	SE	ES	MG	RJ	SP	PR	SC	RS	DF	GO	MT	MS	Total
Maritime	0.0001	0.0002	0.0498	0.0071	0.0025	0.0000	0.0006	0.0020	0.0521	0.0185	0.0263	0.0022	0.0238	0.0003	0.0032	0.0025	0.0515	0.0626	0.1250	0.3685	0.0783	0.0193	0.0820	0.0050	0.0080	0.0046	0.0038	1.0000
Itajai	-	-	0.0002	-	-	-	-	-	0.0003	0.0001	-	-	0.0003	-	-	-	0.0084	0.0298	0.0080	0.1040	0.0730	0.7332	0.0342	0.0016	0.0033	0.0006	0.0030	1.0000
Paranaguá	0.0011	-	0.0017	-	0.0001	-	0.0000	0.0001	0.0002	0.0000	-	-	0.0009	-	-	-	0.0006	0.0055	0.0061	0.0433	0.8554	0.0145	0.0044	0.0043	0.0197	0.0375	0.0047	1.0000
Rio de Janeiro	-	0.0000	0.0013	0.0007	-	-	0.0002	0.0002	0.0024	0.0000	0.0002	-	0.0008	0.0000	0.0001	0.0009	0.0284	0.2510	0.6303	0.0601	0.0024	0.0018	0.0050	0.0108	0.0023	0.0002	0.0009	1.0000
Sepetiba	-	-	0.0004	0.0001	0.0033	-	-	-	0.0002	-	-	-	-	-	0.0000	0.0003	0.0008	0.0529	0.9272	0.0114	0.0003	-	-	0.0021	0.0000	-	0.0008	1.0000
Rio Grande	-	-	-	0.0002	-	-	-	-	0.0006	0.0006	-	0.0003	0.0001	-	-	-	-	0.0008	0.0020	0.0074	0.0122	0.0070	0.9559	0.0010	0.0001	0.0116	-	1.0000
Salvador	-	-	-	0.0005	-	-	-	0.0023	0.9436	0.0000	-	0.0003	0.0021	0.0043	0.0039	0.0262	0.0036	0.0058	0.0001	0.0055	0.0001	0.0004	-	0.0009	0.0001	-	-	1.0000
São Francisco do Sul	-	-	0.0012	0.0001	0.0002	-	-	-	0.0002	-	-	-	-	-	-	-	0.0018	0.0006	0.0002	0.0438	0.5766	0.3226	0.0153	0.0146	0.0037	0.0192	0.0000	1.0000
Vitória	-	-	-	0.0001	-	-	-	0.0207	0.0087	0.0096	0.0002	0.0007	0.0005	-	0.0117	0.0090	0.6028	0.2787	0.0093	0.0173	0.0013	0.0012	0.0001	0.0014	0.0259	0.0007	0.0002	1.0000
Aratu	-	-	-	-	-	-	-	-	0.9390	-	-	-	0.0385	-	-	-	0.0002	-	-	0.0223	-	-	-	-	-	-	-	1.0000
Suape	-	-	-	0.0001	-	-	-	0.0020	0.0008	0.0104	0.0015	0.0297	0.9020	0.0001	0.0307	0.0170	-	0.0000	0.0006	0.0045	0.0002	-	0.0003	0.0003	0.0001	-	-	1.0000
Fortaleza	-	-	-	0.0005	-	-	-	0.0001	0.0001	0.9625	0.0125	0.0003	0.0011	0.0091	0.0111	-	-	0.0007	0.0004	0.0013	0.0000	-	0.0001	0.0001	-	-	-	1.0000
Belém	-	0.0040	-	0.7628	-	-	-	-	-	-	0.2123	-	0.0001	-	0.0000	-	-	0.0001	0.0006	0.0115	-	-	-	0.0086	-	-	-	1.0000
Santos	0.0000	0.0000	0.0001	0.0002	0.0000	-	0.0017	0.0006	0.0029	0.0003	0.0000	0.0001	0.0014	-	-	0.0004	0.0027	0.0409	0.0124	0.8811	0.0146	-	0.0136	0.0086	0.0119	0.0017	0.0049	1.0000
Other ports	0.0000	0.0010	0.2743	0.0163	0.0127	0.0001	-	-	0.0168	0.0000	0.1381	0.0083	0.0244	0.0002	0.0073	0.0027	0.0001	0.0014	0.0600	0.2186	0.0041	0.0061	0.1960	-	0.0000	0.0025	0.0088	1.0000
Other modes	0.0000	0.0001	0.0997	0.0010	0.0005	0.0001	0.0003	0.0031	0.0124	0.0023	0.0007	0.0005	0.0046	0.0002	0.0008	0.0014	0.0235	0.0326	0.0904	0.5349	0.0536	0.0206	0.0588	0.0289	0.0045	0.0040	0.0204	1.0000
Total	0.0001	0.0002	0.0653	0.0052	0.0019	0.0001	0.0005	0.0023	0.0398	0.0135	0.0184	0.0017	0.0179	0.0003	0.0024	0.0022	0.0428	0.0533	0.1142	0.4202	0.0707	0.0197	0.0748	0.0124	0.0069	0.0044	0.0090	1.0000

(B) Exports

Port of Exit	State Origin																										
	AC	AP	AM	PA	RO	RR	TO	AL	BA	CE	MA	PB	PE	PI	RN	SE	ES	MG	RJ	SP	PR	SC	RS	DF	GO	MT	MS	Total
Maritime	0.0001	0.0003	0.0080	0.0347	0.0014	0.0000	0.0003	0.0063	0.0475	0.0102	0.0137	0.0021	0.0055	0.0009	0.0043	0.0008	0.0524	0.1224	0.0684	0.2833	0.1110	0.0598	0.1118	0.0005	0.0115	0.0360	0.0068	1.0000
Itajai	0.0009	-	0.0002	0.0001	0.0027	-	-	-	0.0001	-	-	0.0000	0.0000	-	-	-	0.0000	0.0136	0.0004	0.0507	0.2027	0.5495	0.1283	0.0000	0.0138	0.0093	0.0277	1.0000
Paranaguá	0.0002	-	0.0001	0.0007	0.0090	0.0001	0.0001	-	0.0001	-	0.0000	-	0.0000	-	-	-	0.0000	0.0087	0.0009	0.0839	0.7478	0.0436	0.0123	-	0.0086	0.0661	0.0177	1.0000
Rio de Janeiro	-	0.0001	0.0024	0.0001	0.0005	-	-	-	0.0066	0.0001	0.0000	0.0000	0.0001	0.0000	0.0000	-	0.0104	0.4814	0.3704	0.1197	0.0052	0.0003	0.0023	0.0000	0.0003	0.0001	-	1.0000
Sepetiba	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3446	0.6506	0.0043	0.0003	0.0000	0.0002	-	0.0000	-	-	1.0000
Rio Grande	0.0001	-	-	0.0001	0.0000	-	0.0000	-	0.0013	0.0008	0.0004	0.0001	0.0003	-	-	0.0000	0.0000	0.0002	0.0021	0.0076	0.0061	0.0020	0.9774	-	0.0001	0.0009	0.0005	1.0000
Salvador	-	-	0.0010	0.0000	-	-	0.0000	0.0042	0.9435	0.0001	-	0.0009	0.0289	0.0009	0.0002	0.0098	0.0018	0.0029	0.0003	0.0048	0.0000	0.0000	0.0005	-	-	-	-	1.0000
São Francisco do Sul	0.0000	-	-	0.0001	0.0010	-	-	-	0.0002	-	-	0.0000	-	-	-	-	0.0000	0.0076	0.0006	0.0465	0.2052	0.5519	0.0486	-	0.0036	0.1056	0.0289	1.0000
Vitória	-	-	-	0.0002	0.0002	0.0000	-	0.0000	0.0374	0.0001	-	0.0000	0.0000	-	0.0000	-	0.4312	0.4599	0.0025	0.0037	0.0002	0.0000	0.0000	0.0037	0.0335	0.0273	-	1.0000
Aratu	-	-	-	-	-	-	-	-	0.9992	-	-	-	-	-	-	-	-	-	0.0001	0.0007	-	-	-	-	-	-	-	1.0000
Suape	-	-	0.0007	0.0023	-	-	-	0.0318	0.0480	0.0143	0.0039	0.1923	0.4762	0.0000	0.2131	0.0025	0.0000	0.0005	0.0026	0.0113	-	-	0.0004	-	0.0000	-	-	1.0000
Fortaleza	-	0.0001	-	0.0044	-	-	-	0.0014	0.0101	0.6942	0.0020	0.0480	0.0268	0.0539	0.1319	0.0001	-	0.0001	0.0001	0.0018	-	-	0.0251	-	-	0.0000	-	1.0000
Belém	-	0.0021	0.0021	0.9433	0.0013	-	-	-	0.0003	0.0005	0.0331	-	0.0004	-	0.0000	-	0.0000	0.0007	0.0032	0.0111	0.0004	0.0001	0.0008	-	0.0000	0.0005	-	1.0000
Santos	-	0.0000	0.0005	0.0004	0.0005	-	0.0001	0.0000	0.0022	0.0013	0.0000	0.0003	0.0004	0.0000	0.0000	-	0.0003	0.0770	0.0020	0.8151	0.0154	0.0012	0.0076	0.0001	0.0173	0.0524	0.0061	1.0000
Other ports	0.0000	0.0028	0.0824	0.2764	0.0004	0.0000	0.0033	0.0642	0.0328	0.0034	0.1424	0.0054	0.0230	0.0019	0.0168	0.0052	0.0005	0.0014	0.2243	0.0091	0.0164	0.0146	0.0340	-	0.0012	0.0370	0.0012	1.0000
Other modes	0.0000	0.0002	0.0606	0.0545	0.0004	0.0005	0.0000	0.0000	0.0130	0.0050	0.0002	0.0014	0.0050	0.0004	0.0016	0.0002	0.0090	0.0462	0.0353	0.5868	0.0371	0.0274	0.0933	0.0005	0.0090	0.0071	0.0053	1.0000
Total	0.0001	0.0003	0.0181	0.0385	0.0012	0.0001	0.0003	0.0051	0.0409	0.0092	0.0111	0.0020	0.0054	0.0008	0.0038	0.0006	0.0441	0.1078	0.0621	0.3413	0.0969	0.0536	0.1082	0.0005	0.0110	0.0305	0.0065	1.0000

Source: Author's calculations

Changes in port efficiency can be calculated either through changes in the weights matrix (Table A12.2) or in the *PEI*s' estimates for a given port or set of ports. They can then be incorporated in the interstate CGE model as follows. Rearranging equations (1) and (2), we have:

$$\frac{XMARG(i,"foreign",q)}{X(i,"foreign",q)^{\theta(i,"foreign",q)}} = AMARG(i,"foreign",q) * \eta(i,"foreign",q) \qquad (1')$$

$$\frac{X4MARG(i,s)}{X4(is)^{\theta(is)}} = A4MARG(i,s) * \eta 4(i,s) \qquad (2')$$

with both $\theta(i,"foreign",q)$ and $\theta 4(i,s)$ equal to one, implying that the left-hand side is equivalent to the specific margin rate multiplied by the efficiency index. A percentage change in the margin rate or in the use of port services by trade flow can then be mapped into the technology variable or the state port efficiency index. Thus, in percentage-change form *amarg(i,"foreign",q)* and *a4marg(i,s)* become the relevant linkage variables, as:

$$xm\arg(i,"foreign",q) - x(i,"foreign",q) = am\arg(i,"foreign",q) \qquad (3)$$

and

$$x4m\arg(i,s) - x4(i,s) = a4m\arg(i,s) \qquad (4)$$

The parameters $\theta(i,"foreign",q)$ and $\theta 4(i,s)$ can also be used in the simulation phase, especially in sensitivity analysis experiments. Suppose, for instance, that scale effects to port activity appear for a given commodity flow in a specific port/state. Changing assumptions regarding the values of such parameters allows one to address this issue properly instead of relying on hypotheses on the linkage variables.

Annex 13
Basic Features of the B-MARIA-MG Model

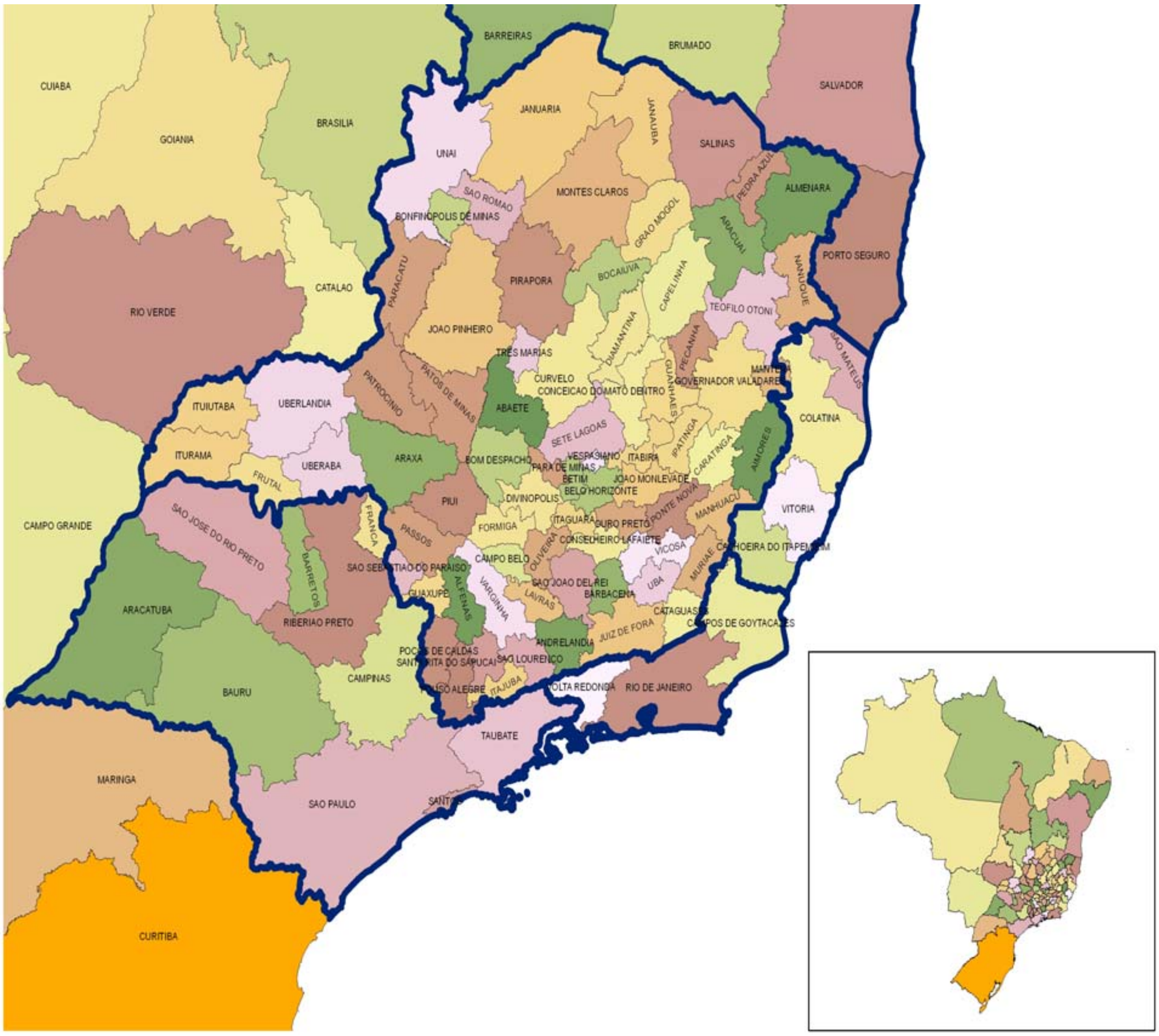
The structure of the interregional CGE model used in our simulations, B-MARIA-MG, represents a further development of the Brazilian Multisectoral And Regional / Interregional Analysis Model (B-MARIA), the first fully operational interregional CGE model for Brazil. Its theoretical structure builds on the MONASH-MRF Model (Peter et al. 1996), which represents one multi-regional framework in the ORANI suite of CGE models of the Australian economy. The version of B-MARIA used in this research contains over 140,000 equations in its condensed form, and it is designed for transportation policy analysis. Agents' behavior is modeled at the regional level, accommodating variations in the structure of regional economies. At a regional setting, the main innovation in the B-MARIA-MG model is its detailed treatment of interregional trade flows in the Brazilian economy, in which the markets connected by regional flows are fully specified for each origin and destination. The model recognizes the economies of 109 Brazilian regions, including 75 within the state of Minas Gerais (Figure A13.1). Results are based on a bottom-up approach in which national results are obtained from the aggregation of regional results. The model identifies 8 production/investment sectors in each region producing 8 commodities (Table A13.1), 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 (land, capital and labor) are used in the production process according to regional endowments. The model is calibrated for 2002, because a nearly complete data set is available for that year, and because it is the most recent year in which the full national input-output tables that served as the basis for the estimation of the interstate input-output database were published (Fipe, 2007).

Table A13.1 Sectors in the B-MARIA-MG Model

1	Agriculture
2	Mining
3	Manufacturing
4	Construction
5	Transportation
6	Trade
7	Public administration
8	Other services

The B-MARIA-MG framework explicitly includes some important elements from an interregional system which are necessary in order to better understand macro-spatial phenomena. These namely include interregional flows of goods and services, transportation costs based on origin-destination pairs, interregional movement of primary factors, regionalization of the transactions of the public sector, and regional labor markets segmentation. The additional structural modifications implemented in the basic model, which are related both to specification issues and to changes in the database are listed below.

Figure A13.1 Regional Setting in the B-MARIA-MG Model



The first major modification was the introduction of the possibility of (external) non-constant returns in the production process following Haddad (2004). This extension is essential in order to adequately represent one of the functioning mechanisms of a spatial economy. The modeling 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 about the parameter values in order to introduce non-constant returns to scale. Changes in the production functions of the manufacturing sector[111] in each of the

[111] Only the manufacturing activities were contemplated with this change.

109 regions were implemented in order to incorporate non-constant returns to scale, a fundamental assumption in the analysis of integrated interregional systems. The hierarchy of the nested CES structure of production, which is convenient for the purpose of calibration (Bröcker, 1998a), was kept intact but the hypotheses on parameter values were modified, leading to a more general form. This modeling technique allows for the introduction of parametric external scale economies (rationalized as agglomeration economies) by exploring local properties of the CES function. Care should be taken to keep local convexity properties of the functional forms in order to guarantee, from a theoretical standpoint, the existence of the equilibrium.

The second major modification, which addresses some of the modeling issues discussed in Annex 12, refers to the introduction of links between the interregional CGE core and a geo-coded transportation network model. This allows for a more adequate characterization of the spatial structure of the economy in which the role of transportation infrastructure and the friction of distance are explicitly considered. Within this more sophisticated specification of transportation costs, the analytical possibility of dealing with scale effects to transportation is also introduced. This is discussed in more detail in Annex 14.

Other lesser changes concern the expansion of the model's set of indicators to include other dimensions of socio-economic development, such as welfare, poverty, competitiveness, and regional concentration.[112] In the public debate, as observed by Dixon and Rimmer (2002), it is often useful to summarize the various results from the CGE simulations in a few figures. The welfare measure was derived from the underlying properties of the utility function. It refers to the equivalent variation, an indicator of welfare, and is included in the model in terms of monetary units for the benchmark year (BRL millions of 2002).[113] The poverty indicator is based on the interaction of changes in regional household income and region-specific poverty elasticities, estimated in Vinhais (2006), while the other indicators are calculated directly from the model's results.

[112] These measures were included from the perspective of the State of Minas Gerais only.
[113] The presentation of the results here focuses only on the economic growth indicator.

Annex 14
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*** 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.

As indicated in Annex 12 as well, 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 account for transfer costs in a broad sense.[114] 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 general functional form used for the margin demand equation is presented below:

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

where *XMARG(i,s,q,r)* is the margin *r* on the flow of commodity *i*, produced in region ***s*** 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)* is the flow of commodity *i*, produced in region ***s*** 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, transportation services (and trade services) are produced by a regional resource-demanding optimizing transportation (trade) sector. A fully specified production possibility frontier (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 commodity flow while providing for spatial price differentiation, which indirectly addresses the issue of regional transportation infrastructure efficiency. In this sense, space plays a major role.

The explicit modeling of transportation costs based on origin-destination flows and taking 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) becomes:

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

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

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

Integration in the Calibration Phase

In the interregional CGE model, it is assumed that the locus of production and consumption in each region is located in the center of each traffic zone. The transport model calculates the matrix of interregional transportation costs based on vehicle operating costs.[115] While the costs of road construction and maintenance consume a large proportion of national budgets, the costs borne by the road-using public for vehicle operation and depreciation are even greater. It is therefore important that road policies take account of total transportation costs. This requires quantitative methods for predicting performance and costs for both roads and vehicles over large and diverse road networks and under various investment and management policies and strategies (see Archondo-Callao and Faiz, 1994).

Data on the Brazilian network were obtained from the database developed for the PELT Minas (Fipe, 2007). As it is used here this data set includes not only the highway network, but also the railroad network, as well as other, less important modes of transportation in Minas Gerais, enabling the examination of multimodal alternatives. All data manipulation and network calculations were carried out using the general and the transport planning modules of the TransCAD software (Caliper, 2000).

Motor vehicle speeds and operating resources are determined by functions of the characteristics of each type of vehicle and the geometry, surface type and current condition of the road under both free flow and congested traffic conditions. The operating costs are obtained by multiplying the various resource quantities by the unit costs or prices, which are specified by the user in financial or economic terms.

The following components of vehicle operating cost were considered in this study: fuel consumption, lubricating oil consumption, tire wear, parts consumption, maintenance labor hours, depreciation, interest, crew hours and overhead.

Railroad costs used in this study were based on the actual freight values charged by operators. Thus, transport costs for each origin-destination pair were initially calculated by specific transport mode, in BRL/ton. These costs were then weighted by the tonnage use in each transport mode, which provided the necessary information for calibration of the model.[116]

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[115] The standard model *HDM-4 – Highway Development and Management* was used.
[116] Fully specified O-D matrices were available to carry on this procedure.

The process of calibration of the B-MARIA model requires information on the transport 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. The problem is how to disaggregate this information considering previous spatial disaggregation of commodity flows in order to generate the interregional input-output accounts, and the further available information – transport model, matrix of weighted multimodal transport costs, and national aggregates for specific margins.

In summary, the calibration strategy adopted here explicitly takes into account key elements of the Brazilian integrated interregional economic system for each origin-destination pair, namely: a) the type of trade involved (margins vary according to specific commodity flows); b) the multimodal transportation network; 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, a process which is discussed in the following section. Margin rates are calculated as a mark-up, considering the relationship between margins and their respective basic flows.

Integration in the Simulation Phase

When running simulations with B-MARIA 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-pocket transfer payments. The challenge becomes one of finding ways to translate such policies into changes in the matrix of interregional transportation costs. This matrix serves as the basis for integrating the transportation model to the interregional CGE model in the simulation phase and is provided by cost estimates using the HDM-4 model.

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 (1), as linkage variables. Changes in the matrix of interregional transport costs are calculated in the transport model, so that an interface with the interregional CGE model is created.

In the B-MARIA model, information on transport rates is available, and so is information on the relevant network links, enabling estimation of a model-consistent transportation cost function. By using this cost function changes in transport rates can be estimated and incorporated in the interregional CGE model. Rearranging equation (1), we have:

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

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

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