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Transport Costs in Brazil under the Light of Geographical Economics

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Summary

In the beginning there was only space. It was only after mankind started to worry and delft into metaphysical considerations about the limitation of their own existence on earth by counting days, seasons, years, that the notion of time came into existence. Yet, time has and will always be somehow connected to space, to movement across space. Geographical economics shrewdly captures the relative notion of time and space with the concept of transport costs. As long as there is a distance between things, it will take time to carry people, goods, knowledge, or information from one place to another. No matter how infinitesimal the dividing time or space between things may be made by technology, there will always be an economic cost related with the abridging of it. As long as our time on this common ground remains scarce, both time and space will have an opportunity cost associated with it and, therefore, an economic cost. Some will argue that, besides transport costs, there are many other determinants to the spreading or agglomeration of human activity over space. I do not dispute with them. Yet, for a geographical economics model to deserve praise, transport costs will have to be reflected in it one way or the other.

The level of transport costs has always played a significant part not only in the development of countries but also in the shaping of the urban scenario within countries and regions. The Brazilian roads system has in the past been the major driving force that propelled development and interconnectivity of urban systems across this continent-size country. Until recently the policy of the federal government had leaned towards granting users free access to roads in order to promote economic development. Under the argument of the 'failure of the state' in providing for the maintenance of the roads system, the federal government shifted its policy towards the privatization of the utility. The change, however, has been decided almost strictly upon political, managerial and financial considerations. Little attention has been given to the possible implications this abrupt policy change might have had on the ongoing economic development process of the affected cities and regions. Now, with the new insights offered by geographical economics, the opportunity of drawing a clearer picture of the issue is at hand. After gathering the necessary historic data, this research sets out to first offer a review of the recent displacements of economic activity over the Brazilian ground, then to present a description of geographical economics, its core model and its variant inclusive of congestion, of the Helpman–Hanson model of geographical economics, and finally we apply the core model of geographical economics to Brazilian recent reality. The expected outcome of this study is to offer politicians in Brazil a tool – shaped to fit more closely to a developing country's reality – to be used when deciding on policies that bear direct implications on trade and displacement of human activity across this continent-size country.

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1. Introduction

1.1. The History of Land Occupation in Brazil

Economics and Geography – or time and space, as you wish – have always come together to play a major role in the manmade sculpturing of the landscape. It has been no different in Brazil. In the XVI century, the first Portuguese colonizers started to occupy the coastal area of Brazil. Ease of access to natural sea harbors where logs, forest products, precious metals and stones were shipped to Europe gave rise to the first villages, some of which have grown to become the global cities of São Paulo and Rio de Janeiro. Coastal mountain ranges and dense forests covering the eastern shores of the upper South American continent prevented the first settlers from advancing much further into the hinterland. For hundreds of years human activity displayed a pattern of concentration along the American shoreline. The scares left on the natural landscape of coastal Americas by the historic occupation process are even visible today through satellite images. It is in this stretch of land where still nowadays lies the highest concentration of municipalities, population, and economic activity.

Figure 1.1. Brazilian States and Macro-regions

Only after the 1940's a more pronounced, coordinated process of gradual occupation beyond the Brazilian coastline towards primarily the Center-west macro-region[1] took place. This occupation process occurred at an incredible fast rate, driven mostly by the construction and upgrading of the federal roads system amid the central tropical forests and prairies of the country. At great human and capital costs, the construction and upgrading of the Brazilian federal roads system made transport costs and accessibility economically viable to hitherto almost isolated regions. After that, it took no more than 40 years for an area of land as big as the gigantic coastal Atlantic Forest – which had taken nearly 400 years to chop down – to be cleared and transformed into farms and urban agglomerations.

1.2. Recent Industrial Displacements in Brazil

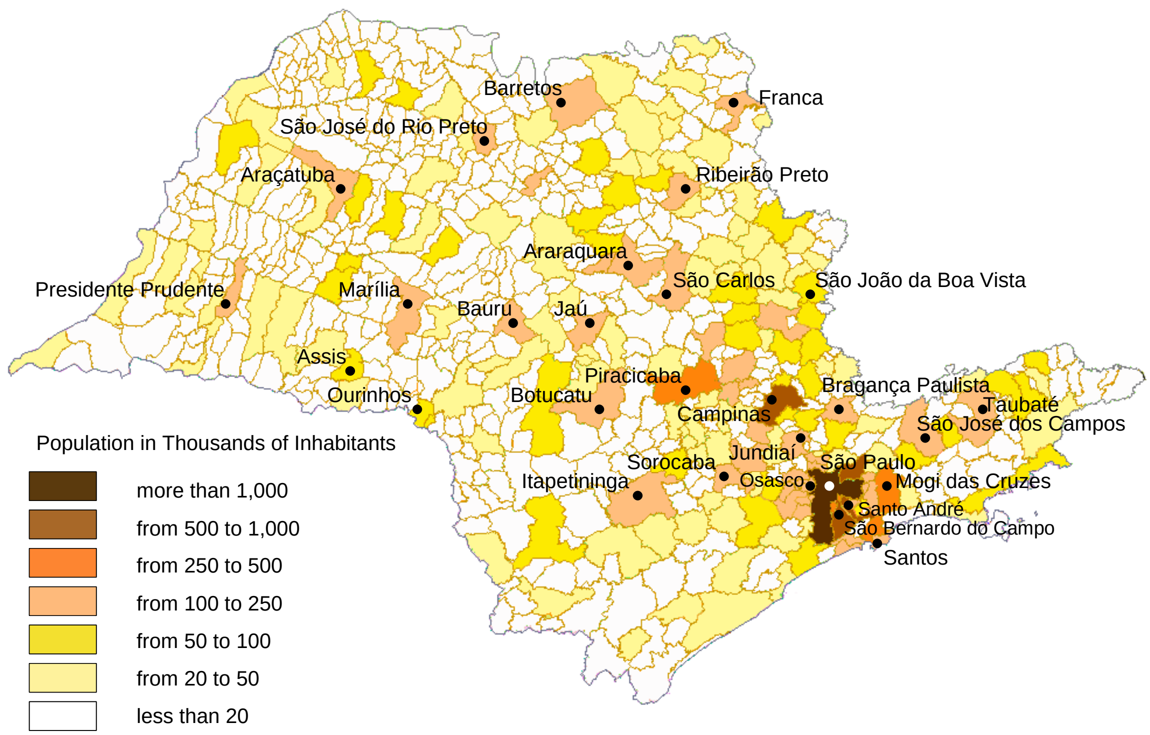
During the 50's, 60's and 70's Brazil could be characterized as a closed economy. National economic development master plans of most Latin American countries at that time exhibited a clear tendency to Import Substitution Industrialization (ISI) strategies aimed at guaranteeing economic independence from world markets and reducing external vulnerability. Protection of home markets through high trade barriers on imports, special incentives for the incipient manufacturing industry, and public investments in infrastructure were the main protectionist policy options adopted[2]. Ample use of such policies in Brazil resulted in the 70's in a somewhat integrated national market with the city of São Paulo as the major industrial center (as stated in IPEA, 1997[3]). In the 80's, the economic crisis – which the ISI policies of latter periods arguably helped to create – forced the termination of the Brazilian ISI strategy; trade barriers were lifted and both public and private industrial investments plummeted. The new scenario of decreasing public investments, privatization, and greater openness of the economy to foreign competition on manufactures of the 80's and 90's led to shifts in the location and in the diversification of the base of industrial activity[4]. Export oriented 'production islands' mushroomed in the country, increasing both the dispersion of economic activity and the heterogeneity of the industrial mix.

The movements in location occurred mainly from the city of São Paulo and from the state of Rio de Janeiro (both in the Southeast macro-region) towards other municipalities in the hinterland of the state of São Paulo, towards neighboring states, and towards states in the North and Center-west macro-regions of the country. Yet, some regions benefited relatively more from the de-concentration process by agency

[1] Refer to Figure 1.1. on the previous page for a description of Brazilian states and macro-regions (map adapted from the original available at www.ibge.gov.br).
[2] For a detailed analysis of ISI and trade policies in Latin America in the XX century see Meller (2000)
[3] IPEA stands in Portuguese for 'Institute for Applied Economic Research', a think-tank sponsored by the Brazilian federal government.
[4] For a more in depth account of the industrial and urban de-concentration process of the 80's and 90's refer to IPEA (2001).

of their proximity to the states of São Paulo and Rio de Janeiro. That is the case with the states of Bahia (Northeast macro-region), Paraná (South macro-region), and Minas Gerais (Southeast macro-region).

Figure 1.2. – The State of São Paulo and its Larger Municipalities



Noteworthy is the later displacement of industrial activity from the metropolitan area of the city of São Paulo to other urban agglomerations in the interior of the state of São Paulo, especially to the cities of Campinas, São Jose dos Campos, Ribeirão Preto, Sorocaba and Santos[5]. This movement gave rise in the hinterland of the state of São Paulo to an economic space currently second only to the metropolitan area of São Paulo in terms of VTI (Value of Industrial Transformation)[6]. According to IPEA (2001), the trend points to a concentration of the higher tier of technological industrial sectors in the metropolitan area of the city of São Paulo, which will eventually remain interconnected with secondary industries in the hinterland of the state and in neighboring states. Peripheral municipalities belonging to the metropolitan area of the city of São Paulo such as those in the 'ABC region' (comprising the cities of Santo André, São Bernardo, and São Caetano) have already received the bulk of displacements of R&D and quality control units. Other municipalities closer to the

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[5] Refer to Figure 1.2. for a description of the state of São Paulo and its more centralizing municipalities (map adapted from the original available at www.transportes.gov.br).

[6] For a discussion on the '*interiorization*' process of the industry of São Paulo refer to Negri, 1996.

city of São Paulo such as Campinas and Santos have also benefited relatively more from the process. The degree of industrial spreading towards other municipalities in the inland seems to decrease with the distance – and to the ease of road access – to the city of São Paulo.

Enlargement of the Brazilian industrial base accompanied the industrial location movements observed in the 80's and 90's. Primary transformation of natural resources started to account for an increasing share of national exports. Both the diversification of the industrial export base and the changes in location have been more clearly characterized by the paper and cellulose industry in the states of Espírito Santo and Minas Gerais (Southeast macro-region), in the states of Paraná and Rio Grande do Sul (South macro-region), and in the state of Bahia (Northeast macro-region); by the plastics industry in the South and Northeast macro-region, and in the state of Minas Gerais (Southeast macro-region); by the leather products industry in the state of Rio Grande do Sul (South macro-region) and in the Northeast macro-region; by the ore transformation industry in almost all of the Brazilian macro-regions; by the chemicals industry especially in the state of Bahia (Northeast macro-region), followed by the states of Paraná (South macro-region) and Minas Gerais (Southeast macro-region); and by the metallurgy industry in the states of Minas Gerais (Southeast macro-region) and Bahia (Northeast macro-region). Light-durable consumption goods industries were not left outside the de-concentration process. Yet, in relative terms the most dynamic sectors of the national industry remained concentrated in the metropolitan area of São Paulo, which continued to display interconnections with related industries in the hinterland of the state and with most other regional industries outside the state. The new productive layouts that are becoming increasingly more the rule in the Brazilian manufacturing sector is similar to that characteristic of the globalized world, that is, a greater subdivision of the production value-chain into intermediary plants organized in multiple part-supplier and assembler systems. By and large, the most industrialized regions of the 70's suffered relatively more with the policy changes of the 80's and 90's due to their intra-industry dependency. Peripheral regions with competitive advantages for agro-industries and for the installation of intermediary production plants tended to attract those industries fleeing the metropolitan areas of São Paulo and Rio de Janeiro, reaping therefore the most benefits from the de-concentration process. According to IPEA (2001), it remains unclear in the foreseeable future any tendency to either agglomeration or spreading of manufacture activity in Brazil. The Northeast macro-region holds a comparative advantage for the future location of unskilled labor-intensive industries such as textiles, shoes, and garments. Techno-mechanical industries tend to keep on de-concentrating from the city of São Paulo towards interior cities within the state of São Paulo and to other states in the South and Southeast macro-regions.

1.3. Recent Agricultural Displacements in Brazil

Similarly to what was observed with the de-concentration process of the Brazilian industry, both location and diversification of the agriculture sector underwent significant transformations during the 80's and the 90's. National agriculture growth rates for the period were higher than the average national industrial growth rates. In spite of the contraction of publicly subsidized credit – a policy shift in accordance with the fiscal crisis of the late 80's – the agricultural sector grew at rates higher than national GDP, partially offsetting the overall negative effects of the industrial crisis on the economy as a whole. In tandem with what had already been happening in the 70's, during the 80's and 90's the Brazilian agriculture sector continued to incorporate the latest technological advances with considerable gains in productivity. The land concentration process continued with the ensuing labor migration from rural areas to urban areas. Yet, conversely to the 70's, the first half of the 80's was marked by a deterioration and ensuing fragmentation of smaller rural properties resulting in more inequality and increased poverty. Cultivated areas that implemented technology usually did so without incorporating additional labor. New areas cleared for cultivation did so incorporating precarious labor conditions and very little technology[7]. The expansion of the cultivated area also continued in the 80's and 90's but – comparatively to the 70's – the far greater increase of absolute production of the sector during the two decades had a lot more to do with the overall gains in efficiency of rural production systems than with increases in cultivated land area. Agriculture, however, grew relatively more in other states of the Federation than in the industrialized state of São Paulo, where much of the rural land occupation of late has been related far less to agricultural activities than to urbanization processes[8].

The increase in export-oriented production, which augmented the participation of Brazilian agro-businesses in international commodity markets, was the touchstone of the diversification of the agriculture sector during the 80's and 90's. Some examples are useful to depict the process. The increasing demand from Asian international markets turned soybean cultivation into an extremely dynamic agro-industry incorporating high-tech production practices with a network of storage and processing facilities. That was the case in the Center-west macro-region states of Goiás, Mato Grosso, and Mato Grosso do Sul, which in little more than one decade became responsible for more than 40% of the soybean production capacity of the entire country. At the beginning of 1992, the Brazilian hard-soybean-oil output was roughly 100,000 tons/day. Of the 100 soybean grinding mills, 18 were installed in the state of São Paulo, 32 in the state of Paraná, and 26 in the state of Rio Grande do Sul. Yet, by the end of 1992, the grinding capacity of the Center-west macro-region, including the

[7] For a more in depth account of the agriculture development process in Brazil during the 80's and 90's refer to IPEA (2001).
[8] For more details concerning the observation refer to Silva, 1996.

states of Minas Gerais (Southeast macro-region) and Bahia (Northeast macro-region), already accounted for 20% of the national hard-soybean-oil output, or 19.5 tons/day. The relative displacement of soybean-cultivated land was accompanied by the relative displacement of grinding facilities. The more specialized refined-soybean-oil industry, however, remained concentrated in the southern and southeastern states of São Paulo with 66 plants, Paraná with 14 plants, and Rio Grande do Sul with 6 installed plants. These plants accounted for 50%, 17%, and 14% of the total national output, respectively[9]. During the period, as the export performance of ground-grain and soybean-oil started to reward less relative to that of hard-grain, larger national agro-industrial enterprises diversified and integrated soybean with frozen meat production. The strategy of agro-industrial multinationals, on the other hand, focused on the integration of the production of hard-grain, hard and refined-soybean-oil, and soybean sub-products. The white-meat agro-industrial complex remained concentrated in the South macro-region, responsible for over 70% of the national production. According to IPEA (2001), however, recent investments in the Center-west and Northeast tend to cause the de-concentration of the industry towards those macro-regions. The southern agro-industries will tend to focus on local southern and on international markets, while the center-western and northeastern industries will tend to focus on both center and northern national markets. During the 80's, public investments in the "*Proalcool*"[10] program had its greatest impact in the state of São Paulo, by far the major national ethanol producer and fuel consumer. In the 90's the phasing down of the federal "*Proalcool*" program coupled with rising prices of sugar in international markets led to the de-concentration of both ethanol and sugar production. The state of São Paulo nevertheless maintains the national leadership of the sugar-cane industry. In the 80's the citrus sector demonstrated growing rates of exports, mainly of orange-juice. According to IPEA (2001), although the state of São Paulo withholds 90% of the national orange-juice production capacity, there is strong tendency for de-concentration of the fruit industry in general due to new investments in projects in the states of Paraná (South macro-region), Sergipe (Northeast macro-region), and Goiás (Center-west macro-region).

Despite the good performance of the agro-business in the State of São Paulo, the aggregate movement of the sector has shown a strong trend for the spreading towards other states and regions, as it had been observed in latter periods. Though in the 80's and 90's such process was more intense towards states in the South, Southeast, and Center-west macro-regions, it has now disseminated throughout the country (IPEA,

[9] Data obtained from Castro and Fonseca (1995).

[10] The "*Proalcool*" program of the Brazilian federal government, implemented shortly after the oil crisis of the 70's, supported the expansion of sugar-cane cultivated area and the installation of distilling plants for the production of ethanol, which was perceived at the time as an economically viable alternative fuel to be used either by a fleet of automobiles running solely on ethanol or as an admixture to gasoline in the gasoline-powered automobile fleet.

2001). Especially in the Northeast macro-region, public investments in infrastructure and irrigation, private investments in irrigation, installation of diversified agro-industrial plants (food processing, capital goods, packing, fertilizers, and building materials), and given the climate of the region – which allows for more than one harvest in the year – gave rise to regional high-tech, export oriented agro-industrial fruit producing and processing poles[11].

1.4. The Urbanization Process of the 80's and 90's

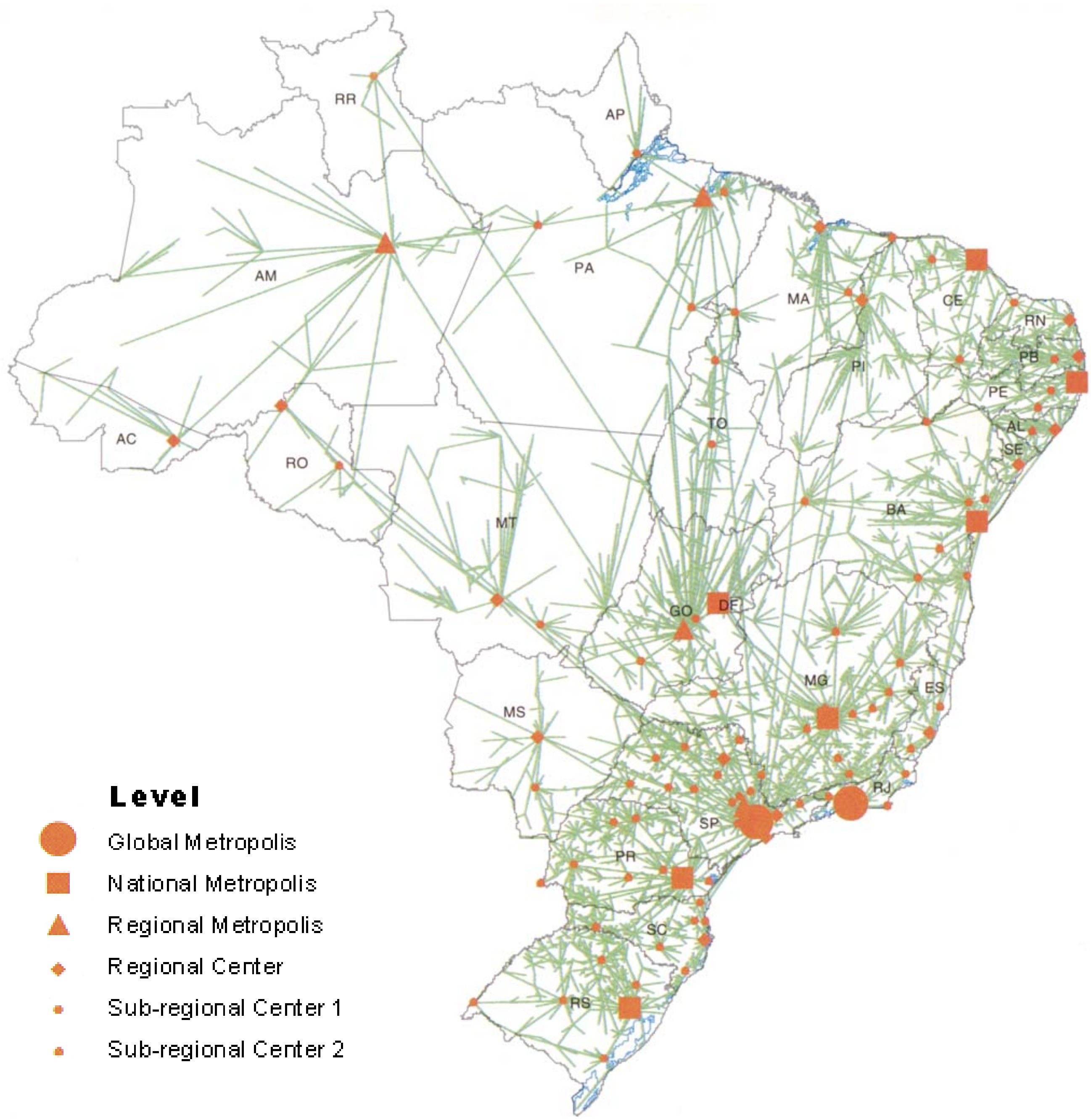
As it was put forth in IPEA (2001), the economic spreading of economic activity of the 80's and 90's increased the socio-economic heterogeneity in the development process of Brazilian cities. This process unfolded the following main characteristics: 1) higher relative population growth rates in the so-called economic *periphery* of the country; 2) lower relative growth rates in the metropolitan regions, especially in the capital of the states 3) higher relative growth rates in medium-size municipalities.

The de-concentration process of manufacturing activity of the 80's and 90's was captured mostly by medium-size cities located in other states of the South and Southeast macro-region, markedly in the hinterland of the state of São Paulo. The '*interiorization*' process of the industry of São Paulo during the 80's and 90's favored those municipalities counting on good infrastructure and easy of access to the federal roads system, further away from the congestion and associated problems of the larger metropolitan area. The good performance of sugar/ethanol and concentrated-citrus-juice agro-industries in the state favored the spreading process from the metropolitan area of the city of São Paulo towards smaller municipalities in the hinterland of the state, as for instance Ribeirão Preto, Araraquara, and São Carlos. Especially during the 90's, investments in irrigated, high-tech agriculture – the agro-business – and in export oriented natural resources industries retrofitted the shifting of human activity from the greater metropolises to municipalities in the *frontier* regions. The movement occurred from virtually every state capital along the coastal land stripe of Brazil towards municipalities in the Center-west and North macro-regions. The development of the agro-industry increased the relative participation in national production of the center-western states of Mato Grosso, Mato Grosso do Sul, Goiás and Tocantins, of the northeastern states of Bahia, Piauí, and Maranhão, and of the southeastern state of Minas Gerais. New municipalities sprang up amid the Amazon forest – which has increasingly been transformed in arable land – expanding the area of influence of the capitals of northern states. Except for the Northeast macro-region, in general the population of medium-size municipalities increased at rates higher than those of the state capitals. National migration movements to the metropolises of the southeastern states decreased considerably during the period. This spreading of economic activity

[11] For more details refer to Katz and Lima (1992) and to Lima (1993).

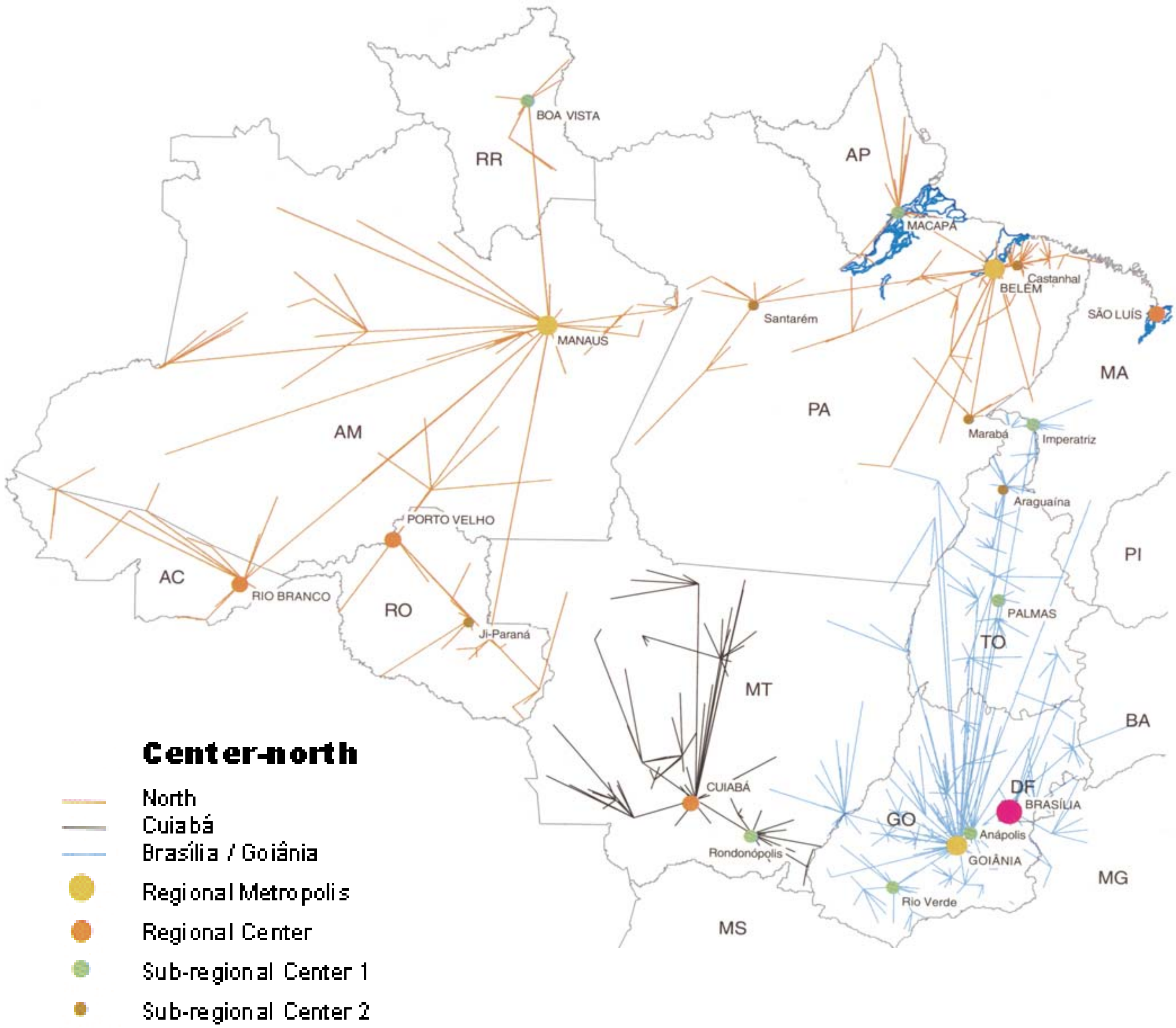
intensified the materialization of a web-like system of cities connected by paved roads over the Brazilian surface, an organization somewhat different from other countries in Latin America[12]. Nevertheless, both the new and the newly consolidated urban agglomerations remained under the influence of the major urban centers that existed before, strengthening the area of influence of such urban system.

Figure 1.3. Brazilian Urban Systems According to IPEA (2001)



[12] For more details refer to Tolosa, 1973, and to Faria, 1976.

Figure 1.4. Brazilian Center-north Urban Systems According to IPEA (2001)



Technical Note: Figures 1.3. to 1.6. offer a picture of the Brazilian urban systems and their areas of influence according to IPEA (2001). Such urban systems are named after the more centralizing urban cluster within its boundaries, generally but not necessarily the capital of the larger state in the region. These urban systems are: 1) *Porto Alegre*, comprising the state of *Rio Grande do Sul*, 2) *Curitiba*, comprising the states of *Paraná* and *Santa Catarina*, 3) *São Paulo*, comprising the states of *São Paulo* and *Mato Grosso do Sul*, 4) *Rio de Janeiro*, comprising the states of *Rio de Janeiro* and *Espírito Santo*, 5) *Belo Horizonte*, comprising the state of *Minas Gerais*, 6) *Brasília/Goiânia*, comprising the states of *Goiás* and *Tocantins*, 7) *Cuiabá*, comprising the state of *Mato Grosso*, 8) *Salvador*, comprising the states of *Bahia* and *Sergipe*, 9) *Recife*, comprising the states of *Alagoas*, *Paraíba*, *Pernambuco*, and *Rio Grande do Norte*, 10) *Fortaleza*, comprising the state of *Ceará*, 11) *Meio Norte/São Luís*, comprising the states of *Piauí* and *Maranhão*, and 12) *Norte*, comprising the states of *Amazonas*, *Pará*, *Amapá*, *Roraima*, *Rondônia*, and *Acre*. IPEA (2001) selected the municipalities belonging to the area of influence of each urban system under the criteria of connectivity and economic interdependency. The area of influence of some urban systems does not always respect administrative boundaries of states, sometimes outreaching municipalities in other neighboring states. When analyzing urban-system specific data, no adjustments were made to precisely include or exclude from urban systems such municipalities falling outside the boundaries of the comprising states. Had such adjustments been made, the differences from the figures and results herein obtained would have been negligible.

Figure 1.5. Brazilian Northeast Urban Systems According to IPEA (2001)

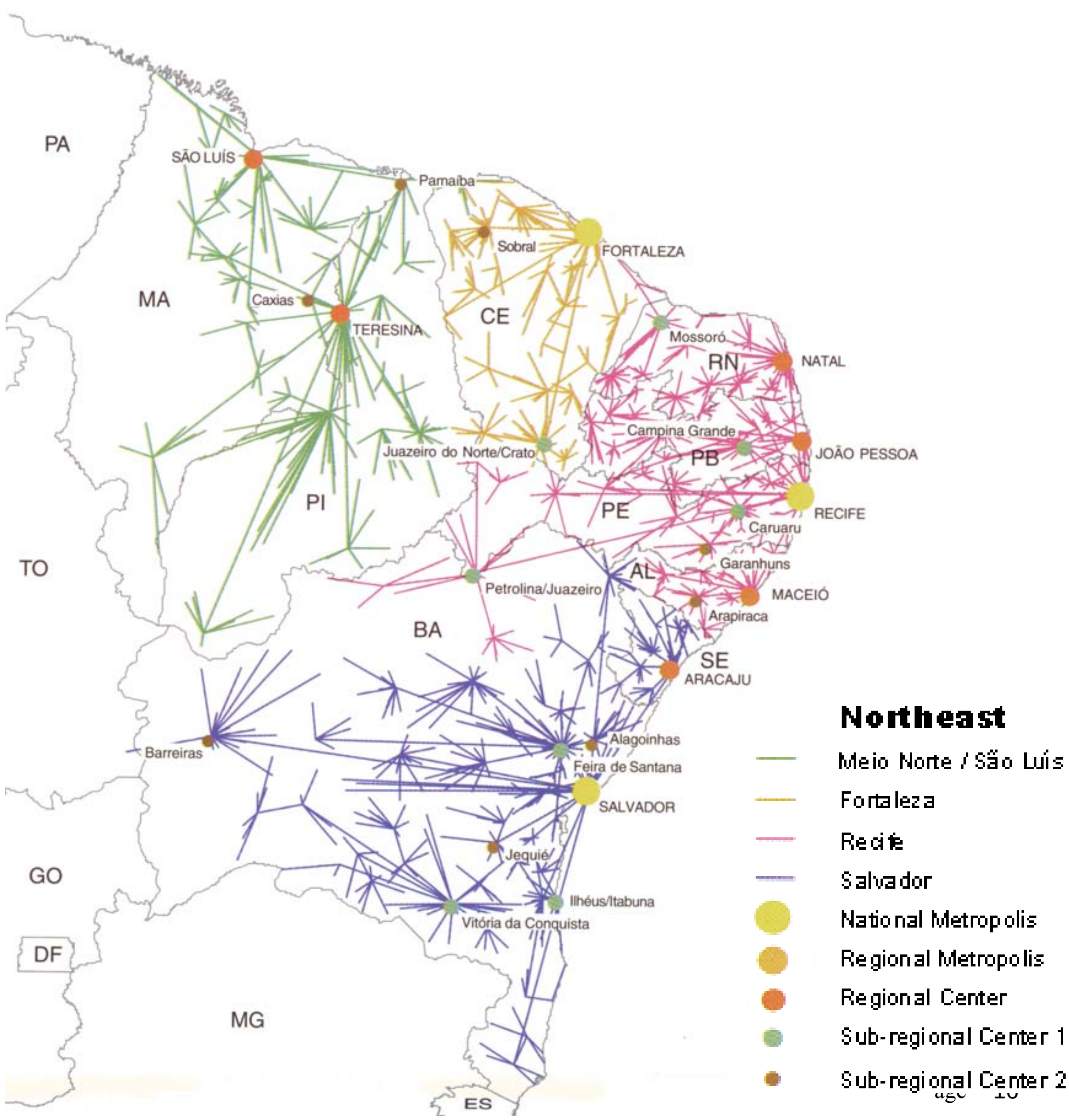
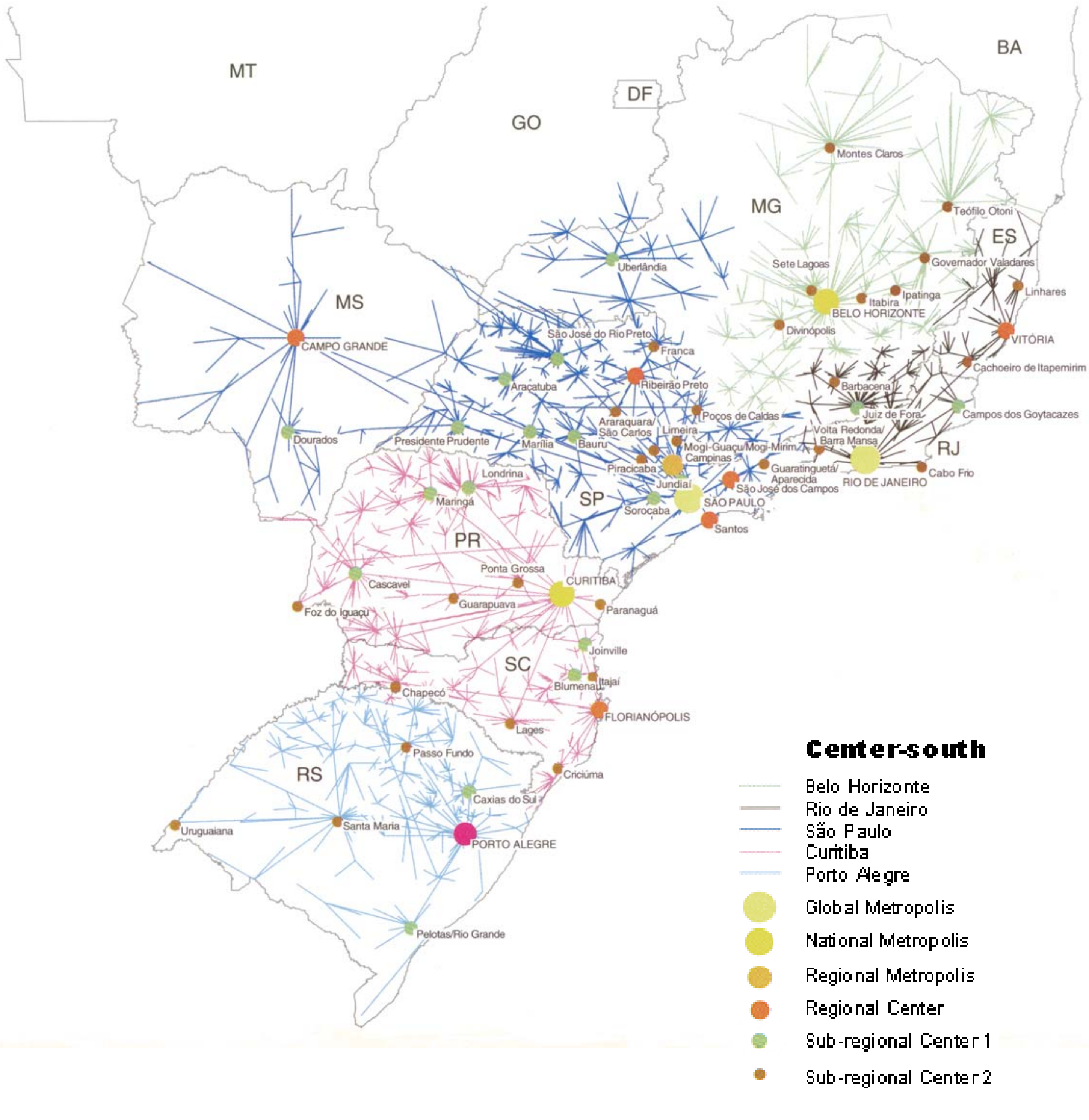


Figure 1.6. Brazilian Center-south Urban Systems According to IPEA (2001)



2. Research Scope

2.1. Two Basic Differences

The author of this paper would like to count on the time and resources necessary to perform experiments to check whether the geographical economics model devised by Professor Elhanan Helpman (1998) and the later practical experimentations carried out by Hanson (1998, 1999) are useful to describe recent and current spatial displacements of human activity in Brazil. This seems nonetheless a good suggestion for further research. This paper starts therefore with the examination of a few basic differences between the core model of geographical economics[13] and the Helpman–Hanson[14] model. Probably the most remarkable difference is that the latter substitutes the immobile agriculture sector of the core model with the non-tradable, mobile housing sector. From the review of physical displacements of economic activity in Brazil during the 80's and 90's it becomes intuitively clear that the assumption of immobility for the food sector makes little sense for the recent case of Brazil. The spreading process triggered by crisis in the manufactures sector in the 80's gave way to the relatively higher growth (when compared with manufactures), to the diversification, to the expansion, to the industrialization, and to the *physical displacement* of agricultural activity. This assertion can be empirically tested with the graphs presented in Figures 2.1. to 2.2.[15] on next page. If immobility of agriculture were to be proven empirically, absolute and relative growth patterns should have behaved in such a way that each urban system would have more or less kept its rank in relation to the other urban systems from 1960 to 2002. Conversely, the graphs reveal a highly uneven growth pattern among urban systems in absolute and – more strikingly – in relative terms. Although the urban system of São Paulo maintained its agricultural production pole-position for most of the period considered, other urban systems followed not very far behind, fiercely disputing and alternating in the intermediary positions, sometimes even challenging the leader. This uneven relative growth pattern in the agriculture sector does not find explanation solely in more efficient production methods employed in some of the already developed farmland. Though the industrialization of the agriculture sector explains a great deal of the productive increase and the resulting alternating relative production hierarchy of Brazilian regions and urban systems, new farmland has also gradually and constantly been acquired in the Brazilian frontier.

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[13] Refer to Krugman (1991).

[14] Refer to Helpman (1998) and to Hanson (1998, 1999).

[15] The graphs in figures 2.1. through 2.6. are based on production data collected from IPEA (available at www.ipeadata.gov.br) ranging from the years of 1960 to 2002. The data for all years is expressed in terms of the Brazilian currency, the *Real* (R$) adjusted for the value of the *Real* in the year 2000 using the GDP deflator calculated by the Brazilian 'FGV – *Fundação Getulío Vargas*'.

Figure 2.1. Agriculture Sector Absolute GDP (R$ Thousands of the year 2000) – 1960 to 2002

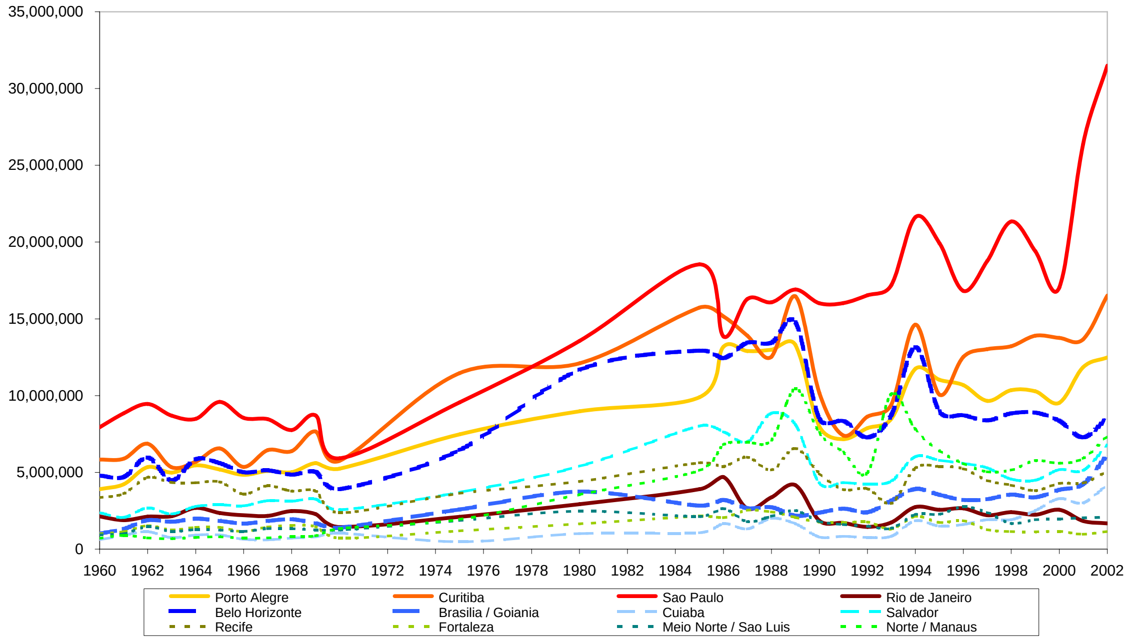
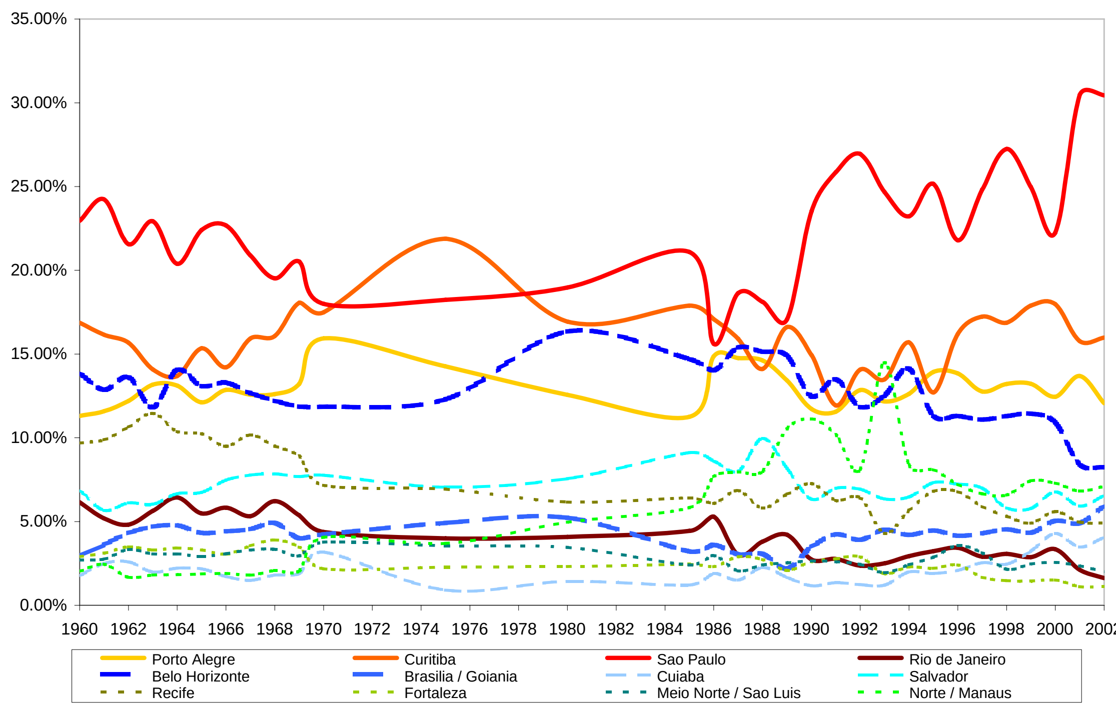


Figure 2.2. Agriculture Sector GDP as Percentage of National Total



Yet, for the sake of argumentation, suppose that technological improvements applied more intensively to existing farmland in certain regions in relation to existing farmland in other regions was alone responsible for the alternating intermediary production positions among urban systems. Even if such proposition were true, it would similarly lead to the conclusion of mobility in technological improvements applied to farmland and consequently of geographical mobility in agriculture production.

The assumption of immobility relative to their manufactures sector counterparts still fails to bear much resemblance to the recent picture of Brazil when farmers and workers in the agriculture sector are considered in isolation. The levels of technology, administration, and trade practices introduced in Brazilian agriculture have turned farming into an activity not very different from any other form of industrial activity. As a matter of fact, many businesses and wealthy individuals in Brazil have diversified their investments in both manufacturing and agricultural enterprises. One of the advantages of this kind of sector diversification lies in the fact that the time and costs involved in the shutting down of an industrial plant can be higher in comparison to the time and costs necessary for making farmland idle. Idle farmland can be made productive again in the next season – when market conditions are expected to have improved – at much lower costs than it would be feasible for most industrial plants. Production methods applied to farms can also be adjusted to yield a wider variety of products according to the demands of the market. In countries as Brazil where agriculture accounts for increasing shares of national production and exports, selling large farms quickly does not necessarily pose a problem because larger farms can always be parceled into smaller ones and sold separately, with greater gains for the seller. Another advantage perceived by businesses willing to hedge against economic downturns through diversification of activities is that high-tech, contemporary agriculture makes it possible – for the same levels of investment and production – to employ less workers relative to manufactures, allowing for greater maneuvering leeway in production management. Moreover, the abundance of under-developed and not-developed farmland in Brazil at relatively low prices can also have strong influences on the mobility of the agriculture sector when compared to the manufactures sector. Figures 2.3. to 2.6. on the following pages depict absolute and relative values of the manufactures sector and of the services sector production in Brazil from 1960 to 2002. As shown in the graphs, absolute and relative growth patterns in both manufactures and services behave much more constantly than what was observed in agriculture. Although intermediary positions in the former sectors do change sometimes from one urban system to another, the dynamism is much lower than that observed in the agriculture sector. From the analysis of the figures, the seemingly paradoxical conclusion for the recent Brazilian case points to a relatively higher immobility of the manufactures sector. The observation reinforces the assertion that in some circumstances it might harder to shut down an industrial plant than to temporarily turn farmland idle. In addition, when analyzing displacements of human activity in relative terms and considering farming just as another form of business owned by people, the assumption of mobility for the agriculture sector gains credibility even between different countries. Albeit land cannot be moved from one place to another, the ownership of land can change hands fairly easy. Farms and agro-industries not only can be owned by foreign individuals or multinationals, but have thus become a major source of Foreign Direct Investment (FDI) in Brazil and in many other countries. Were not for the protectionist agriculture policies and generous farm subsidies programs of the EU and the USA, agriculture in those regions would probably be a much more dynamic activity as well.

As previously discussed, according to IPEA (2001), for some decades before the 80's Brazilian fast economic growth supported high social vertical mobility underpinned by successive expansions of the manufactures labor market especially in urban areas that attracted large numbers of workers from almost every region of the country. In the 80's, the abrupt economic downturn locked vertical urban social mobility[16] giving way to horizontal – or geographical – social and sector mobility. The industrial base of metropolitan areas waned forcing real wages down and causing the deterioration of formal employment relations. The new context forced migrant workers who had been attracted by the job opportunities of the metropolises in latter decades to migrate back to their original regions or to medium-size cities within the area of influence of the metropolises. The Brazilian urban network acted therefore as a buffer to the negative migratory phenomenon of the metropolises in the 80's and 90's – marked by intra-regional, short distance movements – enhancing the area of influence of the Brazilian urban systems.

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[16] For more details refer to Faria (1992).

Figure 2.3. Manufacturers Sector Absolute GDP (R$ Thousands of the year 2000) – 1960 to 2002

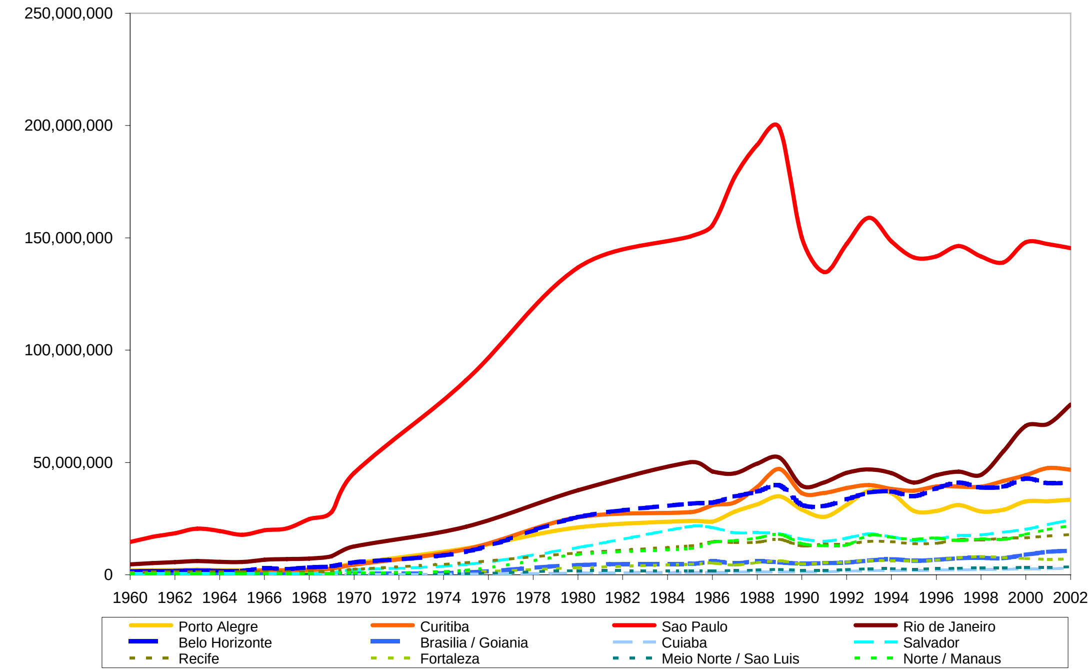


Figure 2.4. Manufactures Sector GDP as Percentage of National Total

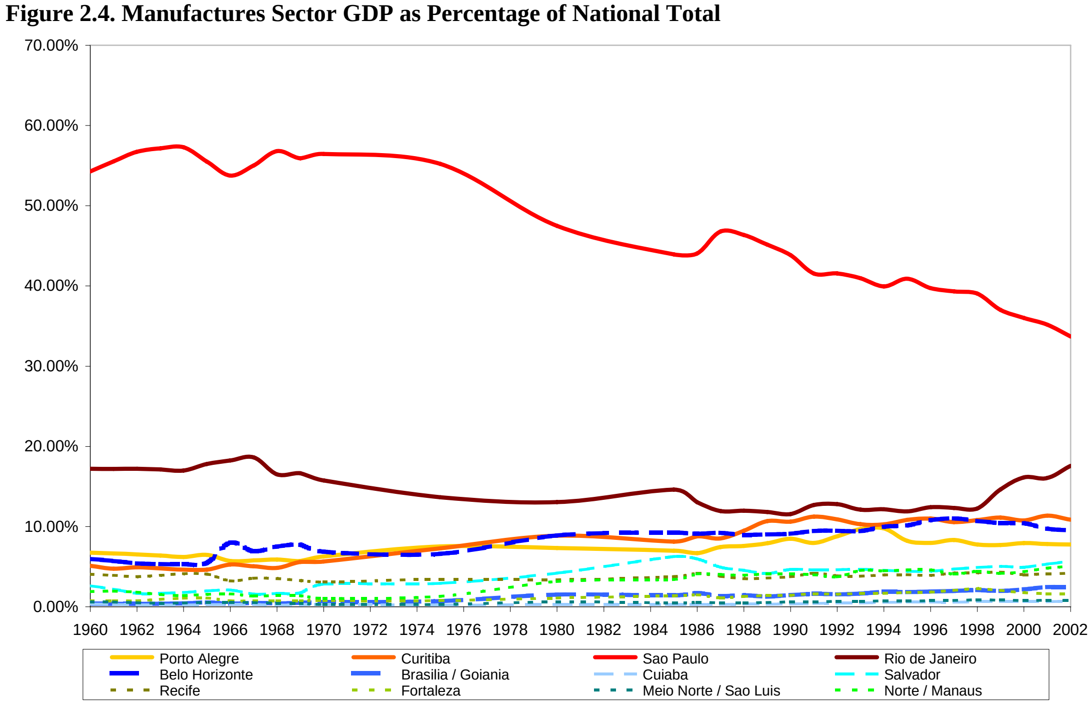


Figure 2.5. Services Sector Absolute GDP (R$ Thousands of the year 2000) – 1960 to 2002

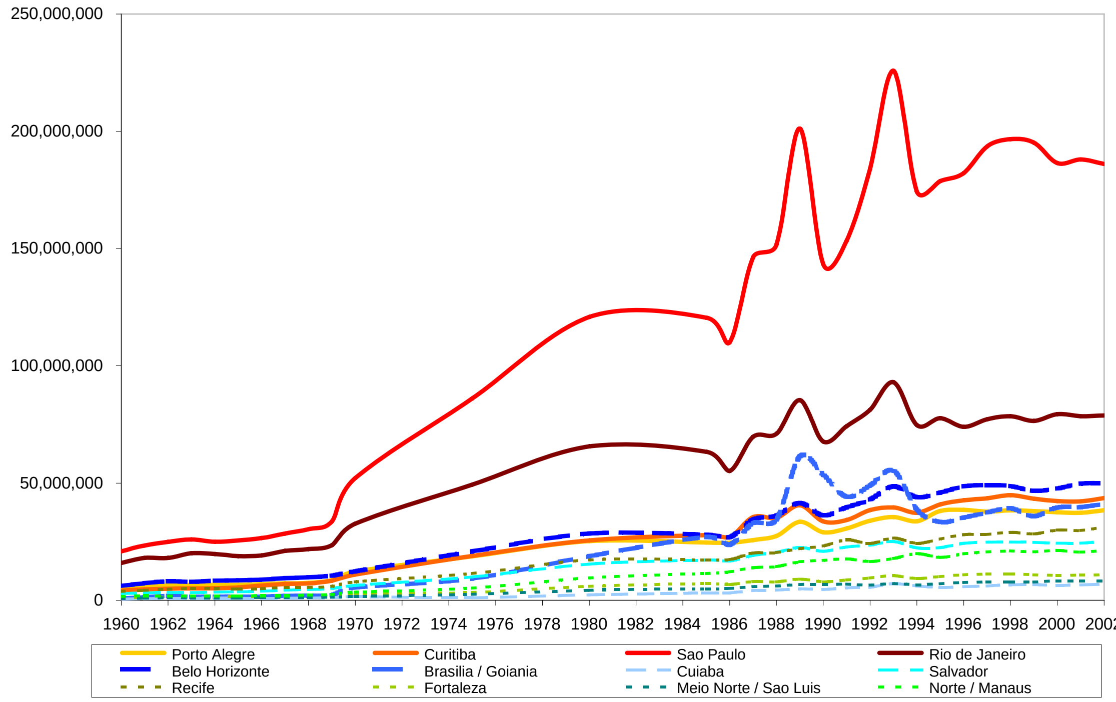
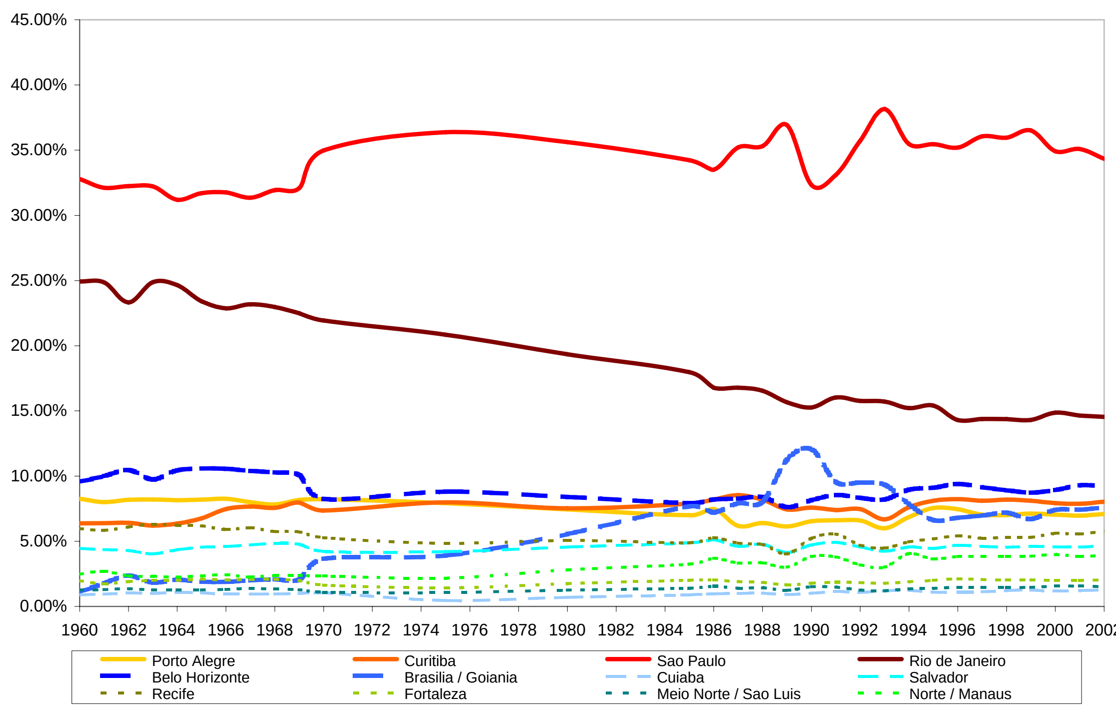


Figure 2.6. Services Sector GDP as Percentage of National Total



The spreading of economic activity across Brazil influenced the migration patterns of the population, which in turn affected the spreading of urbanization processes among cities and regions, feeding back into the spreading of human activity over time and space. Yet, the displacements of human activity in Brazil have been dynamically influenced by *both* the manufactures and the agriculture sectors acting together and playing very similar roles in the geographical economic scenario. It is becoming increasingly difficult to draw the economic boundary between what refers exclusively to agriculture and what refers exclusively to manufacturing. It is much easier and visible, however, to draw the physical dividing line between urban and rural areas, thus defining what is urban and what is rural population. Figures 2.7. to 2.14. on the next pages[17] help better understand migratory phenomena in Brazil during the 80's and 90's. States belonging to the Center-west, Northeast, and North macro-regions started to account for increasingly higher shares of the total national population, while the participation of the states situated in the more developed macro-regions of the South and Southeast participation in total national population gradually decreased. That was true for the relative shares of both national urban population and national rural population. Relative urban population in the southeastern urban systems of São Paulo, Rio de Janeiro, and Belo Horizonte decreased at faster rates arguably because of greater congestion problems in the metropolises. Though relative urban population in the southern urban system of Porto Alegre decreased less, again congestion performed an important task in the negative migration process. Relative urban population in the southern urban system of Curitiba increased at meager rates at the beginning of the period considered, and kept nearly constant thereafter. The reason might be that in the states of Paraná and Santa Catarina (and in their capital cities of Curitiba and Florianópolis, respectively) smaller populations better served by public investments in mass urban transport and in other public services together with the attractiveness of those urban systems to FDI was somewhat able to partly offset congestion problems and the ensuing negative migration processes observed in the other larger urban systems of the south and southeast. The northern urban systems of Norte/Manaus and Meio Norte/São Luís displayed increasing growth rates in relative urban populations. The same holds for the northeastern urban systems of Fortaleza and Salvador. The decreasing growth in relative urban population observed in the northeastern urban system of Recife at the beginning of the period was probably caused by the well known congestion problems of the capital city of Recife, though for most part of the 80's and 90's relative urban population figures remained constant. Urban systems occupying a more central position – in between the southern and southeastern urban systems and the northern and northeastern urban systems – namely the urban systems of Brasília/Goiânia and Cuiabá experienced increases in their relative urban population growth rates.

[17] The graphs in figures 2.7. to 2.14. are based on population and employment data collected from IPEA (available at www.ipeadata.gov.br) ranging from the years of 1970 to 2000.

Figure 2.7. Absolute Total Population in Brazil per Urban System – 1970 to 2000

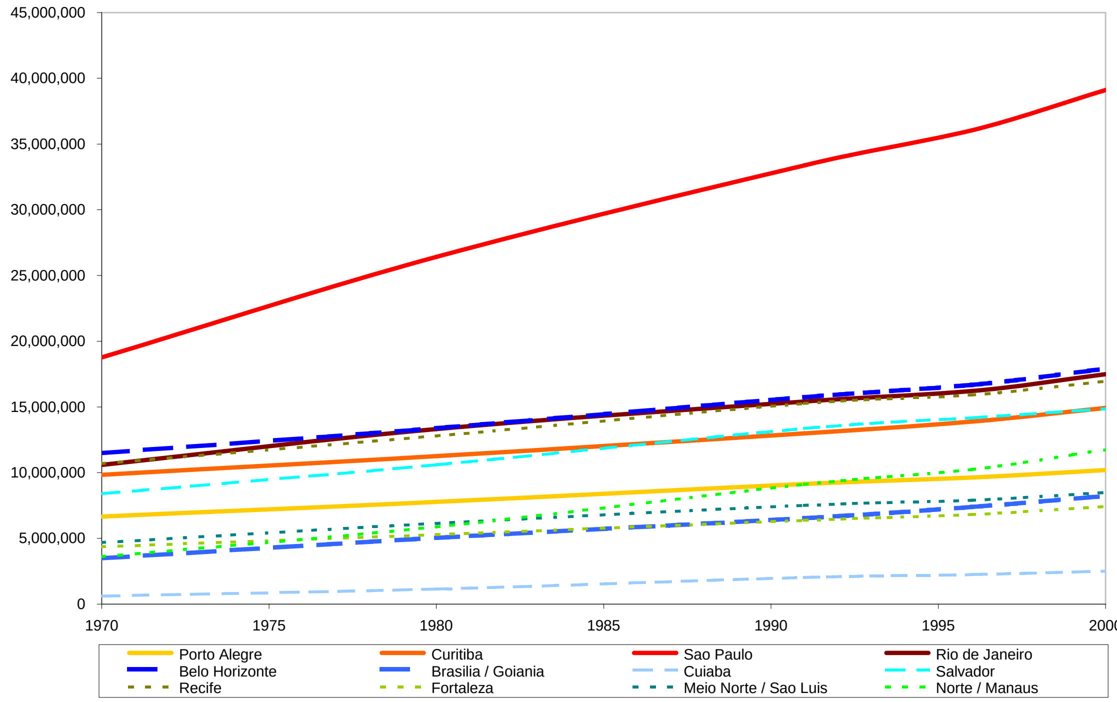


Figure 2.8. Total Population in Brazil per Urban System as Percentage of National Total – 1970 to 2000

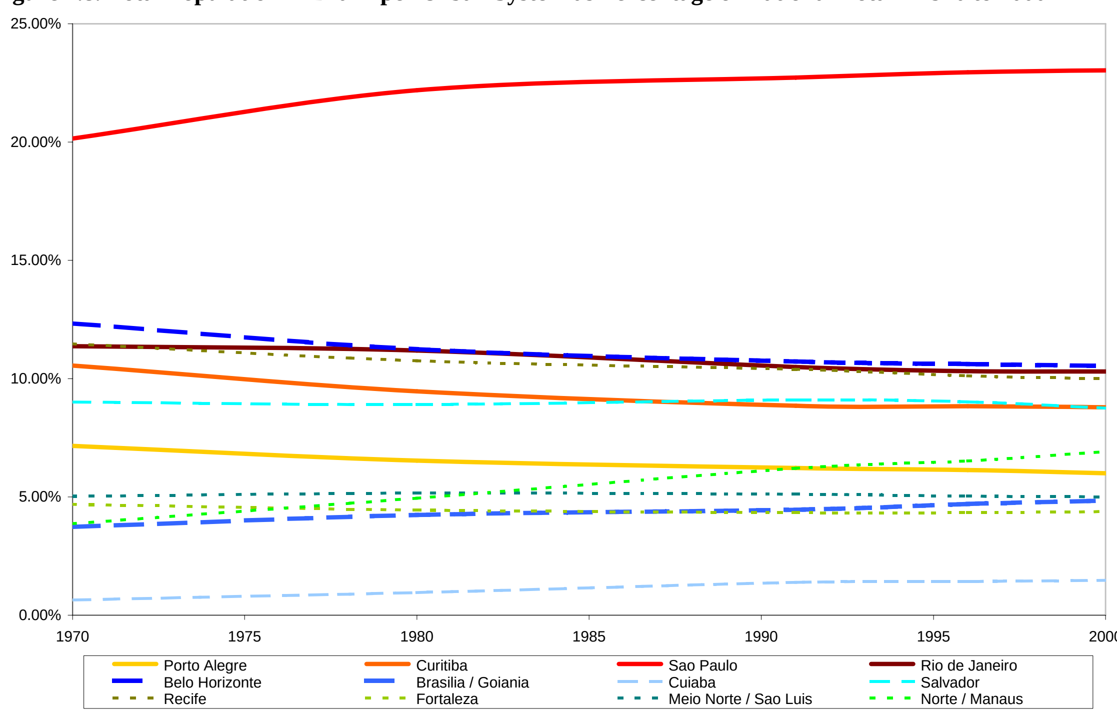


Figure 2.9. Absolute Urban Population in Brazil per Urban System – 1970 to 2000

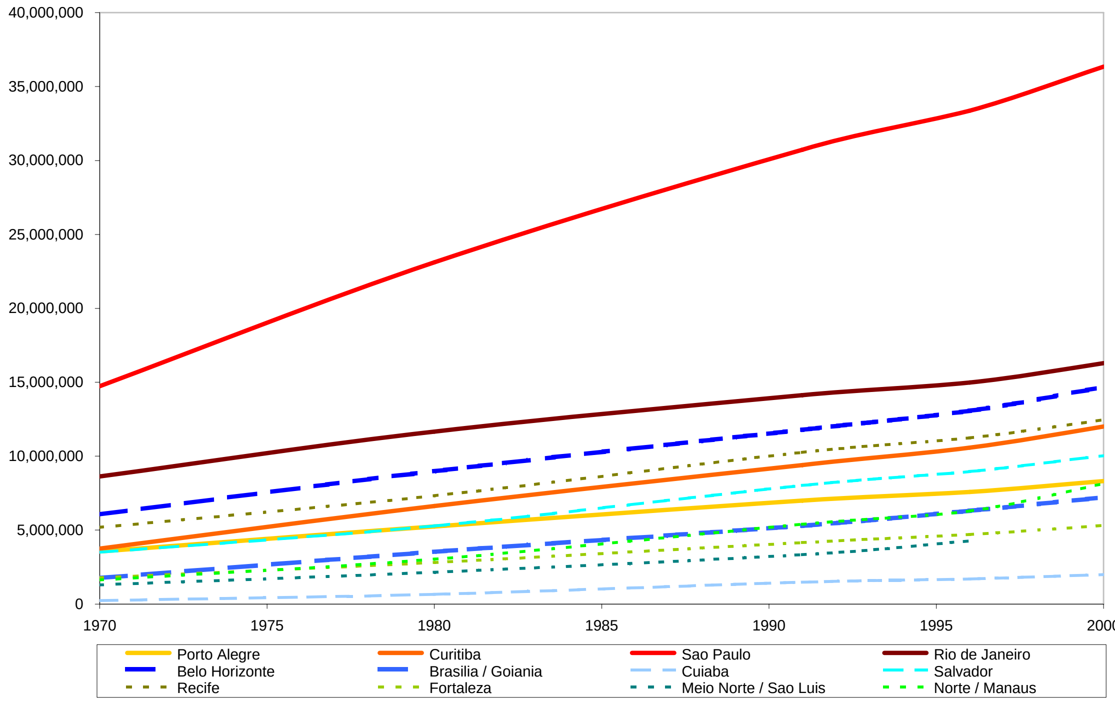


Figure 2.10. Urban Population in Brazil per Urban System as Percentage of National Total – 1970 to 2000

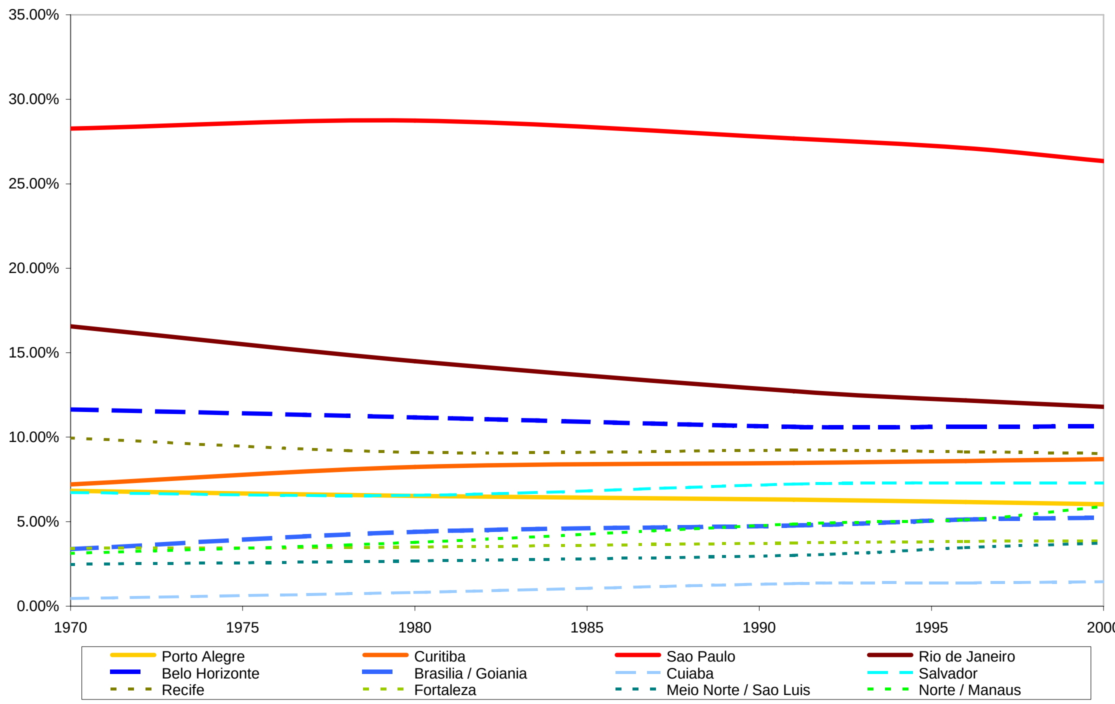


Figure 2.11. Absolute Rural Population in Brazil per Urban System – 1970 to 2000

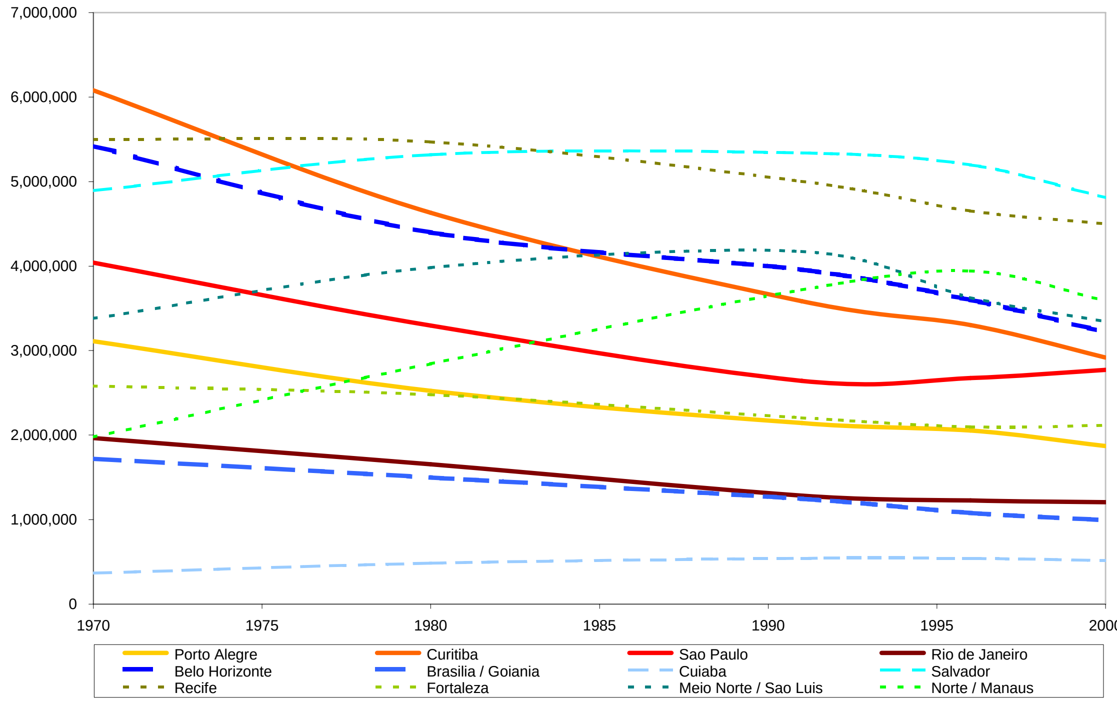


Figure 2.12. Rural Population in Brazil per Urban System as Percentage of National Total – 1970 to 2000

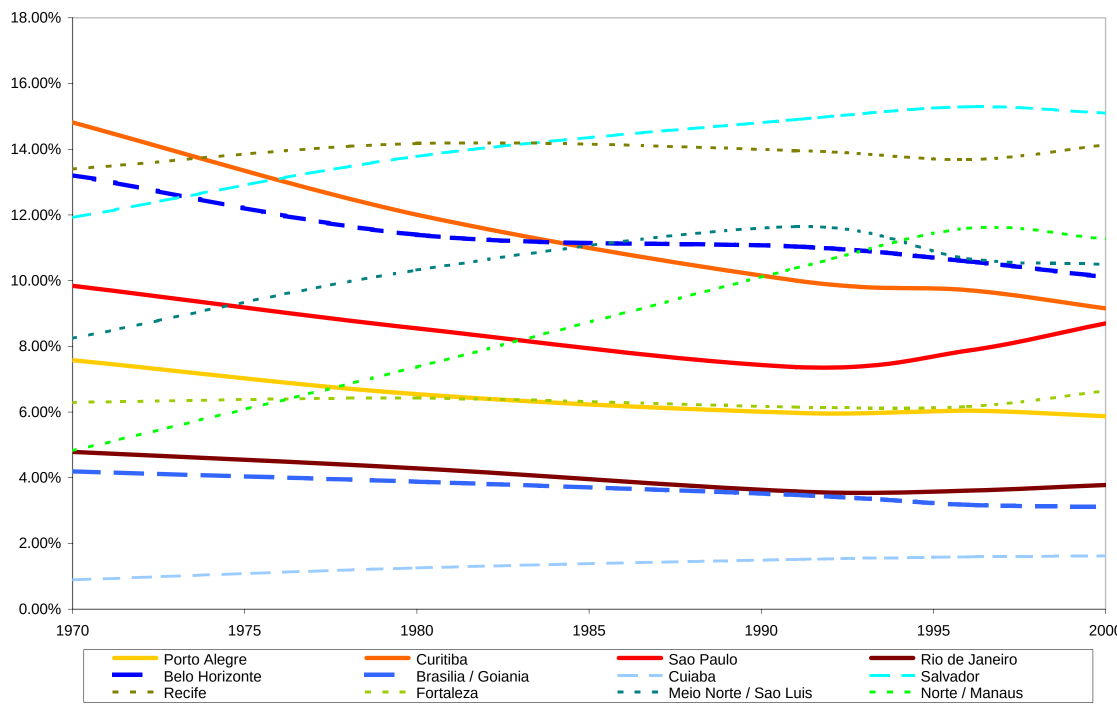


Figure 2.13. Absolute Rural Workforce in Brazil per Urban System – 1970 to 1995

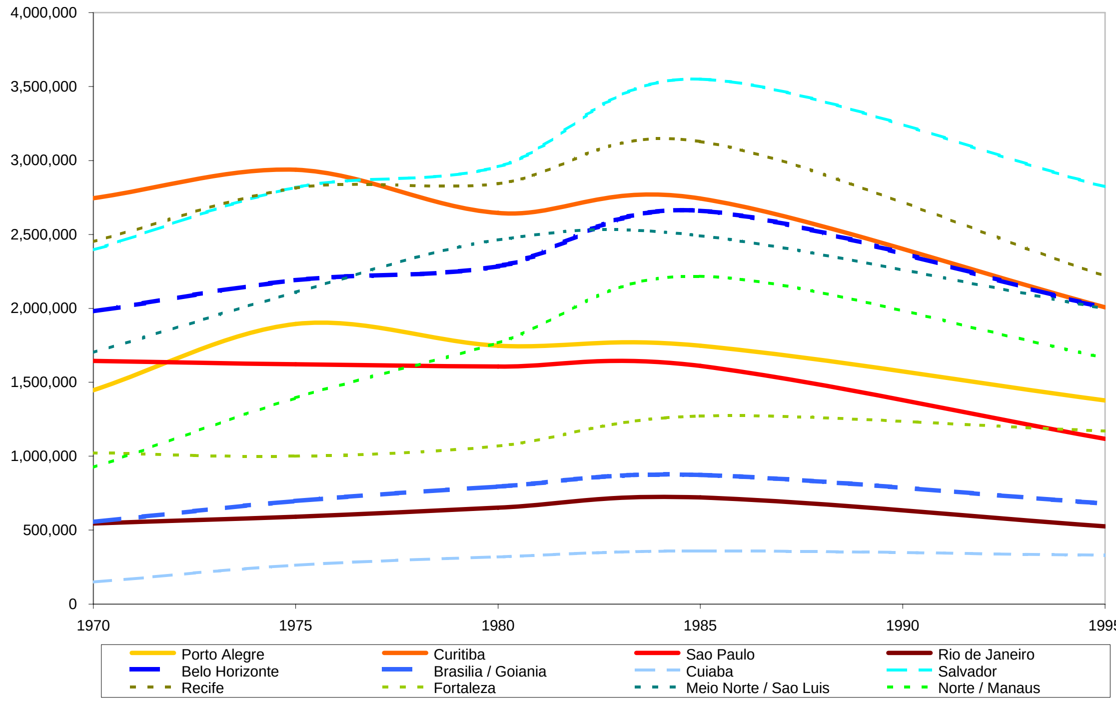
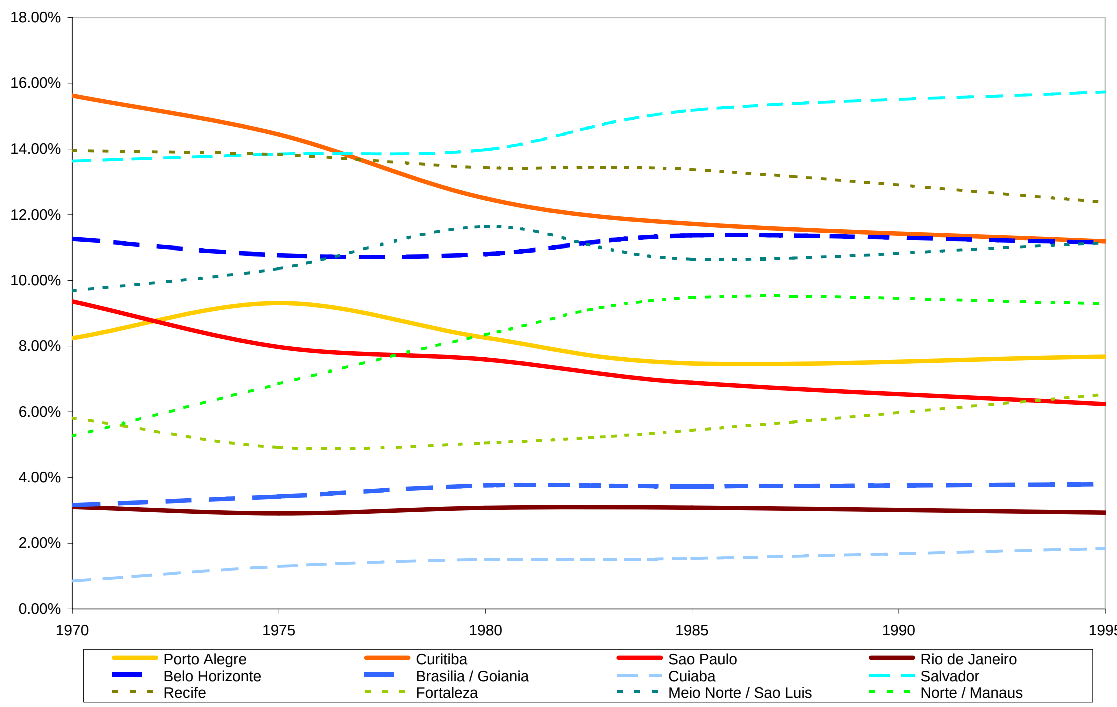


Figure 2.14. Rural Workforce in Brazil per Urban System as Percentage of National Total – 1970 to 1995



Once more, the graphs depicting the absolute and relative growth patterns for rural population and workforce are much more dynamic than those depicting total and urban populations. Analysis of such graphs clearly indicates a movement of human activity among the urban systems that had on the shifts of agriculture activity its major component, underpinning the spread from more to less developed areas, or the so-called economic frontier. Higher levels of technology applied to already industrialized agriculture in the more developed states contributed to the decrease of the rural workforce in such states. Investments in already existing, under-developed farmland especially in the northeastern states and development of new farmland at relatively lower technological and industrial levels especially in the center-west and northern states resulted in relatively higher growth of both the rural and the urban population and workforce in those regions. De-concentration of manufacturing activity tended to be of shorter distance when compared to that of agriculture activity, limited to medium-size municipalities within the more developed regions of the south and southeast. Further range de-concentration of manufacturing activity in the northeast and in the north was basically due to the installation of new natural resources industries. Levels of technological improvements in manufacturing and in agricultural activities tended to be higher in more developed regions, pushing urban and rural workforce to those cities where their real wages were higher. Great share of the migrant population, however, either could not find placement in the demanding specialized labor market of the highly technological manufacturing and agro-industrial southern and southeastern states or opted for the further northern and northeastern regions where their labor relative to living standard tended to be better rewarded. At a minor scale, the same also happened within states and regions where capital cities and larger urban centers lost population and workforce to medium-size cities where housing and basic services such as education and health were easier to procure. The more important conclusion achieved with the aid of the graphs, however, is that both urban and rural population and workforce migration movements were influenced by the displacements of economic activity – and by the problems of congestion, as will be discussed further on – over the Brazilian ground. In addition to confirming the assumption of mobility of human activity irrespective of the economic sector, the observation draws attention to the importance of public and private investments in social and physical infrastructure as a means to attract and keep human capital. Consequently, when relying on the Helpman–Hanson model for modeling recent Brazilian urban clustering or spreading tendencies, both agriculture and manufactures should be considered when using GDP as a proxy for mobile human activity. The inclusion of the services sector becomes redundant because public and private services provision tend to follow human agglomeration, being of less importance if the initial attractor or disperser were agriculture or manufactures economic activity.

The second major difference between the core model of geographical economics and the Helpman–Hanson model lies on the substitution of the agriculture sector by the non-tradable housing sector. Farm owners in Brazil – both small and large – usually invest a considerable share of their income in properties located in urban areas. It is also in urban areas that most of the agriculture workforce chooses to live. After all, it is closer to urban agglomerations that access to markets, services, infrastructure, and all the benefits of human society are more easily found. The rise in property prices in urban agglomerations produces basically the same spreading effect over different income tiers. When housing prices become too high for the city dweller to afford, the tendency is for the spreading towards housing compounds located further away from the city center in the outskirts of the city or in neighboring smaller municipalities with equivalent quality levels of housing and services. The distance from the place of living to the labor market, or to the source of income, are dictated by the income possibilities of city dwellers. The same happens to farm owners and farm laborers living in urban agglomerations. Only in extreme cases will the agriculture workforce – probably the lowest income level – opt to live in the farm in low quality dwellings, far away from urban social and physical infrastructure. Due to the greater opportunities of individual development available in cities perceived by both poor and better off households and firms, urbanization will follow both manufacturing and agricultural economic development. But too much urbanization usually leads to a host of problems that are often bundled under the term ‘congestion’. Positive shifts in the urban demand schedule for housing drive property prices higher. A ‘congestion’ of the housing market, marked by too much demand with a shortage in supply might be desirable by a number of developers that are thus able to reap larger profit margins as a result of imperfect competition. On the long run, however, too much imperfect competition on the housing market will eventually drive people away from the city. Public or private investments in infrastructure and services generally fall short of what would be necessary to effectively offset congestion problems such as commuting time, pollution, and accessibility to services. Moreover, property prices generally go up – not down – as a result of public or private investments in infrastructure and services.

Housing prices and their relation to the housing stock available in urban centers, as presented in the Helpman–Hanson model, works therefore as a convenient – yet simple – proxy for all those urban problems we choose to blame congestion for. It is beyond the scope of this paper to analyze in detail every single problem or advantage created by the clustering of people in cities and the levels at which such agglomeration might be beneficial or detrimental. Even if we tried to do so, the amount of time, data, and resources necessary but to start such a study would by far outdo the possible benefits deriving from it. For the objective of this paper, such an endeavor would also be a waste because it is sufficient to understand that housing directly relates to the well-being and to the continuation of people – and consequently of firms – in a given geographical area. People in cities and in rural areas all over the world have already expressed their judgment on how much they are willing to give up in exchange for what they gain in living in a certain region and not in another. All it takes to measure the aggregate of this myriad of everyday decisions is the market expression of housing prices. A highly paid, highly educated knowledge worker might choose to live in São Paulo, for instance, because there is a tradeoff between the closeness to the market where her activity is best rewarded and the extent to which her income allows her to enjoy a life style that offsets the congestion problems of São Paulo. But her decision could be geographically different if she preferred to have less physical contact and chose to do all her work through the Internet as a free lancer. Similarly, an advertisement outfit might choose to locate in São Paulo for the proximity with the market where it sells its services and the labor pool it hires its labor. Yet, if the best advertising professionals choose to move to Rio de Janeiro due to the congestion problems of São Paulo, the advertisement outfit may have to reconsider its decision resulting in fancy penthouses in Rio de Janeiro probably valued more. An average worker, on the other hand, who could not find a job in her hometown, might have to live in São Paulo bearing the bulk of the problems caused by congestion such as living in very bad conditions far away from the place where she works. Yet, if average workers perceived the chance of finding the same – or even inferior rewards for their work in less congested cities where they do not have to live in the squid row and spend hours commuting, the majority of them would probably choose to move away from São Paulo. The point is: housing prices are a second to none proxy for both people's and firms' decisions when considering all the pros and cons of geographical location ultimately because salaries paid to employees living in congested areas will eventually have to offset – at least partially – the higher housing prices, the higher transport costs (which encompasses higher commuting times) of congested cities, increasing production and the costs of living. The spatial utility of certain cities or regions relative to others are severely affected by congestion, which gives rise to a spatial comparative advantages between cities and regions perceived at different levels by individual persons and firms. Displacements of both people and businesses will eventually occur on the geographical margin and beyond, transport costs directly influencing the distances of such displacements.

2.2. One Fundamental Similarity

Continuing our comparative examination, which – if anything – can be quite useful in better understanding the core model of geographical economics itself, it is time to discuss the main similarity between the core model of geographical economics and the Helpman–Hanson model: transport costs. As described before, congestion (under its multiple definitions) and housing prices are intimately related. Traffic congestion in urban areas will eventually lead to higher housing prices on the long run as well. The resources spent on fares and fuel, the time lost in commuting (when the worker is not productive), the loss of productivity upon arriving at the working place (stress and other psychological effects of congestion which are greater the greater the time spent in commuting), the risks of accidents and robbery while commuting (an unfortunate reality in most developing countries metropolises), and externalities such as air and noise pollution (which are again higher the higher the time spent in commuting) are just some of the economic costs related to urban transport. Though in some instances housing prices are inversely proportional to the distance from the city enter, that is not always the case. Bid-rent curves for housing prices in larger municipalities tend to be directly proportional to the ease of access to main transport arteries and urban mass transit stations. That is to say, the shorter it takes to access reliable urban transport feeders or less congested urban arteries, the higher the price of housing (areas around subway stations in metropolitan São Paulo are a good example of such appreciation). Yet, city dwellers that count on ease of access to mass transit facilities in larger cities are by no means isolated from congestion problems. Increased transport volumes generated by those who live further away will eventually bring congestion and the ensuing costs to everyone. Degraded urban centers – as it is again the case with the city of São Paulo – might turn expensive gated communities in the periphery (where price and availability of land make such developments possible) appealing to the better off. Yet again, increased commuting time to the city center where headquarters of major companies locate will not spare the rich form both contributing to and bearing part of congestion and associated problems. Urban traffic congestion will affect businesses for basically the same reasons it affects workers in urban areas. Urban congestion limits the benefits firms might have from urbanization economies of scale because workers in general demand higher wages in big cities due to higher commuting time and housing prices. Big cities therefore tend to be prime location for more specialized economic activities whose profit margins allow for the better paying of salaries to their employees, as for example high-tech techno-mechanical or advertisement industries. Yet, many businesses engaged in the same economic activity concentrated in one city might end up erasing even the advantages of localization economies of scale. Too much competition for a limited number of customers and for the same supply of inputs will eventually drive profits down and production costs higher until levels at which some enterprises run out of business, or relocate to another region. Imperfect competition will then drive salaries and production costs back to balanced levels in accordance with the profits of the surviving firms.

In urban areas traffic congestion implies higher economic transport costs, which will in turn directly affect worker's nominal and real wages and firms' production costs and profits. The location decision of people and businesses are therefore closely related to the toll in time – and the ensuing costs – of moving people and inputs from one place to another. Yet, the same picture can be drawn in areas broader than the boundaries of big cities. Depending on the intensity of congestion and on the economic environment, the location or the relocation decisions of people and firms might start to reach further, to other municipalities. Individuals are constantly faced with the challenge of striking the right balance between the time (economic transport costs in the broader sense) and congestion (housing prices in the approximate strict sense). That is exactly what has been observed in the recent history of the state of São Paulo and in Brazil. Until the 70's, economic conditions and relatively low congestion created a climate in which it was profitable for the bulk of the national industrial activity to agglomerate in the metropolitan area of the city of São Paulo. Abounding job opportunities offered to even unskilled workers, high real wages as a result of low congestion and low housing prices lured enormous contingents of migrant workers from implicitly every other region of the country into the city of São Paulo. At that time, low levels of technology and management kept returns on investments and wages paid in agriculture too low to counter balance the advantages perceived in locating in the big city. Moreover, low transport costs made it possible to bring raw materials and a range of inputs from other regions. São Paulo easily became the pumping heart of the country's economic prowess. Low fuel costs and a system of well built, well maintained federal and state roads allowed people and inputs to flow within and without urban systems as freely as blood streams in the arteries of a youth. During the 80's and the 90's, however, the economic scenario changed drastically. The rise in fuel prices started to accelerate, public investments and subsidies for manufactures plummeted, and industries had to face increasing foreign competition due to the lifting of trade barriers. The rupture of the fast growing pattern of the Brazilian economy coupled with congestion problems in metropolises caused interesting phenomena of spreading of human activity across the Brazilian geography. First, from the city of São Paulo to its neighboring municipalities – a geographic space that would become what is known today as the greater metropolitan area of São Paulo – as manufacturing plants and control units relocated from the congested city, followed by workers in search of more affordable housing and humane living conditions. Second, from the city of São Paulo to medium-size cities within the state of São Paulo; a spreading movement marked by less specialized industries and intermediary assembly lines relocating to smaller municipalities in the state (closer to where workforce and productive inputs could be procured at lower costs), by firms and wealthier individuals (willing to diversify in high-tech agro-industries), and by people (mostly service providers and liberal professionals in search of better living standards directly reflected in lower housing prices and therefore higher real wages). Third, to other medium-size cities in states neighboring São Paulo, a further spreading characterized by firms interested in investing and diversifying in low skilled labor industries and in high-tech agro-industries, and by individuals seeking higher real wages in less congested, smaller municipalities. Fourth, an even further spread to the economic frontier of the country, that is, to states in the Center-west, in the Northeast, and in the North macro-regions. The spread towards the northeastern states being especially influenced by public incentives such as tax breaks and direct public investments in roads and in irrigated agriculture. The spread towards the far center-western and northern states featuring more adventurous people, the so-called '*pioneers*', who put all their stakes in the clearance of forests for extensive, low-tech faming activities, and by a few natural resources industries receiving incentives from both local and federal public administrations.

The dynamics of the spreading of economic activity that has been observed in Brazil since the 80's seems that of a 'leaking bucket'. Similar to a bucket placed on even ground and then filled with some fluid, the city of São Paulo was – until the 70's – the main receptacle of people and businesses flowing from every part of the country. After the bucket had been filled to the brim and could contain no more – which in our comparison represents unbearable congestion and high costs of living (both reflected in housing prices) – the pressure became enough as if to force the opening of small taps at the bottom of this larger container. The fluid then streamed gently all around the bucket forming concentric circles, increasingly enlarging the area covered by the steady flow overtime. One could also think of a system of pipes and smaller containers connected to the system, representing the roads and those cities and regions that invested in urban infrastructure, allowing further spreading of the pressures of congestion. The economic attractiveness of other cities and regions made the overflowing economic activity from the city of São Paulo to happen in a somehow regular manner. The degree of specialization of both manufacturing and agricultural activities decreasing as the spreading moved further away from the city of São Paulo. It can be argued that the far reach of the spreading movement has been initially favored by cheap long-distance transport costs provided by low fuel prices and a good publicly maintained roads system. The following Figures 2.15. to Figure 2.19.[18] on the next pages offer a visual description of the federal roads system per macro-region and Figures 2.20. and 2.21. of the federal and state roads system of the states of São Paulo and Paraná, respectively. For many years, the main means of connectivity between urban systems in Brazil have been the major national roads system. Accessibility to and quality of this government built infrastructure has been over the years the major driving force that propelled development across this continent-size country. It takes but a look at the Brazilian road maps to conclude that the direction and the intensity of the spreading of economic activity towards certain regions has been a function of the existence and of the quality of a reliable roads system in those regions.

[18] The Brazilian Federal Roads System maps per macro-region and the State Roads System of São Paulo and Paraná presented have been adapted from the originals downloadable at the official site of the Brazilian Ministry of Transport (available at www.transportes.gov.br).

Figure 2.15. Brazilian Federal Roads System – North Macro-region

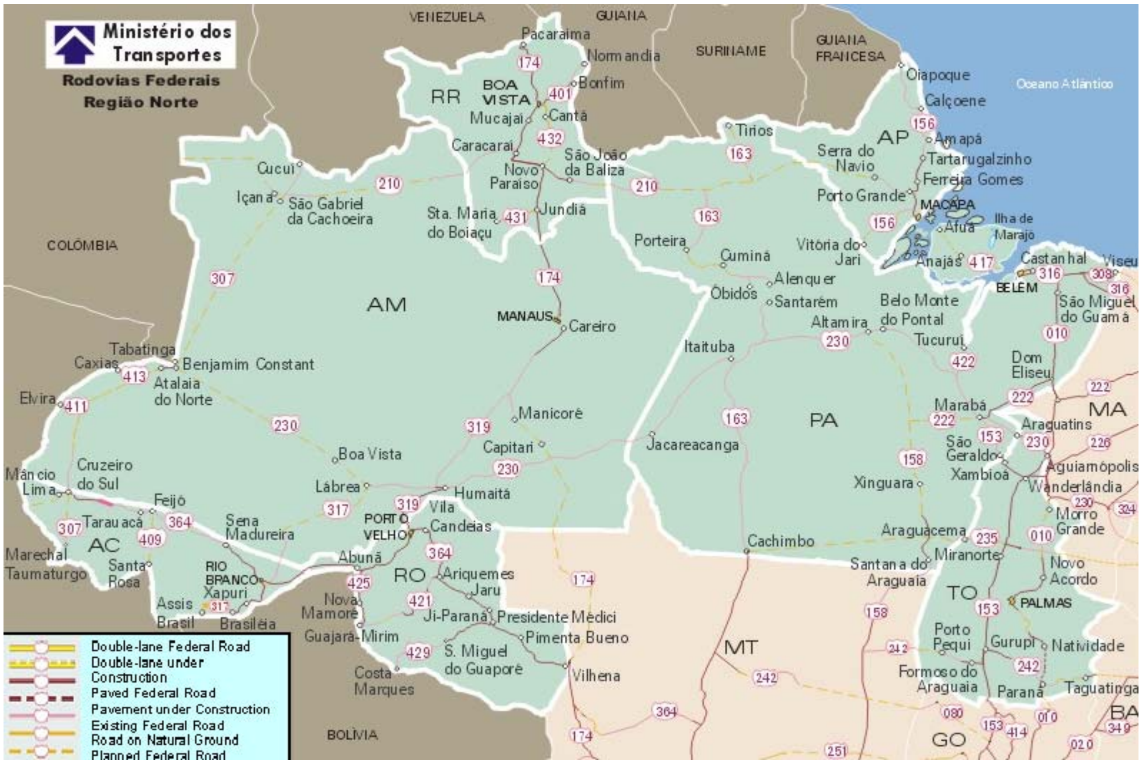


Figure 2.16. Brazilian Federal Roads System – Center-west Macro-region

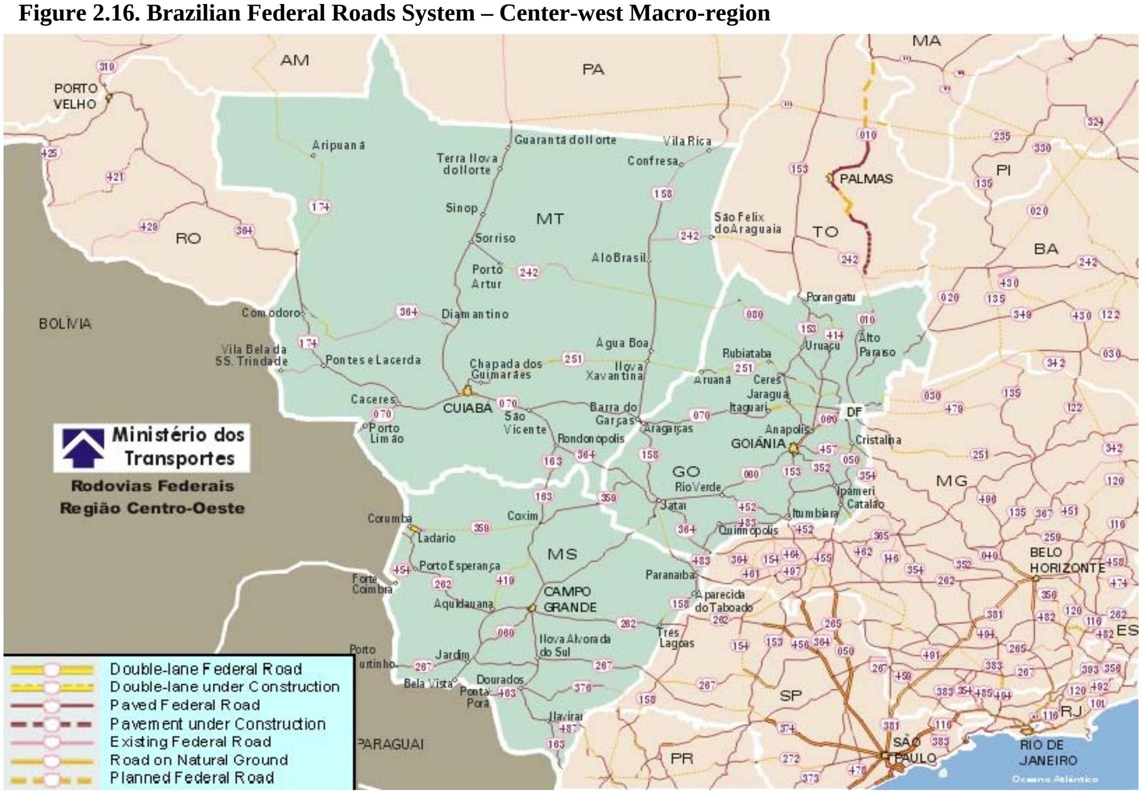


Figure 2.17. Brazilian Federal Roads System – Northeast Macro-region

Figure 2.18. Brazilian Federal Roads System – Southeast Macro-region

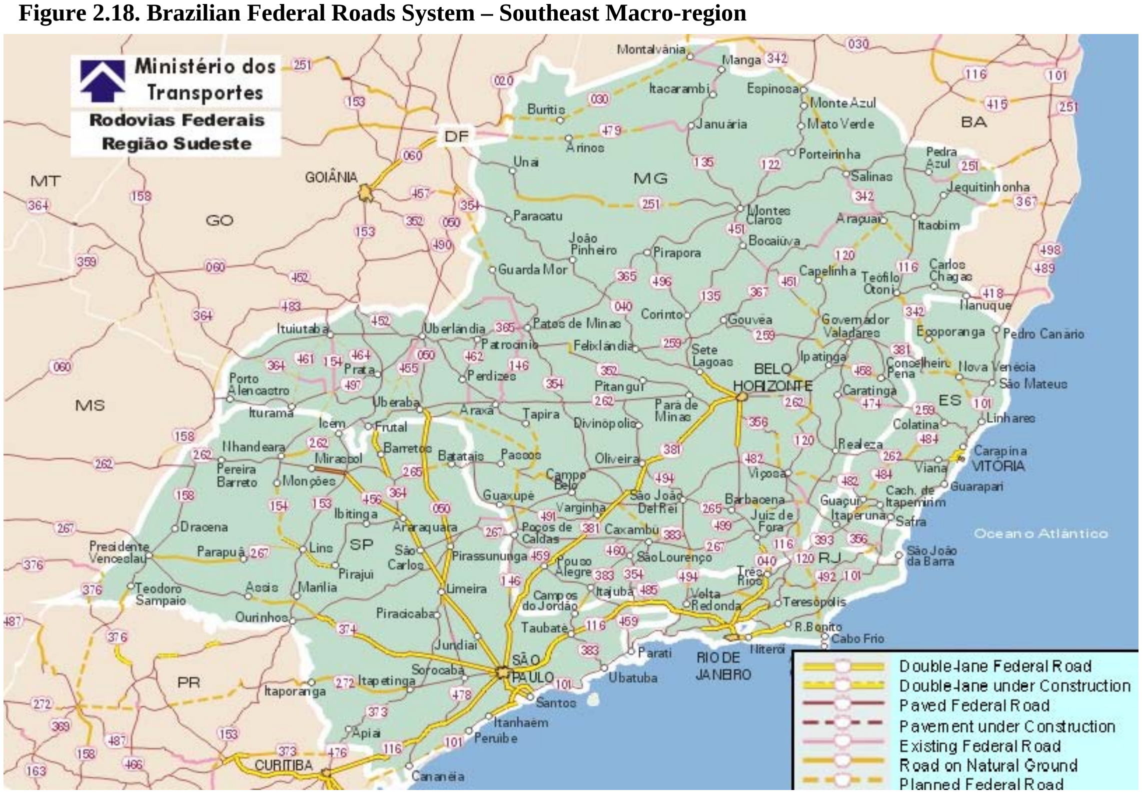


Figure 2.19. Brazilian Federal Roads System South Macro-region

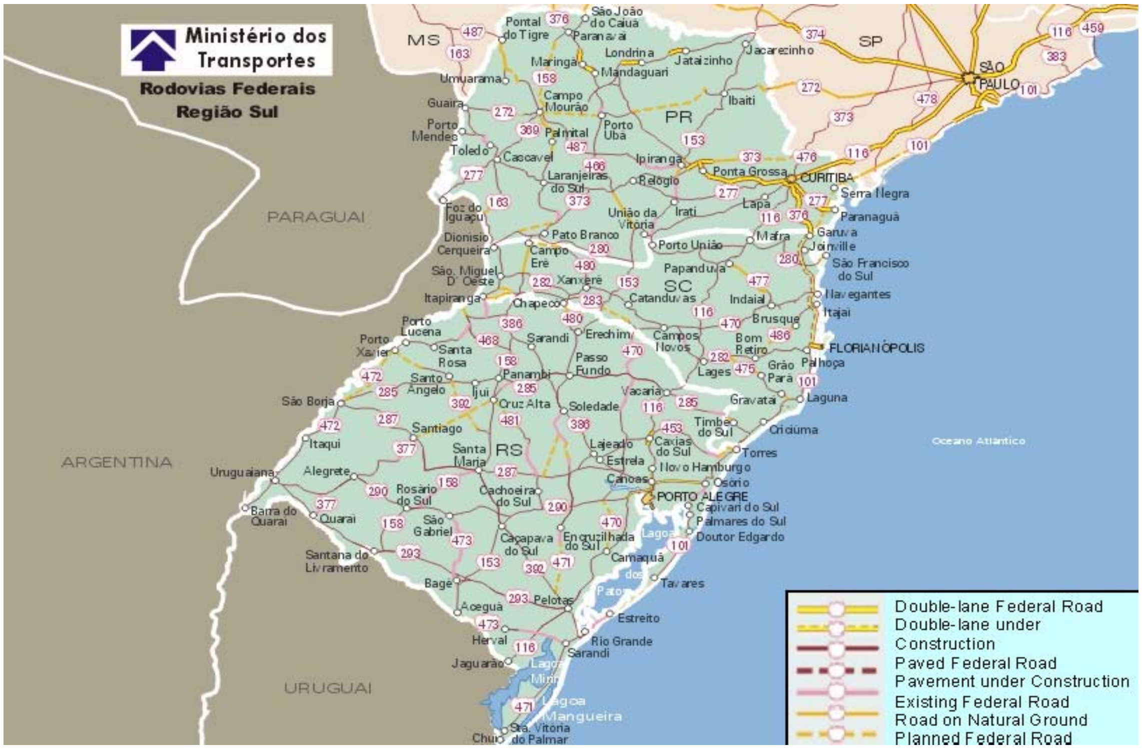


Figure 2.20. State and Federal Roads System of the State of São Paulo

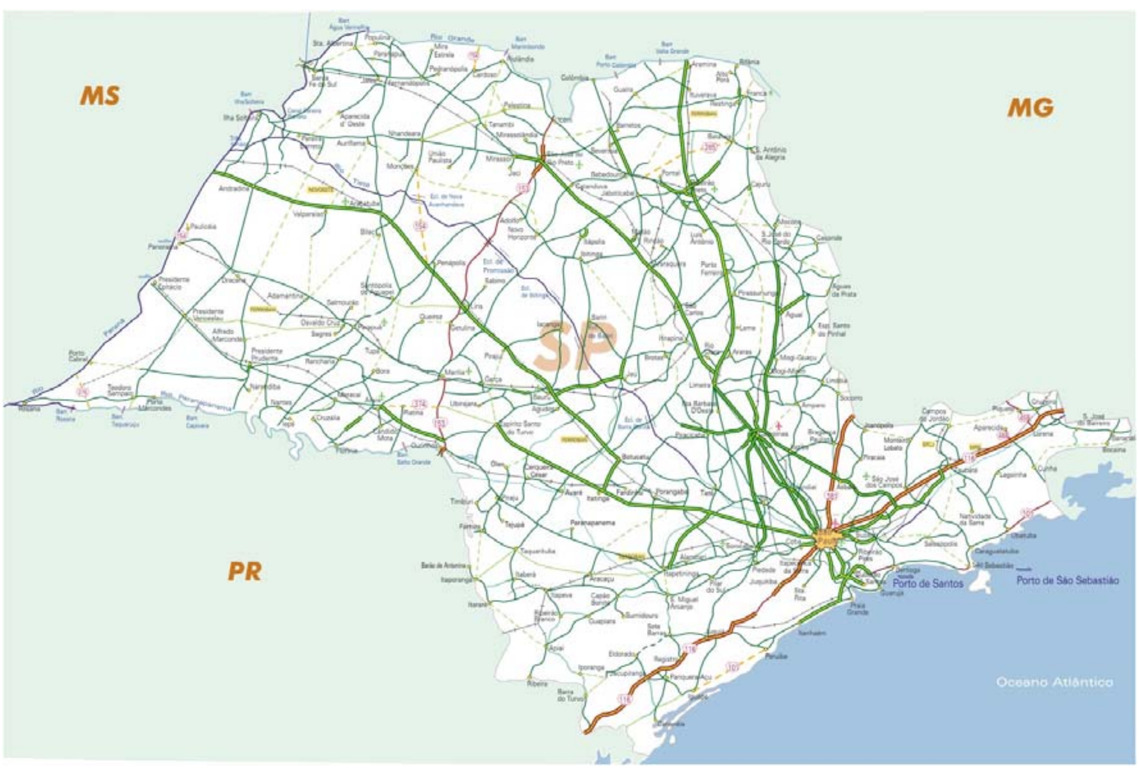
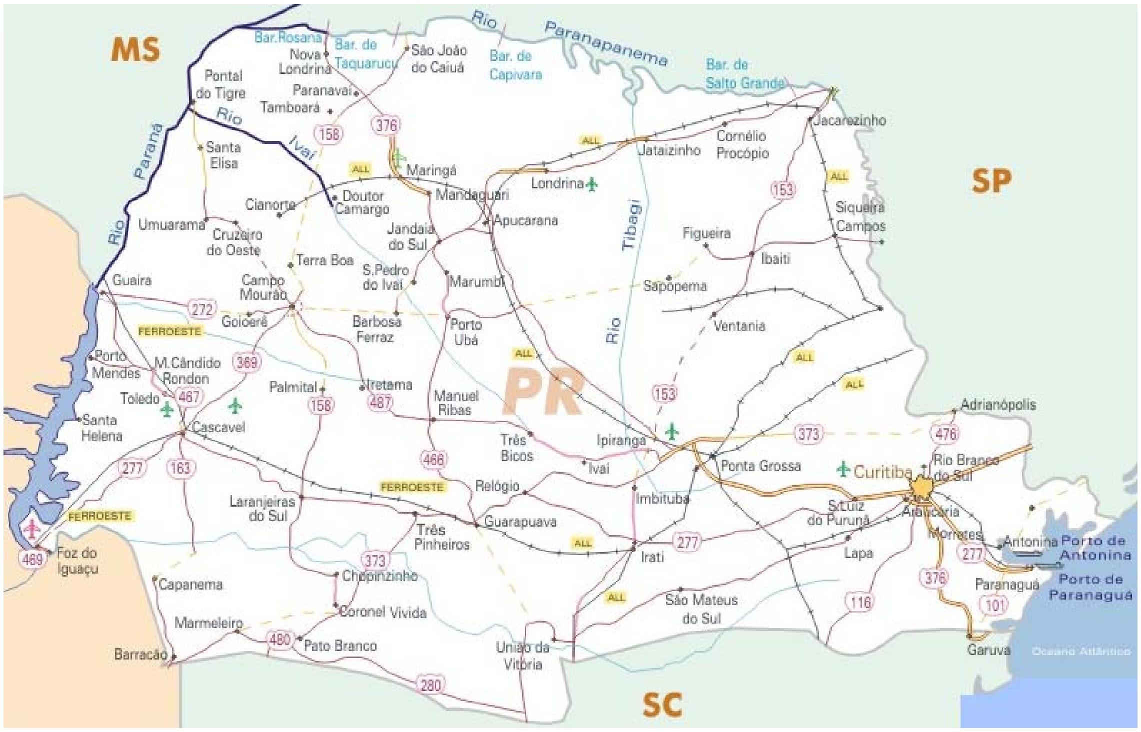


Figure 2.21. State and Federal Roads System of the State of Paraná



State level public investments over the past resulted in the more developed states of the South and the Southeast macro-regions counting on better overall roads systems. In almost every southern or southeastern state, regional investments provided for well-designed and maintained state roads systems offering a complementary network of connections among municipalities within the states and to the main arteries of the federal roads system, ensuring interconnectivity of urban systems with other states and regions of the country. It becomes clear from Figures 2.15. to 2.21. that the city of São Paulo stands as a central node in both the federal – and naturally in the São Paulo – state roads systems. The density of roads within the state is higher in comparison to other states of the federation, probably one of the reasons to explain the ease of the spread of economic activity within the state when overall economic conjuncture pressed upon metropolitan São Paulo (refer to Figure 2.20 on this page). On the other hand, too much dependence on the federal roads system and relatively less regional investments in state roads systems is arguably one of the reasons why northeastern states have lagged behind in industrialization and development. Recent public investments in transport, however, as for instance the 'Barreiras–Brasília' road and the so-called 'North–South' railway, have proven to be vital in bringing the Northeast macro-region back in the tracks of economic growth. Though there are many ways to convey cargo, the ease with which roads promote 'door to door' movement of people and essentially every kind of merchandise have made of this means of transport a second to none facilitator of urbanization. Sometimes the development of regions put pressure on governments to implement the construction or improvement of roads and other transport modes. At other instances, the building or refurbishment of existing means of transport is used as a tool by public administrations to develop certain regions. Both approaches have been observed since the colonization period of Brazilian history. Presently, a core-periphery pattern of land occupation has formed in Brazil where the degree of urbanization – ant the density and quality of roads as well – decrease as a function of the distance to the Atlantic coastal land stripe. The same has also happened in the Center-west and North macro-regions of Brazil, though later on Brazilian regional development history. Center-western and northern states started to have greater participation in national GDP figures from the 70's onwards. Not surprisingly, development has once more been associated with better inter- and intra-regional transport links provided by the improvement of roads systems. Improvements of road connections between the center-western states of Mato Grosso, Mato Grosso do Sul, and Goiás with the southeastern state of São Paulo and the southern state of Paraná certainly were responsible for much of the development of the Center-west region as agriculture production of the region's states was allowed to flow more freely to the major exporting ports of Santos (in the state of São Paulo) and to the port of Paranaguá (in the state of Paraná). In addition, every other element of human activity indispensable for urbanization – and the development that comes as a consequence of it – functioned better with the improved articulation of center-western states with the more developed urban systems of the south. Urbanization and development are more recently – and quickly – taking place as the extension of the roads systems of the Center-west macro-region reaches the northern states of Rondônia and Acre. Naturally, other modes of transport such as waterways and railroads have not had a negligible function in the economic development process of the Brazilian economic frontier. Nevertheless, the principal conveyor of urbanization and overall economic growth in Brazil has been until presently roads. Presumably for that reason, urbanization of the far northern states, where the Amazon plains lie, has been somewhat limited to close distance form the banks of navigable rivers. The mere clearance and grading of unpaved roads that are useable only half of the year at periods of lower rainfall has proven nonetheless the power road transport can have in the urbanization of the Amazon region. There are essentially other policy and public administration issues other than the building or upgrading of roads (the examination of which is beyond the scope of this paper) involved in the fast deforestation of the Amazon plains. History, however, has given enough evidence of the urbanizing power roads can have; so much that the Brazilian central government planned building and improving of roads in the Amazon region has gained top priority on the agenda of officials and environmentalists worldwide for the impacts these facilities will probably bring upon the urbanization and in the ensuing deforestation of the Amazon plains.

Transport time and transport costs are primarily a function of physical distances. Yet, transport technology and certain policy choices can additionally have strong influence on transport costs and therefore on urbanization and development. In Brazilian larger metropolises high land prices have turned the costs of either enlarging existing transport facilities or of installing new, more efficient modes of urban mass transit extremely high. Capital investments in transport infrastructure as desired by urban populations are usually beyond the resources available to many as one developing country's public administrations while falling short of the appeal necessary for private sector involvement. Even though costs of capital investments in improving or building roads between different urban centers in emerging economies are generally higher or at least just as high as the costs of improving transport facilities within cities, transport connections among regions usually deserve priority on the grounds that the absence of those would pose an unavoidable roadblock to the economic growth of both regions and cities. Contributions of the improvement of transport within cities to economic growth are more limited to the city receiving the betterment. Aside from instant economic benefits, the continuation of the spreading of human activity as observed in the two last decades in Brazil would relieve its greater metropolises from a significant part of congestion problems to levels at which public or private investments in urban transport be feasible again. The amelioration of both federal and state roads systems in Brazil would eventually create the conditions for the progression of the spreading of economic activity to other medium-size cities and regions as observed in the later two decades, provided service charges and taxation on users of the facilities do not drive transport costs too high for people and businesses to afford.

Table 2.1. Total Cargo: Transport Mode Distribution and Costs

TRANSPORT MODE	COSTS (R$ Billions)	TONNAGE (TKU Billions)	% TONNAGE (% of TKU)	UNITARY COSTS (R$ / TKU x 1.000)
AIRBORNE	1.9	1.0	0.1%	1,900.0
WATERWAY	9.0	144.0	16.7%	62.5
RAILWAY	7.5	206.0	23.9%	36.4
ROAD	104.3	512.0	59.3%	203.7

Table 2.2. Total Cargo and Transport Costs: A Comparison Between Brazil and the USA

TRANSPORT MODE	BRAZIL UNITARY COSTS (US$/TKUx1.000)		THE USA UNITARY COSTS (US$/TKUx1.000)	
AIRBORNE	0.1%	628.0	0.4%	898.0
WATERWAY	16.7%	22.0	30.6%	9.0
RAILWAY	23.9%	12.0	39.6%	17.0
ROAD	59.3%	70.0	29.5%	274.0

Within contemporary Brazil, the bulk of freight is carried through roads. Table 2.1. and 2.2.[19] give the overall situation of transport mode distribution and costs in Brazil in 2004 and a comparative analysis of unitary transport costs per mode in Brazil and in the USA, respectively. Of the total cargo transported in Brazil in 2004, 67% corresponded to inter-regional transport and 33% represented intra-regional transport. In a country so dependent on road transport, public administrators would presumably wield whatever instruments at their disposal to facilitate the free flow of people and merchandise through motorways hence sponsoring local, regional and national development. That, however, is not what seems to have been coming to pass in Brazil of late. Although road transport costs in Brazil remain relatively lower than in the USA. In the last ten years, the share of the cost of diesel oil in total cargo transport costs jumped from 16.8% to 31.8%. Prices of diesel oil to consumers rose 292.11% from 1996 to 2004, while in the same period international prices of the Brent oil rose 169.29% in international markets. Inasmuch as from 1996 to 2004 the US$ Dollar appreciated 181.73% against the Real, such a steep variation in diesel prices well above the 95.93% variation of the INPC[20] in the same period cannot be explained solely by rises in international oil prices coupled with the devaluation of the Brazilian currency. Had variation in diesel prices in the Brazilian internal market been limited to international variation in oil prices corrected by the depreciation of the Real against the US Dollar, internal variation of diesel would have amounted to no more than 207.65%. It is unusual for a country that today is basically self-sufficient in oil production to charge users internally in excess of international prices. Perhaps some of the motives underlying the state of affairs could be found in the economic inefficiencies that come along with having the production of fuel and many other petroleum derivates as a state monopoly under the so-called public enterprise '*Petrobrás*'.

Apart from high fuel prices, there are other hurdles on the way of Brazilian transporters and road users. Until recently the policy of the federal government had leaned towards granting users free access to roads in order to sponsor economic development. During the 90's, however, under the liberal party rule and the 'failure of the state' justification in providing for the maintenance of the roads system (refer to Table 2.3.[21] on next page), free use was replaced with the privatization of many of the

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[19] The data source of this tables can be found is the research on logistics costs carried out by Mr. Maurício Pimenta Lima of the COPPEAD/UFRJ (Center for Research on Logistics of the University of Rio de Janeiro), available at the restricted area of 'NTC & Logística' website (www.ntcelogistica.org.br). The acronym 'NTC & Logística' stands in Portuguese for 'The National Association of Cargo Transporters and Logistics', an organization acting as the union of and providing technical assistance for Brazilian transport firms. Unless otherwise indicated, 'NTC & Logistics' was the main source of information concerning Brazilian transport utilized in this paper.

[20] The INPC, or the 'National Consumer Price Index' updated monthly by the 'Brazilian Institute of Geography and Statistics' – IBGE.

[21] Data source: the Brazilian Ministry of Transport ('Ministério dos Transportes / GEIPOT').

roads belonging to the southern and southeastern federal system. The policy shift was decided almost strictly upon political, managerial and financial considerations. Little attention was given to the possible implications this abrupt change might have had on the ongoing economic development process of affected cities and regions. In every state of the federation, state roads systems had been designed as a complementary system to the federal roads system, basically connecting state roads to the federal roads system, in such a way that links between various municipalities within states eventually had to go by both state and federal roads. Following the argument that the enlargement of the toll collection base would beneficiate road users in general by lowering individual fares to all, concessionaires of federal roads took full advantage of strategically positioning tollbooths close to junction points of state and federal roads. That has rendered many users – even those traveling short local distances between municipalities within states – incapable of choosing any other alternative byway to convey people or merchandise other than the heavily tolled roads. Though it is out of the range of this paper to conduct a thorough investigation on the public administration merits or demerits of the privatization program of the Brazilian federal roads system in the southern and southeastern states, it is nonetheless important for this study to observe that the majority of state roads – the ones that have not been privatized – are still maintained by state administrations with taxpayers money, that is tantamount to having the public administration paying for the maintenance and improvements of roads that invariably contribute to higher traffic volumes and – as a consequence – to more toll fares paid to the federal roads concessionaires. Another remark pertains to the fact that the concession contracts that privatized the federal roads systems in Brazil centered particularly in the maintenance and touched lightly on improvements of existing roads – roads that had been built at great human and capital costs over decades with taxpayers money. No building of new roads was stipulated on the concession contracts. Furthermore, concession contracts in brazil are designed in a way that allows concessionaries to increase the price of toll fares based on the variations of cost indexes – such as the 'National Land Grading Index', the 'National Paving Services Index', the 'National Bridge Construction Index', the 'National Consulting Services Index', the 'National Civil Construction Index' (INCC), and the 'General Medium Prices Index' (IGPM) – without the corresponding execution of maintenance and improvements to the Brazilian roads[22]. From 1994 through 2004, toll fares in federal roads in the state of São Paulo increased 716% in nominal terms and 210.52% in real terms. An oppressive pecuniary burden on road users at increases well in excess of consumer price indexes.

[22] Though Brazilian law stipulates that concession contracts are public documents, the concession contracts of the federal roads in the states of São Paulo and Paraná are not accessible to the public. This research found, however, some of the more recent concession contracts of roads belonging to other states in the web site of the 'National Agency of Terrestrial Transport' – ANTT (available at www.antt.gov.br).

Table 2.3. Evolution7 of the Brazilian Ministry of Transport Expenses with Transport Investments

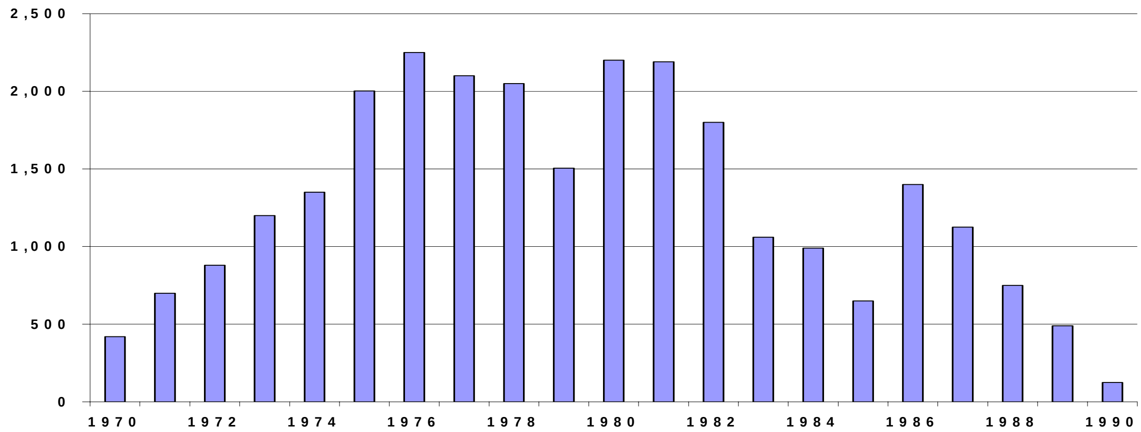

Table 2.4. ABCR's Financial Statement - 2004

FIANCIAL STATEMENT			R$ Millions		
YEAR	2000	2001	2002	2003	2004
TOTAL REVENUES	1,947.8	2,638.7	3,090.2	3,571.1	4,429.9
Toll Fares	1,886.8	2,511.6	2,898.4	3,399.9	4,263.9
Other Revenues	61.0	127.1	191.8	171.2	166.0
TOTAL EXPENSES	3,577.7	4,452.9	4,009.6	3,979.2	5,057.9
Investments	1,524.3	1,744.9	1,560.4	1,024.9	1,034.2
Operational Expenses	830.5	988.1	1,070.6	1,264.7	1,458.0
Financial Expenses	849.6	1,333.9	848.0	1,081.2	1,671.3
Concession Contract Payments	240.9	147.0	241.2	263.4	324.5
Taxation (State and Federal)	132.4	239.0	289.4	345.0	569.9
FINANCIAL DEFICIT	(1,629.9)	(1,814.2)	(919.4)	(408.1)	(628.0)
Total Income	1,614.8	1,925.3	1,000.6	557.8	818.7
Loans from Shareholders	416.3	346.3	279.7	88.9	114.3
External Financing	1,198.5	1,579.0	720.9	468.9	704.4

Table 2.5. Analysis of ABCR's Financial Statement – 2004

YEAR	2000	2001	2002	2003	2004
Traffic Flow Increase	100.0	102.0	100.6	98.8	103.0
Toll Fares Increase	100.0	133.1	153.6	180.2	226.0
Investments Increase	100.0	114.5	102.4	67.2	67.8
Operational Expenses Increase	100.0	119.0	128.9	152.3	175.6
Investments / Toll Fares	80.79%	69.47%	53.84%	30.15%	24.25%
Operational Expenses / Toll Fares	44.02%	39.34%	36.94%	37.20%	34.19%

Tables 2.4.[23] and 2.5[24] above reveal that the rise in revenues with toll fares from 2000 to 2004 were a consequence not of increased traffic flows but of the value of fares tolled from users without the corresponding increase in investments. As a matter of fact, investments decreased sharply in the period. Out of total toll revenues of around 4,3 R$ billion received by the road concessionaires in 2004, maintenance and improvement plough-backs plummeted to 24.25%. Operational expenses also increased as toll fares mounted. Variations in operational expenses should bear some relation to variations in traffic volumes, which remained practically the same in the period under consideration. Conversely to that, operational expenses as a share of toll fares remained on average at 38% of total toll fare revenues. The inspection of the maps portrayed in Figures 2.22. through 2.28.[25] permits to verify that there is a considerable lack of alternative roadways other than those belonging to the privatized federal roads system, especially in the southern state of Paraná and in the southeastern state of São Paulo. Finally, Brazilian ever-present taxation is not missing from road concessionaires' financial statement (Table 2.4.), loading taxpayers in Brazil with another obligation for which the corresponding efficient service provision has yet to be made clear.

Taxation is responsible for a great share of the costs of transport companies. In Brazil, it has been estimated that direct taxation and fines required of transport firms on average amounts up to 19.58% of total administrative and terminal expenses. Businesses and individuals who use transport services eventually have to pay more for such services in behalf of taxation. Against the general belief that diesel oil is subsidized in Brazil, a host of taxes (the state value added tax ICMS and the federal CIDE, PIS, COFINS) on diesel amounts to 26.2% of the price paid at the pump by consumers. Taxation on the 36 million square meters of diesel consumed yearly in Brazil channels 15.5 R$ billion on revenues to state and federal coffers. Revenues generated only by the fuel tax (CIDE) in 2002, 2003, and 2004 mounted to 22.4 R$ billions. Moreover, figures of transport related revenues received by local, state, and central administrations would grow even higher if other taxes incident on transport, such as taxation on the distribution and retail sales of fuels, taxation on motorized vehicles, and taxation on the services of road concessionaires (refer to table 2.4.), were taken into account. Nonetheless, figures of revenues generated with fuel taxes alone suffice to dwarf expenses in both investments and operations as put forth in road concessionaires' financial statements on Table 2.4. No wonder Brazilian

[23] Financial Statement data as reported in the 'ABCR – Annual Report 2004' (available at www.abcr.org.br), ABCR being the acronym in Portuguese for the 'Brazilian Association of Road Concessionaires'.

[24] Traffic flow indexes, though calculated and informed by ABCR, was obtained from the restricted area of 'NTC & Logistics' website. The remainder of the table being calculated from the ABCR's financial statement reproduced on Table 2.4.

[25] The maps at the end of this section were obtained at the ABCR's website (www.abcr. org.br).

taxpayers are finding a hard time in trying to understand why should they have to pay high service charges for inefficient service provision when using federal roads when they are already heavily burdened with taxes that are more than enough to meet the costs of maintaining, operating, and building new state and federal roads. Likewise, it is difficult to grasp the reasons why, after so many taxes and tolls paid under the guise of transport investments, should more than 80% of state and federal roads in Brazil have been recently graded as in 'bad condition' by 'NTC & Logística'.

As stated before, the objective of this paper is not to delve too deeply in the examination of the Brazilian federal roads concession program. The prime objective of this paper is to use the possibilities offered by geographical economics to draw a clearer picture of how variations in road transport costs might induce the continuation of the spreading of human activity in Brazil, to a marked degree in the states of São Paulo and Paraná. High duty charged in most federal roads in the southern and southeastern states appear to have contributed to the spreading of economic activity to states where privatization of roads did not come about. As earlier described in the introductory part of this paper, toll-free center-western, northern, and northeastern states seem to have benefited relatively more from the spreading of human activity, along with 'fringe' regional southeastern states of Minas Gerais and Espírito Santo – where privatization of roads practically did not happen – and with the southern state o Santa Catarina – where privatization did not happen at all. Though other determinants of the spreading or agglomeration of activity will be also discussed in further sections of this research, road transport costs seems to be the one to lay claim over greater interest in the current case of Brazil. Not only in view of the importance road transport have had on the history of the development of the country, but by reason of the great margin of maneuver at the disposal of decision-makers over transport costs made possible by high taxation, amongst others.

Figure 2.22. Privatized Roads in the State of Rio Grande do Sul

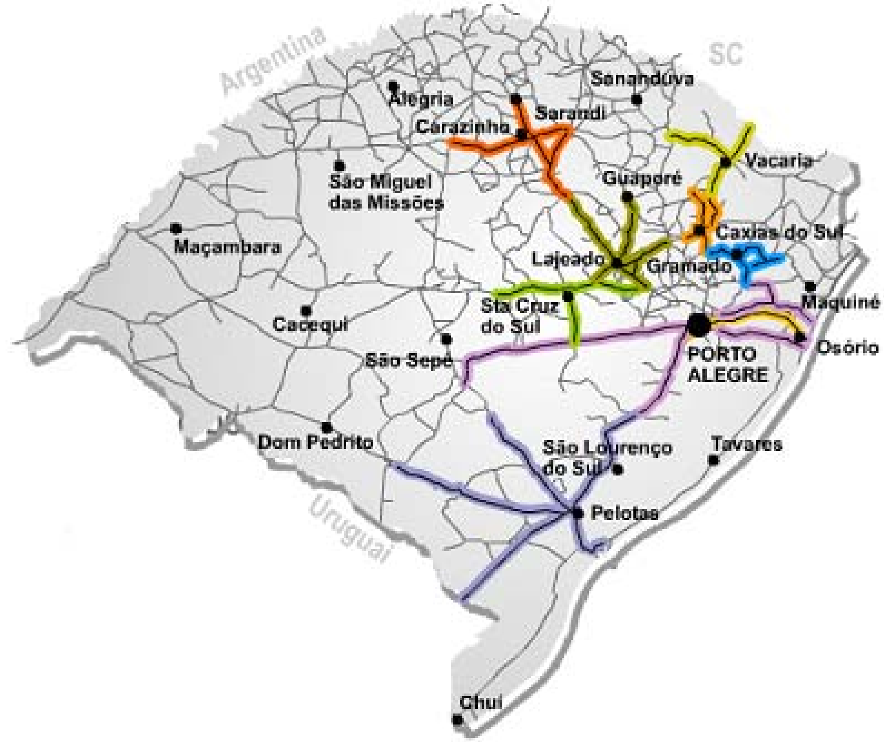

Figure 2.23. Privatized Roads in the State of Paraná

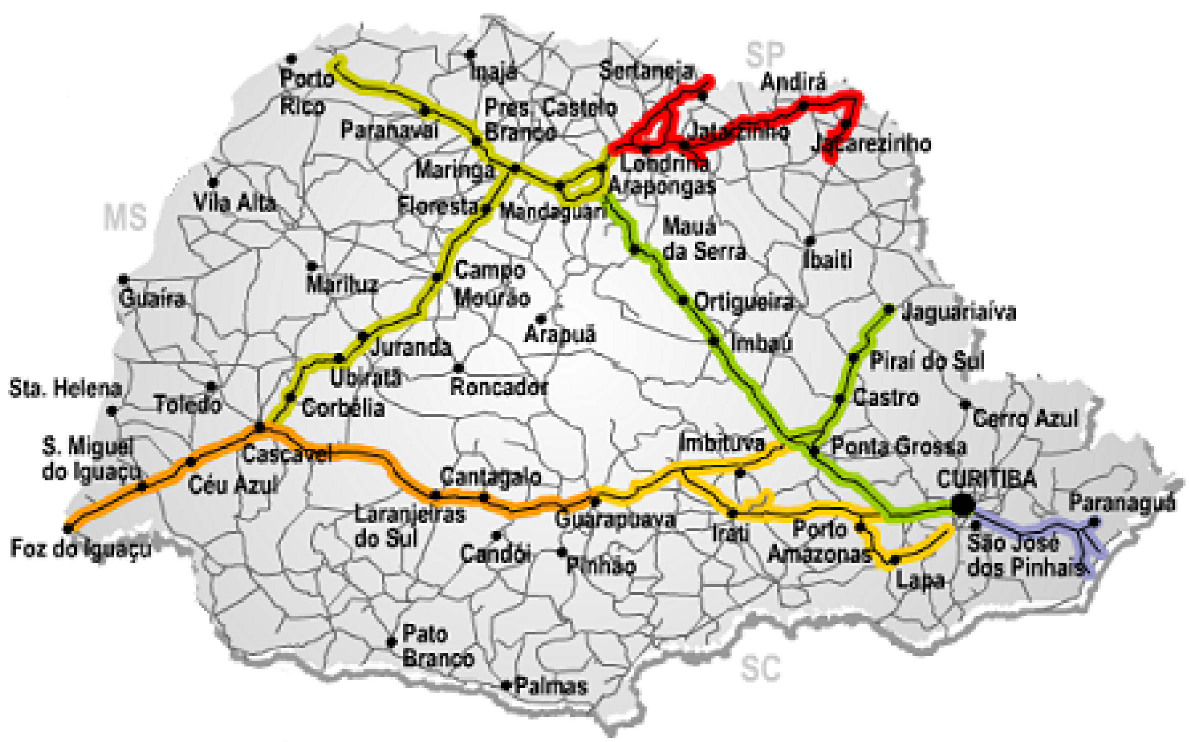

Figure 2.24. Privatized Roads in the State of São Paulo

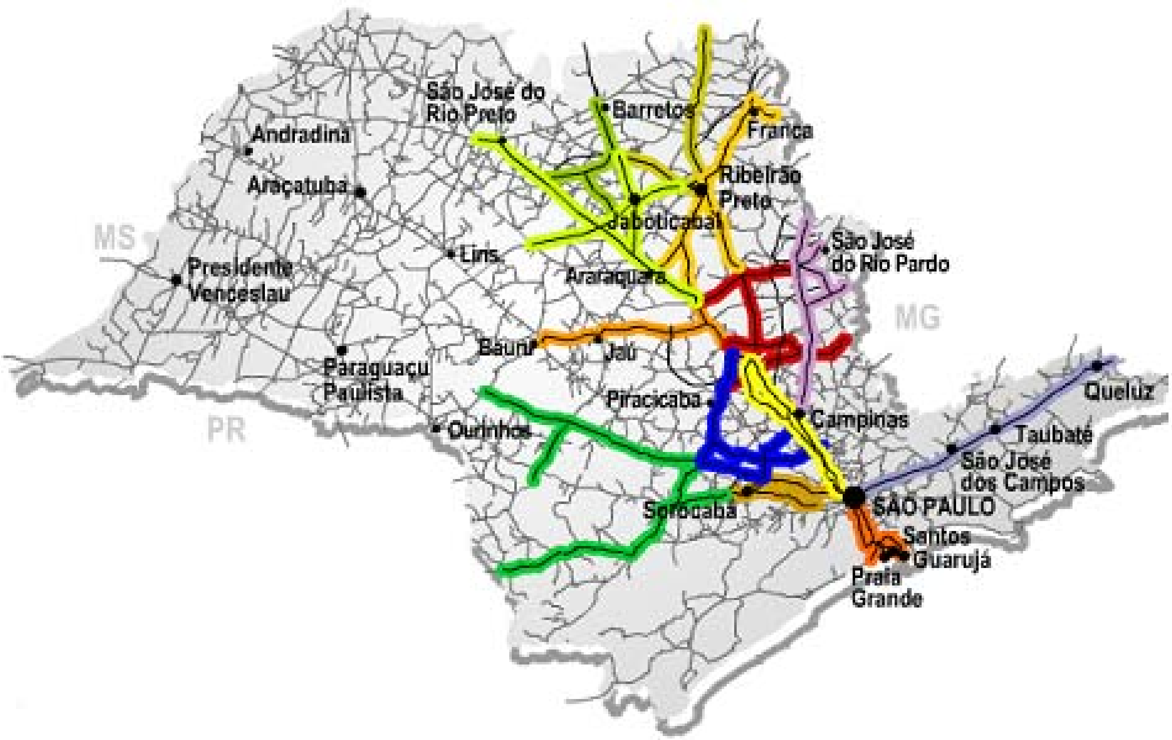

Figure 2.25. Privatized Roads in the State of Rio de Janeiro

Figure 2.26. Privatized Roads in the State of Minas Gerais

Figure 2.28. Privatized Roads in the State of Bahia

3. Theoretical Background

3.1. Some Preliminary, Intuitive Insights

From the first insights into the forces that shape the distribution of human activity over space, scholars intuitively understood that transport costs and land prices played a decisive part. Both roles are present in Von Thünen's (1826)[26] *monocentric city model* with its widely known bid-rent curves portraying land prices as a function of the distance to the city center. Despite the absence of imperfect competition – requisite to explain the spatial behavior of individual economic agents – Christaller (1933)[25] and Lösch's (1940)[25] *central place theory* and its graphical arrangement of (semi-)equidistant cities at different hierarchical levels of productive specialization nevertheless bears exceptional similarity to the illustration offered in the introductory part of this paper. In the state of São Paulo, the metropolitan area reassures itself as the prime location for the upper technological tier of industries and the state as a whole reaffirms the prowess of its agriculture through investments in high-tech agro-industries. Economic circumstances forced technologically less intensive productive activities to relocate to medium-size cities within the state, creating an economic space where a hierarchy of technology dictates the distance to the prime city. In opposition to the *central place theory*, however, the location and the technological hierarchy as a function of the distance to city of São Paulo have been greatly influenced by transport costs and road accessibility. Alonso (1964)[25] added a little more economics to Von Thünen's model by letting the city be a central business area and by substituting the farmers with the commuters. Yet, increasing returns to scale were still missing, rendering Alonso's model incapable of dealing with the spatial location of cities and their interactions. The shortcoming of Alonso's model was partly mended by Mills (1967)[25] and latter on by Henderson (1974, 1977, 1988)[25] with the introduction of external economies of scale. By virtue of the inclusion of congestion as a spreading force and industry-specific economies of scale, Mills-Henderson's model could address quite successfully issues concerning the size of cities and their interdependency. Nevertheless, the absence of transport costs precluded the model to deal with the relative location of cities and the space between them.

3.2. International Trade Theory

It is no surprise that the core model of geographical economics seems to have been devised to explain the core-periphery pattern observable in the spatial distribution of global economic activity. The core model has categorically evolved from neo-classical trade theory and its conspicuous north–south representation of industrialized

[26] For a more in depth account of the development of urban economics, trade theory, and geographical economics refer to Brakman, Garretsen, and Van Marrewijk (2001).

and developing hemispheres. Krugman (1979)[27], through the introduction of the love-of-variety effect coupled with internal returns to scale (and therefore a market environment of imperfect competition), remedied the inability of Hecksher, Ohlin, and Samuelson's (1933)[25] *factor abundance model* to explain trade between countries in the absence of comparative advantages. But still Krugman's (1979) model was in want of the inclusion of transport costs, an oversight redressed in by Krugman (1980)[26]. Amid other improvements, Krugman's (1980) model is a step closer to the core model of geographical economics preeminently owing to the acknowledgement of the home-market effect, which states that countries counting on large domestic demand for a product have a vocation for becoming exporters of that product. Firms are accordingly no longer indifferent to the location of their production sites, on the contrary, closeness to demand matters. Entrance and exit of firms in the market is allowed in Krugman (1980), albeit firms cannot yet move from one country to another. Similarly to the core model of geographical economics, Krugman (1980) has no objection to the "*non-linear relationship between a country's share in world industry and transport costs (…) in which the shares always sum to one*" (Paul Krugman, as quoted in Brakman, Garretsen, and Van Marrewijk, 2001). Location of economic activity is now treated as an endogenous variable that explains the spatial comportment of individual economic agents in the market place. The next step would be to devise a model in which the core-periphery pattern, or the initial clustering of economic activity, is just another endogenous variable.

3.3. The Core Model of Geographical Economics

The cornerstone that marked the birth of geographical economics was presented in Krugman (1991)[28] as an accessible, yet full of insights, model combining factor mobility across countries with the handling of imperfect competition conforming to Dixit-Stiglitz's (1977) approach. The event brought together modern urban economics and international trade theory in what became known as the core model of geographical economics. In this model there are two countries and two sectors: manufactures and food. Farm workers exchange their labor supply in farms for wages and manufacture workers exchange their labor supply in factories for wages. Farm workers produce food under constant returns to scale and perfect competition. The production of food is sold in both countries and without incurring transport costs. The number of manufacturing firms is different in each country and each firm produces one differentiated variety under internal economies of scale having as input only labor. A market environment of imperfect competition in the manufactures sector allows firms to have control over the price of their product through monopolistic

[27] For a more in depth account of the development of urban economics, trade theory, and geographical economics refer to Brakman, Garretsen, and Van Marrewijk (2001).

[28] For a detailed explanation of the core model of geographical economics, refer to Brakman, Garretsen, and Van Marrewijk (2001).

power. Transport costs are incurred when exporting manufactures to the other country. The demand side is represented by the workers in the food sector and by the workers in the manufactures sector who spend their wages in both food and manufactures. Null transport costs for food means that both food prices and farm workers wages are the same in both countries. Positive transport costs for manufactures imply that imported varieties will cost more than home varieties, but the love-of-variety effect ensures that each variety will be consumed both at home and abroad. After a series of technical considerations respecting internal economies of scale, imperfect competition, external economies of scale, location, mobile workforce, and parameter normalization[29], the model yields three basic equilibrium equations for the case of '*r*' regions:

$$Y_r = \delta\lambda_r W_r + (1-\delta)\phi_r \tag{3.3.1}$$

$$I_r = \left(\sum_{s=1}^{r} \lambda_s T_{rs}^{1-\varepsilon} W_s^{1-\varepsilon}\right)^{1/(1-\varepsilon)} \tag{3.3.2}$$

$$W_r = \left(\sum_{s=1}^{r} Y_s T_{rs}^{1-\varepsilon} I_s^{\varepsilon-1}\right)^{1/\varepsilon} \tag{3.3.3}$$

where the exogenous variables of the model are given by:

δ → share of income spent on manufactures

λ_r → share of mobile (manufactures sector) workforce in region *r*

ϕ_r → share of immobile (food sector) workforce located in region *r*

ε → elasticity of substitution between varieties

T_{rs} → transport costs from region *r* to region *s*

note that $T_{rs} = T^{Drs}$, where *D* is the economic distance between regions *r* and *s*

A solution for the system of equations (3.3.1), (3.3.2), and (3.3.3) is reached when the three equations hold for the three endogenous variables: the income Y_r, the price index for manufactures I_r, and the wage rate W_r for a given set of values. That is to say, when a short-run equilibrium is reached. The number of equations in the system

[29] For a broad examination of the derivation and assumptions underlying the equilibrium equations of the core model of geographical economics, refer to Brakman, Garretsen, and Van Marrewijk (2001).

depends on the number of regions under consideration. For two regions there will be six equations and six variables, for three regions there will be nine equations and nine variables, and so on. The large number of non-linear equations in the core model calls for numerical calculations with the aid of a computer software. The solution method of *sequential iterations* as worked out by Brakman, Garretsen, and Van Marrewijk (2001), has been reproduced below for the instance in which two regions are considered:

(i) "*Guess an initial solution for the wage rate in the two regions, say* $(W_{1,0}, W_{2,0})$*, where '0' indicates the number of iterations.*

(ii) *Using* $(W_{1,0}, W_{2,0})$ *calculate the income levels* $(Y_{1,0}, Y_{2,0})$ *and the price index* $(I_{1,0}, I_{2,0})$ *as implied in equations (3.3.1) and (3.3.2), respectively.*

(iii) *Using* $(Y_{1,0}, Y_{2,0})$ *and* $(I_{1,0}, I_{2,0})$ *as calculated in step (ii) determine a new possible solution for the wage rate* $(W_{1,1}, W_{2,1})$ *as implied in equation (3.3.3).*

(iv) *Repeat steps (ii) and (iii) until a solution is found.*"

A *stopping criterion* (σ) needs however be specified otherwise the computer will never stop 'jumping' onto the next iteration. The stopping criterion suggested by Brakman, Garretsen, and Van Marrewijk (2001) is "*the condition that the relative change in the wage rate should not exceed some small value* σ *from one iteration to the next for all regions r*". Note that every set of exogenous variables, or *parameters*, produces one solution and that real wage rates (w_r) and real incomes (y_r) in each region are easily calculated with equations (3.3.4) and (3.3.5), respectively:

$$w_r = W_r I_r^{-\delta} \tag{3.3.4}$$

$$y_r = Y_r I_r^{-\delta} \tag{3.3.5}$$

The examination of relative real wage rates against the share of mobile workforce (λ) in each region allows the drawing of important conclusions about the results of simulations using the core model of geographical economics[30]. Though there are an infinite number of short-run solutions (or equilibria) as a consequence of an infinite set of different values that can be attributed to the parameters, the number of long-run equilibria is rather limited. A long-run equilibrium is only reached when the relative wage rate for all regions is the same or when the totality of the mobile workforce agglomerates in one single region. Besides that, long-run equilibria can also be stable or unstable. A long-run equilibrium is said to be stable when the relative real wage and share of mobile workforce structure surrounding the equilibrium point will lead

[30] For a more detailed elucidation of stable and unstable equilibria, welfare, structural changes in parameters, and sustain and break analysis, refer to Brakman, Garretsen, and Van Marrewijk (2001).

on the long-run to a complete convergence of the mobile workforce to that point. Inversely, a long-run equilibrium is said to be unstable when the relative real wage and share of mobile workforce structure surrounding the equilibrium point is such that any infinitesimal perturbation of that structure will trigger a complete divergence of the mobile workforce away from that point. For all practical intentions, unstable equilibria on the one hand can be compared to the case in which the displacement of one firm from one region to another is enough to set in motion a process of cumulative causation that on the long-run will lead to either even spreading between regions or total agglomeration in one single region. Stable equilibria, on the other hand might be equivalent to those situations in which the spreading or agglomeration of economic activity require deeper structural economic changes. Brakman, Garretsen, and Van Marrewijk (2001) present an example for the specific case of two regions in which ninety short-run equilibria – each resulting from a different input value of transport costs holding the value of the remaining parameters fixed – are plotted in a graph of relative wages (w_1/w_2) against the share of mobile workforce in region 1 (λ_1). In this graph five long-run equilibria are identified: three stable (one spreading and two total agglomeration) and two spreading unstable equilibria. Following the example, the authors draw important considerations on the effects *structural changes* on the values of the parameters might have to the number and type of long-run equilibria. Due to the high concentration of people in urban areas all over the world, Brakman, Garretsen, and Van Marrewijk (2001) acknowledge that the spreading forces in the core model, to wit "*the demand for manufactures from farm workers in the peripheral regions, is probably not very strong and that in this respect the Helpman (1998) model (…) may be preferred*". Congestion can nonetheless be included in the core model of geographical economics allowing for a stronger spreading force to act alongside the weak demand for manufactures of the farm workers. Congestion then is taken up solely as a function of city-size (more firms in larger cities) having direct impact on the production function of every firm. After the necessary adjustments to include congestion, equations (3.3.1), (3.3.2), and (3.3.3) are rewritten as follows:

$$Y_r = \delta\lambda_r W_r + (1-\delta)\phi_r \tag{3.3.6}$$

$$I_r = \left(\sum_{s=1}^{r} \lambda_s^{1-\tau\varepsilon} T_{rs}^{1-\varepsilon} W_s^{1-\varepsilon} \right)^{1/(1-\varepsilon)} \tag{3.3.7}$$

$$W_r = \lambda_r^{-\tau} \left(\sum_{s=1}^{r} Y_s T_{rs}^{1-\varepsilon} I_s^{\varepsilon-1} \right)^{1/\varepsilon} \tag{3.3.8}$$

where both the endogenous and the exogenous variables of the model comprising equations (3.3.6), (3.3.7), and (3.3.8) have the same interpretation as those of equations (3.3.1), (3.3.2), and (3.3.3), with the exception of the inclusion of parameter tau:

τ → external (dis)economies of scale

note that parameter tau can vary from $-1 < \tau < 1$; and that $\tau < 0$ represents economies of scale; whereas $\tau > 0$ represents diseconomies of scale

Congestion has thus been incorporated to a solvable model of geographical economics[31]. Three practical concerns have to be considered when using the core model of geographical economics with congestion. The first regards finding a good measure of congestion. This might turn into a formidable task because congestion can be anything, in the sense that any problem associated with the agglomeration of human activity over a limited area can be labeled as congestion or may find in congestion a fine explanation for its causes. Congestion can be traffic congestion and a host of related problems (by nature difficult to measure), which affects both people and firms. Brakman, Garretsen, and Van Marrewijk (2001) exemplify two proxies that could be used to measure traffic congestion: the number of motor vehicles per 1,000 inhabitants, or the number of motor vehicles per kilometer of road. The deficiencies of these proxies are evident because depending on the circumstances they might not be measuring traffic congestion at all. One interpretation of congestion focuses on the counter productive effects too many businesses in the same geographical area competing for the same clients and inputs can have on firms and on imperfect competition. Parameter τ directly introduced in equations (3.3.7) and (3.3.8), indirectly in equation (3.3.5), reflects exactly this aspect of congestion. At any rate, the outcomes of traffic congestion on the production of firms, the influences of congestion on people, on services, and many other effects of congestion are not accounted for in this approach. The second concern has to do with the use one level of congestion proportional to city size for the economy as a whole. In the absence of specific data, it might be difficult to decide which level of congestion to choose as the initial input to the model – the lowest, an intermediary one, or the highest. One attempt to overcome this drawback would be have parameter τ vary and then opting for that level of congestion which more closely yields the expected results, turning congestion into a self-fulfilling prophecy. Another option would be to adjust the equations to allow input separately different levels of congestion for each city. Yet, that would lead back to the initial question on what method to use that can deliver a reliable approximation of congestion. The third concern, perhaps the most important

[31] For the incorporation of congestion into the core model of geographical economics refer to Forslid (1998), Ottaviano (1999), Brakman et al. (1996), and Brakman, Garretsen, and Van Marrewijk (2001).

for developing countries, concerns the hard decision before the researcher on to what extent can congestion act as a spreading force. Albeit a lot of people in Europe or in the USA may shiver just by listening the word 'congestion', the common citizen is Brazil is invariably more worried about trying to find a living in urban centers where access to better public and private services and jobs can be found more easily. The assumed deleterious consequences of congestion become thus a secondary matter that depends on each individual's income, culture, personality, and physiology. Adding to the difficulty of the task, many firms in Brazil have had to learn how to adapt their production processes to cope with congestion in the hope rewards for their efforts would eventually come from gaining a competitive edge over those firms that could not find their way amid crowded places. In this sense congestion and imperfect competition can coexist peacefully. To put it short, the resources necessary to fully assess the relativity of congestion and its myriad of associated and interconnected problems (or advantages) may lie beyond any practical aim.

3.4. The Helpman–Hanson Model of Geographical Economics

For the sake of illustration and as a suggestion for further research, as it is beyond the scope of this research to perform simulations with the Helpman– Hanson model, the micro-economic fundamentals that dictate the behavior of individual economic agents on the marketplace in Helpman (1998) are the same of Krugman (1991), with the exception of the replacement of the food sector with the non-tradable, perfectly competitive housing sector. Though on both models agglomeration derives from the labor mobility between regions, in Helpman (1998) the *no-black-hole* condition is 'reversed'[32]. For all practical aspirations, it suffices to bear in mind that in the core model of geographical economics, high levels of transport costs lead to local provision of manufactures because the higher transport costs are, the costlier it is to trade manufactures between regions, which results in demand being more effectively supplied from home producers entailing the spreading of economic activity. For lower transport costs, spreading becomes unstable and agglomeration becomes stable equilibrium. At an intermediate range of transport costs, either agglomeration or spreading of economic activity are both long-run, stable equilibria. Very low transport costs contribute for the efficient trade of manufactures between regions, which leads to the feasibility of provision of manufactures from abroad entailing agglomeration of economic activity in accordance with the home-market-effect. On the other hand, in the Helpman (1998) model the interpretation is reversed, as stated in Helpman (1998): "*It is shown that whenever transport costs are low, a unique stable equilibrium exists in which both regions are occupied. Population density is determined by the relative availability of housing. If the amount of housing is the same in both regions, half of the population resides in each of them. When the*

[32] Please refer to Brakman, Garretsen, and Van Marrewijk (2001).

demand for housing is high or the elasticity of substitution across brands is high, the same unique, stable equilibrium prevails for all levels of transport costs. When the demand for housing is low, however, or the elasticity of substitution across brands is low, there exist two asymmetric equilibria with regions of unequal size in each of them, even when the supply of housing is the same in both locations. The higher the transport costs, the more unequal the regions, while the inequality in the size of regions rises very rapidly with transport costs. These results are different from Krugman's (1991) regarding the link between agglomeration and transport costs."

Following Helpman (1998) and Hanson (1998, 1999)[33] experiments with the model in US counties Brakman, Garretsen, and Schramm (2002)[34] delineating the short-run equilibrium equations of Helpman (1998)[35] and Hanson (1998, 1999) in a manner similar to those of the core model of geographical economics:

$$Y_r = \lambda_r L W_r \tag{3.4.1}$$

$$I_r = \left(\sum_{s=1}^{r} \lambda_s T_{rs}^{1-\varepsilon} W_s^{1-\varepsilon} \right)^{1/(1-\varepsilon)} \tag{3.4.2}$$

$$W_r = \left(\sum_{s=1}^{r} Y_s T_{rs}^{1-\varepsilon} I_s^{\varepsilon-1} \right)^{1/\varepsilon} \tag{3.4.3}$$

where equations (3.4.2) and (3.4.3) are identical to equations (3.3.2) and (3.3.3) of the core model of geographical economics and the exogenous variables in equation (3.4.1) signify:

L → total mobile workforce

λ_r → share of mobile workforce in region r

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[33] Refer to Brakman, Garretsen, and Van Marrewijk (2001).

[34] Based on different estimation strategies and taking empirical data of a number of features of the re-unified German economy into account, not only the spatial distribution of wages is tested, but also the spatial structure with respect to German unemployment, employment and land prices.

[35] The original specifications of the model are found in Helpman (1998).

Hanson (1998, 1999)[36] rewrites the price index equation, allowing for able to estimate, exogenous parameters in US counties, arriving at the following two additional equilibrium conditions:

$$P_r H_r = (1-\delta) Y_r \tag{3.4.4}$$

which can be rewritten as:

$$Y_r = \frac{P_r H_r}{(1-\delta)} \tag{3.4.4'}$$

where

P_r → price of housing services in region *r*

H_r → fixed stock of housing in region *r*

$(1-\delta)$ → share of income spent on housing services

and at:

$$\frac{W_r}{P_r^{1-\delta} I_r^{\delta}} = \frac{W_s}{P_s^{1-\delta} I_s^{\delta}} \tag{3.4.5}$$

which is the real wage equalization, where

δ → share of income spent on manufactures

Conforming to Brakman, Garretsen, and Schramm (2002), we choose to term the full model specification above as the Helpman–Hanson model. In this model, long-run equilibrium is achieved when real wages are identical for all regions, or as put by Brakman, Garretsen, and Schramm (2002) "*this implies that labor has no incentive to migrate (interregional labor mobility is solely a function of interregional wage differences)*".

This paper also argues that the solution method employed for the core model of geographical economics could also be applied to the Helpman–Hanson model with minor alterations, making it possible to perform spreadsheet simulations in like manner. Hereafter a solution method using Helpman–Hanson is presented. Note that it is but an adaptation of the *sequential iterations* method utilized by Brakman,

[36] Refer to Brakman, Garretsen, and Schramm (2002).

Garretsen, and Van Marrewijk (2001) presented earlier and outlined below for the case of two cities:

(i) Guess an initial solution for the wage rate in the two regions, say ($W_{1,0}$, $W_{2,0}$), where '0' indicates the number of iterations.

(ii) Using ($W_{1,0}$, $W_{2,0}$) calculate the exogenous income levels ($Y_{1,0}$, $Y_{2,0}$) as implied in equation (3.4.4') and the price indexes ($I_{1,0}$, $I_{2,0}$) as implied in equation (3.4.2).

(iii) Using ($Y_{1,0}$, $Y_{2,0}$) and ($I_{1,0}$, $I_{2,0}$) as calculated in step (ii) determine a new possible solution for the wage rate ($W_{1,1}$, $W_{2,1}$) as implied in equation (3.4.3).

(iv) Repeat steps (ii) to (iii) until a solution is found.

Again, the *stopping criterion* is that suggested by Brakman, Garretsen, and Van Marrewijk (2001), or:

$$\left| \frac{W_{iteration} - W_{r,iteration-1}}{W_{r,iteration-1}} \right| < \sigma \text{ , for all } r$$

3.5. Research Questions

Is it possible, using the core model of geographical economics with congestion, to determine a range of transport costs that contributes to the spreading (or to the agglomeration) of economic activity, especially towards medium-size cities in the hinterland of the Brazilian states of São Paulo and Paraná?

Is it possible, using the core model of geographical economics with congestion, to draw any conclusions on what have been the effects in terms of spreading (or agglomeration) of economic activity, if any, brought about by taxation and toll duties on transport, especially to medium-size cities in the hinterland of the Brazilian states of São Paulo and Paraná?

Can the core model of geographical economics with congestion, the way it has been applied to this concrete case, through the analysis of structural changes be of some guidance in the shaping of policy options available to decision-makers in Brazil?

4. Research Outline

4.1. Geographical, Economic Bounds

Given the continental dimensions of Brazil with roughly nine million square kilometers – half South America's size and half South America's economy – an analysis reducing the country to only two regions would seem way too simplistic for the design of this research. IPEA (2001) with its subdivision of the country into twelve urban systems turns out to be quite helpful in addressing the crucial question on how to divide the country into meaningful regions taking into consideration municipalities, their connectivity, their economic interdependency, their hierarchy, and their area of influence[37]. The main objective of this paper is to address the issue of the impact transport costs and other parameters may have over the economic movement from the metropolitan areas towards medium-size municipalities within states[37]. It would be engaging to include in a single research the displacements of human activity across both the whole of the country and within each urban system considered separately respecting IPEA's (2001) classification. Time and resources have constrained this paper, however, to deal specifically with the states of São Paulo and Paraná and their major cities. This paper avails itself of the classification adopted by IPEA (2001), in which certain municipalities surrounding major cities are grouped to frame each urban center. Nevertheless, given both the limitations of computer resources required to simulate a large number of different urban centers and for the practical hardships involved in representing in one graph all thirty urban centers of the states of São Paulo and Paraná divided in IPEA's (2001) classification (the final portion of this research depends heavily on graphs to draw conclusions on the results of the simulations), this research found itself forced to conduct further grouping of some of the urban centers in IPEA (2001)'s description. Figures 4.1. and 4.2. depict the urban centers, their prime cities, and all the municipalities within the states belonging to the area of influence of such urban centers as considered in this research. The grouping strategy adopted by this paper should not impair the results of the simulations owing to the similar features of the bundled urban centers. Note also that according to IPEA's (2001) division of Brazil in major urban systems, the states of São Paulo and Paraná have been placed in different positions. Both states nonetheless share enough historical and economic connections to allow them being analyzed as one major system of cities. In the second half of the nineteenth century the state of Paraná was still attached to the state of São Paulo and much of the colonization of the northern and western part of the state of Paraná has been done from the first half of the twentieth century onwards with migratory movements of agrarian families from the state of São Paulo. The consolidated cultural, productive, and road links between the two states, which IPEA (2001) does not fail to acknowledge, confers the two

[37] Please refer to the introductory part of this paper.

regions an economic symbiosis ample sufficient to allow both states to be dealt with as one single urban system. Moreover, by simulating both states together as one single larger system of cities offers the possibility of evaluating inter-state displacements of human activity and the consequences structural changes might have on the economic relationship between the two states as well.

4.2. Simulations

This paper has availed itself of a 'before and after' procedure in trying to 'calibrate' the core model of geographical economics with congestion to become a useful tool to gauge trends in recent Brazilian regional reality. Data has been collected for the year of 1996 – the 'before' scenario – when the privatization process of federal roads in Brazil in practice had just started and the majority of the roads belonging to the federal roads system were still free of charge to users. 2002, the last year when the necessary data to perform the simulations was accessible stands for the 'after' scenario when the privatization of the federal roads system had already acquired virtually the same extension it has today in both the states contemplated. Rounds of simulations were then ran using the data available for the 'before' and for the 'after' scenarios. The ensuing analysis of the results, comments and recommendations all belong to the specific subsequent sections of this paper.

In trying to answer the research questions, this paper relies on simulations performed with the aid of spreadsheets that apply numerical calculation methods to the equilibrium conditions of the core model with congestion. Equations (3.3.6), (3.3.7), and (3.3.8) were then inserted into a spreadsheet programmed with the solution method described in sub-section 3.3. (downloadable from Professor Charles G. M. van Marrewijk's web page[38]). A few adaptations were nevertheless necessary to the spreadsheet generated by Professor Van Marrewijk to allow for the inclusion of the desired number of urban centers an to alter the way with which the spreadsheet deal with transport costs, as it will be detailed further on this paper. At any rate, this research centers on the outcomes the modeling strategies have on the size of urban centers. It is beyond the scope of this paper to perform further analysis on the stability of the equilibria obtained with structural changes in parameters or the examination of either total or local welfare consequences long-run equilibria might have. Though transport costs are of prime concern for this research, complementary simulations are carried out to assess the implications structural changes in the other exogenous variables might have on the spreading or agglomeration of economic activity in the urban centers under investigation. The parameters, a brief explanation of their

[38] Several simulation spreadsheets based on the core model of geographical economics can be found on Professor Charles van Marrewijk's web page (www.few.eur.nl/few/people/vanmarrewijk), including those that deal with refinements and extensions of the core model of geographical economics discussed at length in Brakman, Garretsen, and Van Marrewijk (2001).

significance for the research at hand, the ranges of structural change systematic variations performed, and the proxies utilized for the research simulations are subsequently summarized.

4.2.1. Transport Costs *T*

Parameter *T*, transport costs, refers to economic distances between regions. Driven by the importance transport costs have had on the overall distribution of economic activity within Brazil and by the fact that slight variations in transport costs might bring forth significant changes in the number and configuration of stable and unstable equilibria, structural change systematic variations in transport costs are to deserve the greater attention of this paper. Transport costs can be amply interpreted as "*(…) many different types of obstacles to trade between locations, such as tariffs, language and culture barriers, and indeed the costs of actually getting goods or services at another location*", as stated in Brakman, Garretsen, and Van Marrewijk (2001). Transport costs can also be interpreted more broadly as a proxy for the development of the economy. This paper however focuses on the more restrict interpretation of transport costs, more specifically: the monetary price that must be paid by any individual person or firm to have goods transported from one city to another in Brazil by road. As a reminder, transport costs in the simulations carried out by this research adopt the geographical economics concept of 'iceberg' transport costs[39]. Transport costs are then considered as if part of the merchandise being transported 'melted' on the way, thus making necessary to ship more merchandise to arrive at the destination with the desired quantity of merchandise. Or analogously, the more taxes and toll duties paid, the more of the cost of merchandise has to be earmarked for transport expenses, reducing profit margins of producers and making prices charged to consumers in other regions higher. Originally, the simulation spreadsheets made use of equation (4.2.1) to calculate 'iceberg' transport costs:

$$T_{rs} = T^{\ln(1+Drs)} \tag{4.2.1}$$

Which is a similar way to evaluate transport costs in the core model of geographical economics as the one presented before with equation (4.2.2):

$$T_{rs} = T^{Drs} \tag{4.2.2}$$

In both equations (4.2.1) and (4.2.2), as stated by Brakman, Garretsen, and Van Marrewijk (2001), "*(…) parameter T denotes the number of goods that need be shipped to ensure that one unit of a variety of manufactures arrives per unit of distance, while* T_{rs} *is defined as the number of goods that need to be shipped from*

[39] For a more detailed analysis of 'iceberg' transport costs refer to Brakman, Garretsen, and Van Marrewijk (2001).

region r to region s. (…) These definitions ease notation in the equations below and allow us to distinguish changes in the parameter T, that is the general change in (transport) technology applying to all regions, and changes in the 'distance' D_{rs} *between regions, which may result from a policy change, such as tariffs changes, a cultural treaty, new infrastructure, etc.*" These theoretical equations, however, might blur the picture of what 'iceberg' transport costs mean in terms of actual transport costs. Soybean, for instance, a major produce of Brazil, has to be transported by road from center-western states to processing units and exporting ports located in the south and southeast, especially to the port of Paranaguá in the southern state of Paraná. One ton of unprocessed soybean in 1996 fetched R$ 233.20 (US$ 232.17 at the exchange rate of the time) in international markets and the 700 km trip necessary to cross the state of São Paulo cost at that time on average R$ 76.00 per ton. In 'iceberg' transport costs terms that would amount to 32.45% more merchandise having to be loaded on the truck to account for transport costs, as if some of the soybeans actually fell off the truck on the way. Taking the above-mentioned definition, *T* would then be equal to 1.3245. The quotation of soybean both inside Brazil and in international commodity markets has oscillated considerably from 1996 to 2002 (from US$ 13.93 to US$ 10.03 for a 60 Kg sac on average for each year, respectively). The Brazilian currency, the *Real* (R$), has also moved against the US$ Dollar in that period (one US$ Dollar to 1.0045 R$ in 1996 and one US$ Dollar to 2.8452 R$ in 2002, on average for each year). Nevertheless, in trying to figure what 'iceberg' transport costs really mean in practical terms this research needs merchandise that allows for everything else constant, except transport costs. This paper has then considered an imaginary product which costs R$ 300.00 per ton in both 1996 and 2002 as the basis for the analysis of transport costs structural change systematic variation, without any further provisions for exchange rate oscillations or for the share of freight price that changes depending on the value of the product transported.

In the search of real transport costs with which to compare to geographical economics 'iceberg' transport costs, this paper has dissected transport costs into three parts for years 1996 and 2002. One corresponds to general road transport costs expressed in terms of the Brazilian currency (R$) of one ton of merchandise (T) per kilometer (K) without taxation. Another corresponds to administrative taxes on the transport firms, direct taxation incident on fuel, and the so-called 'social contributions' (a form of Brazilian taxation on the wages firms pay to employees): all added and expressed in the common unit (R$/TK). The last part of actual transport costs corresponds to toll duties paid for the use of roads, again expressed in the common unit (R$/TK). All costs[40] have been estimated for a standard five-axle truck and trailer with a payload of twenty-five tons traveling a distance of 400 kilometers according to one of the

[40] All data used in this paper to estimate transport related costs were obtained at the restricted area of 'NTC & Logística' website (www.ntcelogistica.org.br).

standards used by FIPE[41] to calculate the INCTL – 400 (the 'National Index of Road Freight Transport Costs' for a 400-kilometer road distance) which we consider appropriate for this research taken into account the size of both the states of São Paulo and Paraná and the average truck and trailer used in road freight transport. INCTL indexes consisting of transport costs plus taxation excluding toll duties are available from November 2000 onwards, making it necessary to use the INCTF – 400x40 (the 'National Index of Door to Door Road Transport Costs' for a 400-kilometer road distance and a 40-kilometer urban distance) prior to year 2000 to obtain the proxy this paper uses for transport costs plus taxation excluding toll duties for year 1996. The share of average direct taxation on transport has been estimated with the aid of the detailed road operations freight budget used by FIPE to calculate average operational costs for a 400-kilometer road distance, amounting to 16.97% in July 2002. In this budget are listed all road operation costs for a 400-kilometer road distance, including provisions for profits, overhead, financial costs, administration of cargo terminals, insurance, risk management, depreciation, maintenance, average increase in prices charged according to merchandise value, and every other expense transport companies must face to charge customers the theoretical average price of their services. In the absence of a detailed budget for year 1996, the 2002 estimated 16.97% share of direct taxation on transport has then been used as a proxy for the year 1996 as well. Average toll duties per kilometer per axle per kilometer for the year 2002 were directly obtained at the restricted area of 'NTC & Logística' web site. Due to the fact that the so-called 'national privatization program' had just started in 1996, this paper assumes no toll duties for that year in neither the states of Paraná or São Paulo. In the state of São Paulo the privatization of roads took place mostly in the center and eastern portions of the state (please refer to Figure 2.24.) In this research average toll duties are nonetheless included for all roads connecting urban centers first because the plans are for the extension of privatization to the roads on the western portion of the state of São Paulo and second because links between most urban centers considered in this study, between the state capitals of the states of São Paulo and Paraná with most urban centers, and between urban centers and state capitals with other urban centers in neighboring states are tolled. In the state of Paraná, tolls started to be charged on federal roads within the state in 1997 and in 2002 it was virtually impossible to travel long distances by road within the state or to exit the state by road without paying toll (please refer to Figure 2.23.)

Therefore, taking into account actual transport costs in 1996 and in 2002 expressed in R$/TK, the constant price of R$ 300.00 per ton of our imaginary product in both 1996 and 2002, the total real distances between every urban center considered in this study, we were able to determine first $T_{(u)rs}$ between each of the urban centers with the aid of

[41] FIPE in Portuguese stands for the 'Foundation Institute of Economic Research', which contributes with data to 'NTC & Logística' (www.fipe.com.br).

equation (4.2.3) below. Note that $T_{(u)rs}$ in equation (4.2.3) is the correspondent of T in equation (4.2.1), or "*the number of goods that need be shipped to ensure that one unit of a variety of manufactures arrives per unit of distance*". Yet, note also that $T_{(u)rs}$ in this research is not the same per unit of distance for all urban centers. Though actual transport costs, or the 'economic' distances (D_{rs}), are proportional to the distances between every urban center, $T_{(u)rs}$ will be different depending on each two urban centers considered separately because we are using one imaginary merchandise as the basis of our calculations with fixed price of R$ 300.00 per ton. For that reason this paper adopts $T_{(u)rs}$ as the notation for 'unitary iceberg transport costs', or the tonnage that need be shipped to ensure that one ton of a variety that costs R$ 300.00 per ton arrives from region *r* to region *s*. Second, we were able to determine $T_{(t)rs}$, or "*the number of goods that need to be shipped from region r to region s*". Note that we make use of the index (*t*) to denote 'total iceberg transport costs', or the monetary expression of the tonnage that need be shipped to ensure that one ton of a variety that costs R$ 300.00 per ton arrives from region *r* to region *s*. This definition is similar to the definition for $T_{(u)rs}$, except that $T_{(t)rs}$ is expressed in terms of the actual monetary cost of transporting one ton of a variety that costs R$ 300.00 per ton between each pair of urban centers. The values of $T_{(t)rs}$ were obtained with equation (4.2.4):

$$T_{(u)rs} = \frac{(C + D_{rs})}{C} \tag{4.2.3}$$

$$T_{(t)rs} = CT_{(u)rs} \tag{4.2.4}$$

where

C → the constant price of our imaginary product, at R$ 300.00 for 1996 and 2002

D_{rs} → the actual 'economic' distance, or in our case the actual transport cost between every urban center for years 1996 and 2002

Following our reasoning concerning transport costs and their link to a merchandise whose value we know, we initially built a matrix for actual transport costs (D_{rs}) between every urban center considered in this research. We employed equation (4.2.3) to calculate the values of 'unitary iceberg transport costs' ($T_{(u)rs}$) for each entry in the matrix, originating a matrix of $T_{(u)rs}$. With the aid of equation (4.2.4) we multiplied every entry in matrix $T_{(u)rs}$ by C (the constant value of our imaginary product priced at R$ 300.00) thus obtaining a matrix of 'total iceberg transport costs' ($T_{(t)rs}$). Similarly, starting from the matrix of actual transport costs (D_{rs}) between every urban center we were able to compute a matrix of unitary T_{rs} dependent on the value of T using equation (4.2.1). We then multiplied every entry in this matrix by C (the constant value of our imaginary product priced at R$ 300.00) to generate a forth matrix of total T_{rs}, also dependent on the input value of T as expressed in equation

(4.2.1). We then added the entries in the matrix of $T_{(t)rs}$ and the entries in the matrix of total T_{rs}. Finally, by systematically making the value of *T* vary and using some trial and error, we were able to assess the level of actual transport costs in terms of the geographical economics definition of transport costs. *Id est*, the value of *T* that makes the sum of all transport costs in the matrix of total T_{rs} equals the sum of all transport costs in the matrix of $T_{(t)rs}$. Applying the same solution method to all levels of actual transport costs (D_{rs}) relevant for this research, we were able to determine the levels of actual transport costs in terms of the geographical economics definition of transport costs (please, refer to the tables at the end of this section), reproduced below:

(i) 1.03745 → for year 1996 considering full taxation

(ii) 1.04534 → for year 2002 considering a 100% reduction in both taxation and toll duties

(iii) 1.04986 → for year 2002 considering a 50% reduction in both taxation and toll duties

(iv) 1.05418 → for year 2002 considering no reduction in neither taxation or toll duties

In our search of what actual transport costs signify in the core model of geographical economics it has became mandatory to compare the outputs of simulations using as input transport costs evaluated with equation (4.2.1) to the outputs of simulations using as input transport costs evaluated with equation (4.2.5), described below:

$$T_{rs} = \frac{(C + TD_{rs})}{C} \qquad (4.2.5)$$

where

C → the constant price of our imaginary product, at R$ 300.00 for 1996 and 2002

D_{rs} → the actual 'economic' distance, or in our case the actual transport cost between urban centers for years 1996 and 2002

T → the parameter representing general changes in (transport) technology applying to all regions

The definitions of *T*, T_{rs}, and *Drs* in equation (4.2.5) are analogous to those applicable when analyzing equation (4.2.1). Notice that the number of simulations and the range of structural changes necessary to compare the outputs with different inputs of transport costs – one calculated with equation (4.2.1) and the other with equation

(4.2.5) – had to increase accordingly in the initially designed 'before' and 'after' scenarios. The new sets of simulations are then:

(i) Structural change systematic variation in parameter $T \rightarrow 1.00$ to 1.80 at increments of 0.025 using equation (4.2.1) to compute T_{rs} having as proxy for D_{rs} the physical road distances between urban centers and the shares of mobile and immobile workforce of 1996.

(ii) Structural change systematic variation in parameter $T \rightarrow 0.00$ to 10.00 at increments of 0.10 using equation (4.2.5) to compute T_{rs} having as proxy for D_{rs} the physical road distances between urban centers and the shares of mobile and immobile workforce of 1996.

(iii) Structural change systematic variation in parameter $T \rightarrow 1.00$ to 1.80 at increments of 0.025 using equation (4.2.1) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 1996 (considering full taxation) and the shares of mobile and immobile workforce of 1996.

(iv) Structural change systematic variation in parameter $T \rightarrow 0.00$ to 10.00 at increments of 0.10 using equation (4.2.5) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 1996 (considering full taxation) and the shares of mobile and immobile workforce of 1996.

(v) Structural change systematic variation in parameter $T \rightarrow 1.02$ to 1.06 at increments of 0.005 using equation (4.2.1) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 1996 (considering full taxation) and the shares of mobile and immobile workforce of 1996.

(vi) Structural change systematic variation in parameter $T \rightarrow 0.00$ to 2.00 at increments of 0.050 using equation (4.2.5) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 1996 (considering full taxation) and the shares of mobile and immobile workforce of 1996.

(vii) Structural change systematic variation in parameter $T \rightarrow 1.02$ to 1.06 at increments of 0.005 using equation (4.2.1) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 2002 (considering no reduction in neither taxation or toll duties) and the shares of mobile and immobile workforce of 2002.

(viii) Structural change systematic variation in parameter $T \rightarrow 0.00$ to 2.00 at increments of 0.050 using equation (4.2.5) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 2002 (considering no reduction in neither taxation or toll duties) and the shares of mobile and immobile workforce of 2002.

(ix) Structural change systematic variation in parameter $\delta \rightarrow 0.1$ to 0.9 at increments of 0.1, using equation (4.2.1) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 2002 (considering no reduction in neither taxation or toll duties) and the shares of mobile and immobile workforce of 2002.

(x) Structural change systematic variation in parameter $\delta \rightarrow 0.1$ to 0.9 at increments of 0.1, using equation (4.2.5) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 2002 (considering no reduction in neither taxation or toll duties) and the shares of mobile and immobile workforce of 2002.

(xi) Structural change systematic variation in parameter $\varepsilon \rightarrow 2$ to 8 at increments of 0.5, using equation (4.2.1) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 2002 (considering no reduction in neither taxation or toll duties) and the shares of mobile and immobile workforce of 2002.

(xii) Structural change systematic variation in parameter $\varepsilon \rightarrow 2$ to 8 at increments of 0.5, using equation (4.2.5) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 2002 (considering no reduction in neither taxation or toll duties) and the shares of mobile and immobile workforce of 2002.

(xiii) Structural change systematic variation in parameter $\tau \rightarrow 0.05$ to 0.16 at increments of 0.005, using equation (4.2.1) to compute T_{rs} and having as proxy for D_{rs} the actual values of transport costs for 2002 (considering no reduction in neither taxation or toll duties) and the shares of mobile and immobile workforce of 2002.

(xiv) Structural change systematic variation in parameter $\tau \rightarrow 0.05$ to 0.16 at increments of 0.005, using equation (4.2.5) to compute T_{rs} and having as proxy for D_{rs} the actual values of transport costs for 2002 (considering no reduction in neither taxation or toll duties) and the shares of mobile and immobile workforce of 2002.

Table 4.1. at the end of this section presents the matrix of distances between all urban centers and used as inputs for D_{rs} in simulation rounds (i) and (ii); Table 4.2. the matrix for actual transport costs (D_{rs}) at 1996 levels (considering full taxation) and used as inputs for D_{rs} in simulation rounds (iii) to (vi); Table 4.3. the matrix of 'unitary iceberg transport costs' ($T_{(u)rs}$) at 1996 levels (considering full taxation); Table 4.4. the matrix of 'total iceberg transport costs' ($T_{(t)rs}$) at 1996 levels (considering full taxation); Table 4.5. the matrix of unitary T_{rs} at 1996 levels

(considering full taxation); and Table 4.6. the matrix of total T_{rs} at 1996 levels (considering full taxation).

Table 4.7. at the end of this section depicts the matrix for actual transport costs (D_{rs}) at 2002 levels (considering a 100% reduction in both taxation and toll duties); Table 4.8. the matrix of 'unitary iceberg transport costs' ($T_{(u)rs}$) at 2002 levels (considering a 100% reduction in both taxation and toll duties); Table 4.9. the matrix of 'total iceberg transport costs' ($T_{(t)rs}$) at 2002 levels (considering a 100% reduction in both taxation and toll duties); Table 4.10. the matrix of unitary T_{rs} at 2002 levels (considering a 100% reduction in both taxation and toll duties); and Table 4.11. the matrix of total T_{rs} at 2002 levels (considering a 100% reduction in both taxation and toll duties).

Table 4.12. at the end of this section portrays the matrix for actual transport costs (D_{rs}) at 2002 levels (considering a 50% reduction in both taxation and toll duties); Table 4.13. the matrix of 'unitary iceberg transport costs' ($T_{(u)rs}$) at 2002 levels (considering a 50% reduction in both taxation and toll duties); Table 4.14. the matrix of 'total iceberg transport costs' ($T_{(t)rs}$) at 2002 levels (considering a 50% reduction in both taxation and toll duties); Table 4.15. the matrix of unitary T_{rs} at 2002 levels (considering a 50% reduction in both taxation and toll duties); and Table 4.16. the matrix of total T_{rs} at 2002 levels (considering a 50% reduction in both taxation and toll duties).

Table 4.17. at the end of this section displays the matrix for actual transport costs (D_{rs}) at 2002 levels (considering no reduction in neither taxation or toll duties) and used as inputs for D_{rs} in simulation rounds (vii) to (xiv). Table 4.18. the matrix of 'unitary iceberg transport costs' ($T_{(u)rs}$) at 2002 levels (considering no reduction in neither taxation or toll duties); Table 4.19. the matrix of 'total iceberg transport costs' ($T_{(t)rs}$) at 2002 levels (considering no reduction in neither taxation or toll duties); Table 4.20. the matrix of unitary T_{rs} at 2002 levels (considering no reduction in neither taxation or toll duties); Table 4.21. the matrix of total T_{rs} at 2002 levels (considering no reduction in neither taxation or toll duties).

4.2.2. Share of Income δ

Parameter δ represents the share of income spent on manufactures. In the core model the share of income spent on manufactures stands for the importance the mobile workforce has on the income and consequently for the importance the manufactures sector has on the economy. Other things held constant, high values of δ favor agglomeration while low values of δ favor spreading. Important to notice that a higher value of δ can also be interpreted as a proxy for a more advanced economy, in the sense that it is able to deliver cheaper manufactures and food to its population thus increasing welfare on the whole. Analogously, a higher value of δ can also be interpreted can be interpreted as a proxy for a more equalitarian economy, in the sense that the population in general is able to count on a greater share of their income to spend on manufactures with gains in welfare. An empirical value to be used as an approximation for δ was obtained from table 1.1.7 of IBGE (2004)[42], and used as the proxy for both 1996 and 2002. Table 1.1.7 of IBGE (2004) presents the results of the 'Family Budget Research' in the form of individual accounts, each assigned for a specific expenditure. In evaluating the proxy for the share of income spent on manufactures and on housing services, this research bundled certain expense items related to manufactures, the result being:

Proxy for δ (in the core model) → 23.11%

Parameter δ underwent structural change systematic variations ranging from 0.1 to 0.9 at increments of 0.1. When other parameters were subject to structural changes, δ was held constant at the proxy value.

4.2.3. Share of Mobile Workforce λ

Parameter λ, the share of mobile workforce in each region, is both one of the initial inputs and the output informing the resulting size of cities calculated by the simulation spreadsheet regarding the equilibrium conditions of the core model with congestion and the values of the parameters. The proxy used in this research as the initial input values of λ are the shares of total urban populations of the meso-regions within the states the urban centers of importance for this research are located. The information could be obtained form IBGE's 1996[43] census and 2002 population count[43] reporting the population of each municipality in the states of São Paulo and Paraná. Note that the unavailability of data concerning the shares of urban and rural populations in the year 2002 made necessary to resort to the shares of urban and rural population per municipality of year 2000 (when the last official national census was carried out). These were then multiplied by the total population of each municipality thus obtaining an approximation for the total urban and rural populations per municipality in 2002. Note thereto that if only the population of municipalities comprising urban clusters as defined in IPEA (2001) were considered, there would be a bias towards representing a greater share of urban population than the real share in the wider area (meso-region), which is nevertheless under the influence of the prime city of each urban center. To avert this bias, this research grouped the municipalities belonging to the same geographical area in observance to IBGE's (1996) subdivision of the states of São Paulo and Paraná into 'Geographic Meso-regions'. After the municipalities were batched together the total urban and rural populations per

[42] Please, refer to IBGE (2004), or 'Family Budget Research 2002/2003' available at www.ibge.gov.br.
[43] Available at the 'Brazilian Institute of Geography and Statistics' – IBGE web page (www.ibge.gov .br).

municipality were summed up to yield total urban and rural populations per meso-region. These were then used to compute the shares of regional urban and rural populations that are used as proxies for the mobile and immobile workforce shares in this paper, respectively. Note finally that some urban centers – and their regional urban and rural populations accordingly – have been bundled as explained before. Table 4.22. at the end of this section portrays urban and rural shares of population for each urban center after all the necessary adjustments required by the research design have been made, mentioning which urban centers (IPEA 's 2001 categorization) have been grouped under the name of the prime city in the regional urban center.

Human concentration follows economic activity, but economic activity might also seek human concentration. In the absence of more specific data on the numbers of mobile and immobile workers in each region, the question arises concerning which proxy should be used in the core model with congestion: the shares of urban and rural population or the shares of manufacturing and agricultural production. Having access to both these figures, this paper chose to rely on urban and rural population figures to calculated the proxies for the shares of manufacturing and agricultural labor force, respectively. Note that metropolitan São Paulo stands by far as the major population center, holding nearly half of the total population figure of both states added together. Had meso-regional GDP been used as a proxy instead of population, the share of mobile workforce allotted to São Paulo would have been higher, weakening even more the already weak spreading forces of the core model of geographical economics. The differences in the proxies used as shares of mobile and immobile workforces using population or meso-regional GDP are small enough to allow the use of either one or the other with negligible changes in the results of the simulations. Table 4.23. summarizes the shares of urban and rural GDP per urban center as considered in this research.

4.2.4. Share of Immobile Workforce ϕ

Parameter ϕ, the share of immobile workforce located in each urban center, remains constant throughout the simulations using the core model with congestion once agriculture workforce is taken as immobile. Similarly to the share of mobile workforce, it needs not undergo structural change systematic variations. In the core model the proxies for ϕ are the rural shares of the total rural population as reproduced in Table 4.26. The observations concerning the data, the proxies, and the necessary adjustments are the same applicable to the mobile workforce (parameter λ) in the preceding subsection.

4.2.5. Elasticity of Substitution ε

Parameter ε, the elasticity of substitution between varieties, or the demand elasticity, can be interpreted as a degree of competitiveness between varieties. Parameter ε plays a very meaningful role in the 'balancing' of the demand schedule in the core model[44]. This paper puts higher attention on the implications structural changes in ε can have on the size of regions. In the core model with congestion if the elasticity of substitution is high, it is easier for the consumer to procure other varieties because these are easier to substitute amongst each other. As a result the impact transport costs have on real wages (welfare) is lower and spreading is a long-run, stable equilibrium. Conversely, if the elasticity of substitution is low, locally produced varieties are more attractive, acting as an additional agglomerating force. Due to the fact that data providing a reasonable approximation of parameter ε were not easily available, this research submitted ε to structural change systematic variations from 2 to 8 in increments of 0.5 and held ε constant at 3 when performing structural change systematic variations with other parameters.

4.2.6. Congestion τ

Parameter τ, which can originally represent both external economies and external diseconomies of scale, for the intent of this paper represents only diseconomies of scale (a proxy for congestion) and has thus been made to vary from 0.05 to 0.16 at increments of 0.005 while holding other parameters constant. When other parameters were subject to variation, parameter τ was held constant at 0.012. Note that this value and the range of structural change systematic variation have been chosen based on preliminary simulations that showed that agglomeration forces in the core model (for the data utilized) became too strong for values of τ lower than 0.05 making complete agglomeration in São Paulo the only long-run, stable equilibrium. On the other hand, for values of τ higher than 0.16 even spreading among all cities became the only outcome of the model irrespective of the value of the other parameters.

4.2.7. Parameters σ and η

Parameters σ and η do not show on structural equations (3.3.1) to (3.3.3) or on equations (3.3.6) to (3.3.8) of the core model of geographical economics without and with congestion, respectively. They are nonetheless relevant for the solution method employed and wherefore for the simulations with spreadsheet programming. Albeit both σ and η can have implications on the configuration of the stable equilibria and be therefore interpreted as structural parameters representing the speed of migratory movements, for the aim of this research it is sufficient to state that parameter σ stands

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[44] For a detailed account of the specifications of the core model refer to Brakman, Garretsen, and Van Marrewijk (2001).

for the aforementioned stopping criterion and that it has been kept constant at 0.0001 for all simulations, the same value as that adopted in the simulations carried out in Brakman, Garretsen, and Van Marrewijk (2001). Likewise, parameter η stands for the 'speed-of-adjustment' and it has been kept constant at the value of 2 throughout this paper's simulations.

4.3. Figures and Tables

Figure 4.1. State of São Paulo: Research Urban Centers, Prime Cities, and Municipality Boundaries

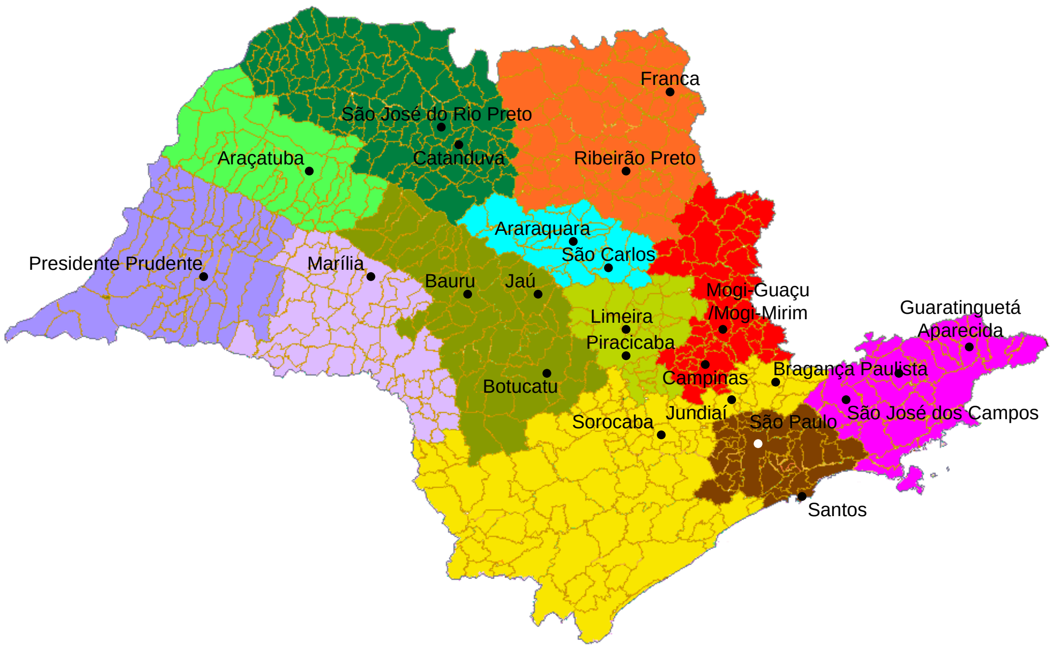


Figure 4.2. State of Paraná: Research Urban Centers, Prime Cities, and Municipality Boundaries

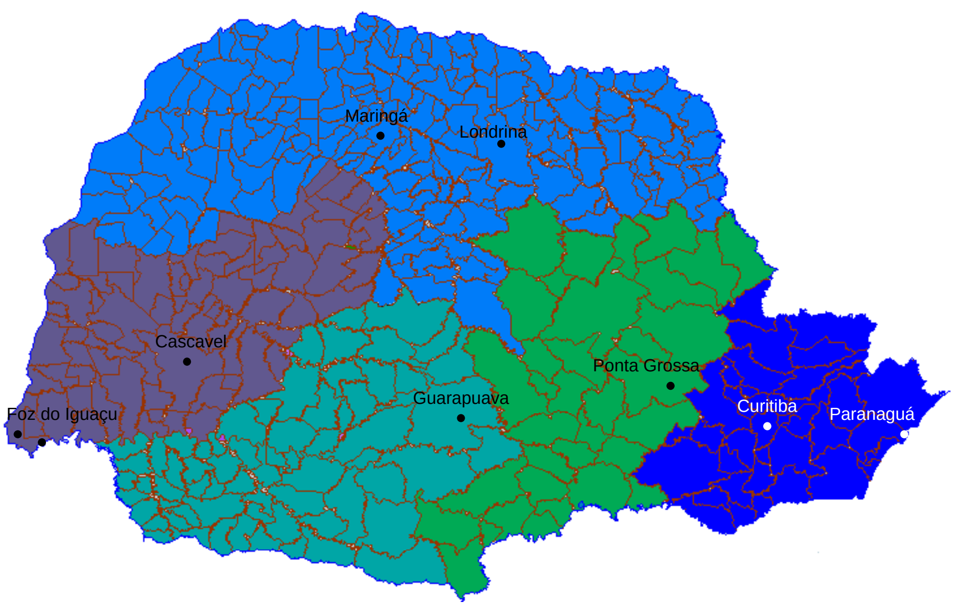


Table 4.1. Matrix of Distances Between Urban Centers

	ACTUAL DISTANCES BETWEEN URBAN CENTERS													Km				
	Urban Center	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	**São Paulo**	0	102	100	333	109	474	294	547	157	343	437	609	408	556	898	471	700
2	**Campinas**	102	0	145	237	95	393	189	462	81	263	374	540	411	505	866	465	685
3	**São José dos Campos**	100	145	0	350	192	517	337	608	229	414	512	760	498	716	970	575	730
4	**Ribeirão Preto**	333	237	350	0	296	193	95	330	187	213	299	453	552	486	876	561	756
5	**Sorocaba**	109	95	192	296	0	416	233	460	106	251	353	510	333	454	752	395	543
6	**São José do Rio Preto**	474	393	517	193	416	0	186	135	324	183	181	302	566	386	787	534	681
7	**Araraquara/São Carlos**	294	189	337	95	233	186	0	294	128	123	229	407	465	410	750	472	598
8	**Araçatuba**	547	462	608	330	460	135	294	0	399	222	134	159	537	280	591	477	529
9	**Piracicaba**	157	81	229	187	106	324	128	399	0	176	296	464	397	436	758	423	571
10	**Bauru**	343	263	414	213	251	183	123	222	176	0	107	294	393	293	695	377	478
11	**Marília**	437	374	512	299	353	181	229	134	296	107	0	173	414	197	547	364	431
12	**Presidente Prudente**	609	540	760	453	510	302	407	159	464	294	173	0	480	145	429	405	412
13	**Curitiba**	408	411	498	552	333	566	465	537	397	393	414	480	0	358	517	114	275
14	**Londrina**	556	505	716	486	454	386	410	280	436	293	197	145	358	0	356	258	265
15	**Cascavel**	898	866	970	876	752	787	750	591	758	695	547	429	517	356	0	415	258
16	**Ponta Grossa**	471	465	575	561	395	534	472	477	423	377	364	405	114	258	415	0	160
17	**Guarapuava**	700	685	730	756	543	681	598	529	571	478	431	412	275	265	258	160	0

Table 4.2. Matrix of Average Actual Transport Costs (D_{rs}) – 1996 (considering full taxation)

	TRANSPORT COSTS + TAX (100%) - R$/T - 1996												R$/TK =		0.1081			
	Urban Center	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	**São Paulo**	0	11	11	36	12	51	32	59	17	37	47	66	44	60	97	51	76
2	**Campinas**	11	0	16	26	10	42	20	50	9	28	40	58	44	55	94	50	74
3	**São José dos Campos**	11	16	0	38	21	56	36	66	25	45	55	82	54	77	105	62	79
4	**Ribeirão Preto**	36	26	38	0	32	21	10	36	20	23	32	49	60	53	95	61	82
5	**Sorocaba**	12	10	21	32	0	45	25	50	11	27	38	55	36	49	81	43	59
6	**São José do Rio Preto**	51	42	56	21	45	0	20	15	35	20	20	33	61	42	85	58	74
7	**Araraquara/São Carlos**	32	20	36	10	25	20	0	32	14	13	25	44	50	44	81	51	65
8	**Araçatuba**	59	50	66	36	50	15	32	0	43	24	14	17	58	30	64	52	57
9	**Piracicaba**	17	9	25	20	11	35	14	43	0	19	32	50	43	47	82	46	62
10	**Bauru**	37	28	45	23	27	20	13	24	19	0	12	32	42	32	75	41	52
11	**Marília**	47	40	55	32	38	20	25	14	32	12	0	19	45	21	59	39	47
12	**Presidente Prudente**	66	58	82	49	55	33	44	17	50	32	19	0	52	16	46	44	45
13	**Curitiba**	44	44	54	60	36	61	50	58	43	42	45	52	0	39	56	12	30
14	**Londrina**	60	55	77	53	49	42	44	30	47	32	21	16	39	0	38	28	29
15	**Cascavel**	97	94	105	95	81	85	81	64	82	75	59	46	56	38	0	45	28
16	**Ponta Grossa**	51	50	62	61	43	58	51	52	46	41	39	44	12	28	45	0	17
17	**Guarapuava**	76	74	79	82	59	74	65	57	62	52	47	45	30	29	28	17	0

Table 4.3. Matrix of 'Unitary Iceberg Transport Costs' ($T_{(u)rs}$) – 1996 (considering full taxation)

ACTUAL UNITARY 'ICEBERG' TRANSPORT COSTS — **TON OF IMAGINARY PRODUCT = 300.00**

	Urban Center	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Σ
1	São Paulo	1.0000	1.0368	1.0360	1.1200	1.0393	1.1708	1.1060	1.1971	1.0566	1.1236	1.1575	1.2195	1.1470	1.2004	1.3236	1.1697	1.2523	18.3563
2	Campinas	1.0368	1.0000	1.0523	1.0854	1.0342	1.1416	1.0681	1.1665	1.0292	1.0948	1.1348	1.1946	1.1481	1.1820	1.3121	1.1676	1.2469	17.0582
3	São José dos Campos	1.0360	1.0523	1.0000	1.1261	1.0692	1.1863	1.1215	1.2191	1.0825	1.1492	1.1845	1.2739	1.1795	1.2580	1.3496	1.2072	1.2631	16.6698
4	Ribeirão Preto	1.1200	1.0854	1.1261	1.0000	1.1067	1.0696	1.0342	1.1189	1.0674	1.0768	1.1078	1.1633	1.1989	1.1752	1.3157	1.2022	1.2725	14.9090
5	Sorocaba	1.0393	1.0342	1.0692	1.1067	1.0000	1.1499	1.0840	1.1658	1.0382	1.0905	1.1272	1.1838	1.1200	1.1636	1.2710	1.1424	1.1957	13.7321
6	São José do Rio Preto	1.1708	1.1416	1.1863	1.0696	1.1499	1.0000	1.0670	1.0487	1.1168	1.0660	1.0652	1.1088	1.2040	1.1391	1.2836	1.1925	1.2454	12.5371
7	Araraquara/São Carlos	1.1060	1.0681	1.1215	1.0342	1.0840	1.0670	1.0000	1.1060	1.0461	1.0443	1.0825	1.1467	1.1676	1.1478	1.2703	1.1701	1.2155	11.3969
8	Araçatuba	1.1971	1.1665	1.2191	1.1189	1.1658	1.0487	1.1060	1.0000	1.1438	1.0800	1.0483	1.0573	1.1935	1.1009	1.2130	1.1719	1.1907	10.1994
9	Piracicaba	1.0566	1.0292	1.0825	1.0674	1.0382	1.1168	1.0461	1.1438	1.0000	1.0634	1.1067	1.1672	1.1431	1.1571	1.2732	1.1524	1.2058	9.2690
10	Bauru	1.1236	1.0948	1.1492	1.0768	1.0905	1.0660	1.0443	1.0800	1.0634	1.0000	1.0386	1.1060	1.1416	1.1056	1.2505	1.1359	1.1723	7.9504
11	Marília	1.1575	1.1348	1.1845	1.1078	1.1272	1.0652	1.0825	1.0483	1.1067	1.0386	1.0000	1.0623	1.1492	1.0710	1.1971	1.1312	1.1553	6.7662
12	Presidente Prudente	1.2195	1.1946	1.2739	1.1633	1.1838	1.1088	1.1467	1.0573	1.1672	1.1060	1.0623	1.0000	1.1730	1.0523	1.1546	1.1460	1.1485	5.6743
13	Curitiba	1.1470	1.1481	1.1795	1.1989	1.1200	1.2040	1.1676	1.1935	1.1431	1.1416	1.1492	1.1730	1.0000	1.1290	1.1863	1.0411	1.0991	4.4555
14	Londrina	1.2004	1.1820	1.2580	1.1752	1.1636	1.1391	1.1478	1.1009	1.1571	1.1056	1.0710	1.0523	1.1290	1.0000	1.1283	1.0930	1.0955	3.3168
15	Cascavel	1.3236	1.3121	1.3496	1.3157	1.2710	1.2836	1.2703	1.2130	1.2732	1.2505	1.1971	1.1546	1.1863	1.1283	1.0000	1.1496	1.0930	2.2425
16	Ponta Grossa	1.1697	1.1676	1.2072	1.2022	1.1424	1.1925	1.1701	1.1719	1.1524	1.1359	1.1312	1.1460	1.0411	1.0930	1.1496	1.0000	1.0577	1.0577
17	Guarapuava	1.2523	1.2469	1.2631	1.2725	1.1957	1.2454	1.2155	1.1907	1.2058	1.1723	1.1553	1.1485	1.0991	1.0955	1.0930	1.0577	1.0000	155.5912

Table 4.4. Matrix of 'Total Iceberg Transport Costs' ($T_{(t)rs}$) – 1996 (considering full taxation)

ACTUAL TOTAL 'ICEBERG' TRANSPORT COSTS — **TON OF IMAGINARY PRODUCT = 300.00**

	Urban Center	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Σ
1	São Paulo	0.0	311.0	310.8	336.0	311.8	351.2	331.8	359.1	317.0	337.1	347.2	365.8	344.1	360.1	397.1	350.9	375.7	5,506.9
2	Campinas	311.0	0.0	315.7	325.6	310.3	342.5	320.4	350.0	308.8	328.4	340.4	358.4	344.4	354.6	393.6	350.3	374.1	5,117.5
3	São José dos Campos	310.8	315.7	0.0	337.8	320.8	355.9	336.4	365.7	324.8	344.8	355.4	382.2	353.8	377.4	404.9	362.2	378.9	5,000.9
4	Ribeirão Preto	336.0	325.6	337.8	0.0	332.0	320.9	310.3	335.7	320.2	323.0	332.3	349.0	359.7	352.5	394.7	360.7	381.7	4,472.7
5	Sorocaba	311.8	310.3	320.8	332.0	0.0	345.0	325.2	349.7	311.5	327.1	338.2	355.1	336.0	349.1	381.3	342.7	358.7	4,119.6
6	São José do Rio Preto	351.2	342.5	355.9	320.9	345.0	0.0	320.1	314.6	335.0	319.8	319.6	332.7	361.2	341.7	385.1	357.7	373.6	3,761.1
7	Araraquara/São Carlos	331.8	320.4	336.4	310.3	325.2	320.1	0.0	331.8	313.8	313.3	324.8	344.0	350.3	344.3	381.1	351.0	364.7	3,419.1
8	Araçatuba	359.1	350.0	365.7	335.7	349.7	314.6	331.8	0.0	343.1	324.0	314.5	317.2	358.1	330.3	363.9	351.6	357.2	3,059.8
9	Piracicaba	317.0	308.8	324.8	320.2	311.5	335.0	313.8	343.1	0.0	319.0	332.0	350.2	342.9	347.1	382.0	345.7	361.7	2,780.7
10	Bauru	337.1	328.4	344.8	323.0	327.1	319.8	313.3	324.0	319.0	0.0	311.6	331.8	342.5	331.7	375.1	340.8	351.7	2,385.1
11	Marília	347.2	340.4	355.4	332.3	338.2	319.6	324.8	314.5	332.0	311.6	0.0	318.7	344.8	321.3	359.1	339.4	346.6	2,029.9
12	Presidente Prudente	365.8	358.4	382.2	349.0	355.1	332.7	344.0	317.2	350.2	331.8	318.7	0.0	351.9	315.7	346.4	343.8	344.5	1,702.3
13	Curitiba	344.1	344.4	353.8	359.7	336.0	361.2	350.3	358.1	342.9	342.5	344.8	351.9	0.0	338.7	355.9	312.3	329.7	1,336.7
14	Londrina	360.1	354.6	377.4	352.5	349.1	341.7	344.3	330.3	347.1	331.7	321.3	315.7	338.7	0.0	338.5	327.9	328.7	995.0
15	Cascavel	397.1	393.6	404.9	394.7	381.3	385.1	381.1	363.9	382.0	375.1	359.1	346.4	355.9	338.5	0.0	344.9	327.9	672.8
16	Ponta Grossa	350.9	350.3	362.2	360.7	342.7	357.7	351.0	351.6	345.7	340.8	339.4	343.8	312.3	327.9	344.9	0.0	317.3	317.3
17	Guarapuava	375.7	374.1	378.9	381.7	358.7	373.6	364.7	357.2	361.7	351.7	346.6	344.5	329.7	328.7	327.9	317.3	0.0	46,677.4

Table 4.5. Matrix of Unitary T_{rs} – 1996 (considering full taxation)

THEORETICAL UNITARY 'ICEBERG' TRANSPORT COSTS — T = 1.03745

	Urban Center	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Σ
1	São Paulo	1.0000	1.0958	1.0950	1.1420	1.0982	1.1566	1.1369	1.1626	1.1121	1.1432	1.1532	1.1671	1.1503	1.1632	1.1837	1.1563	1.1730	18.2890
2	Campinas	1.0958	1.0000	1.1090	1.1282	1.0931	1.1488	1.1193	1.1555	1.0874	1.1324	1.1467	1.1620	1.1506	1.1592	1.1821	1.1558	1.1721	17.1022
3	São José dos Campos	1.0950	1.1090	1.0000	1.1440	1.1199	1.1602	1.1425	1.1670	1.1269	1.1509	1.1598	1.1765	1.1586	1.1739	1.1870	1.1647	1.1748	16.2066
4	Ribeirão Preto	1.1420	1.1282	1.1440	1.0000	1.1372	1.1201	1.0931	1.1416	1.1189	1.1240	1.1376	1.1547	1.1629	1.1576	1.1826	1.1636	1.1763	14.8702
5	Sorocaba	1.0982	1.0931	1.1199	1.1372	1.0000	1.1511	1.1276	1.1553	1.0972	1.1305	1.1444	1.1596	1.1420	1.1548	1.1760	1.1490	1.1622	13.7497
6	São José do Rio Preto	1.1566	1.1488	1.1602	1.1201	1.1511	1.0000	1.1187	1.1063	1.1409	1.1180	1.1176	1.1380	1.1640	1.1480	1.1780	1.1615	1.1718	12.5628
7	Araraquara/São Carlos	1.1369	1.1193	1.1425	1.0931	1.1276	1.1187	1.0000	1.1369	1.1043	1.1027	1.1269	1.1502	1.1558	1.1505	1.1759	1.1564	1.1663	11.4259
8	Araçatuba	1.1626	1.1555	1.1670	1.1416	1.1553	1.1063	1.1369	1.0000	1.1494	1.1256	1.1060	1.1126	1.1618	1.1349	1.1658	1.1568	1.1611	10.2741
9	Piracicaba	1.1121	1.0874	1.1269	1.1189	1.0972	1.1409	1.1043	1.1494	1.0000	1.1165	1.1372	1.1557	1.1492	1.1531	1.1764	1.1518	1.1644	9.2042
10	Bauru	1.1432	1.1324	1.1509	1.1240	1.1305	1.1180	1.1027	1.1256	1.1165	1.0000	1.0975	1.1369	1.1488	1.1368	1.1727	1.1471	1.1569	7.9966
11	Marília	1.1532	1.1467	1.1598	1.1376	1.1444	1.1176	1.1269	1.1060	1.1372	1.0975	1.0000	1.1158	1.1509	1.1209	1.1626	1.1456	1.1526	6.8484
12	Presidente Prudente	1.1671	1.1620	1.1765	1.1547	1.1596	1.1380	1.1502	1.1126	1.1557	1.1369	1.1158	1.0000	1.1571	1.1090	1.1524	1.1500	1.1507	5.7192
13	Curitiba	1.1503	1.1506	1.1586	1.1629	1.1420	1.1640	1.1558	1.1618	1.1492	1.1488	1.1509	1.1571	1.0000	1.1449	1.1602	1.0999	1.1342	4.5392
14	Londrina	1.1632	1.1592	1.1739	1.1576	1.1548	1.1480	1.1505	1.1349	1.1531	1.1368	1.1209	1.1090	1.1449	1.0000	1.1447	1.1316	1.1327	3.4091
15	Cascavel	1.1837	1.1821	1.1870	1.1826	1.1760	1.1780	1.1759	1.1658	1.1764	1.1727	1.1626	1.1524	1.1602	1.1447	1.0000	1.1510	1.1316	2.2827
16	Ponta Grossa	1.1563	1.1558	1.1647	1.1636	1.1490	1.1615	1.1564	1.1568	1.1518	1.1471	1.1456	1.1500	1.0999	1.1316	1.1510	1.0000	1.1128	1.1128
17	Guarapuava	1.1730	1.1721	1.1748	1.1763	1.1622	1.1718	1.1663	1.1611	1.1644	1.1569	1.1526	1.1507	1.1342	1.1327	1.1316	1.1128	1.0000	155.5927

Table 4.6. Matrix of Total T_{rs} – 1996 (considering full taxation)

THEORETICAL TOTAL 'ICEBERG' TRANSPORT COSTS — T = 1.03745

	Urban Center	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Σ
1	São Paulo	0.0	328.7	328.5	342.6	329.5	347.0	341.1	348.8	333.6	343.0	346.0	350.1	345.1	349.0	355.1	346.9	351.9	5,486.7
2	Campinas	328.7	0.0	332.7	338.5	327.9	344.6	335.8	346.6	326.2	339.7	344.0	348.6	345.2	347.8	354.6	346.7	351.6	5,130.7
3	São José dos Campos	328.5	332.7	0.0	343.2	336.0	348.1	342.7	350.1	338.1	345.3	347.9	352.9	347.6	352.2	356.1	349.4	352.4	4,862.0
4	Ribeirão Preto	342.6	338.5	343.2	0.0	341.2	336.0	327.9	342.5	335.7	337.2	341.3	346.4	348.9	347.3	354.8	349.1	352.9	4,461.0
5	Sorocaba	329.5	327.9	336.0	341.2	0.0	345.3	338.3	346.6	329.2	339.2	343.3	347.9	342.6	346.4	352.8	344.7	348.7	4,124.9
6	São José do Rio Preto	347.0	344.6	348.1	336.0	345.3	0.0	335.6	331.9	342.3	335.4	335.3	341.4	349.2	344.4	353.4	348.5	351.5	3,768.8
7	Araraquara/São Carlos	341.1	335.8	342.7	327.9	338.3	335.6	0.0	341.1	331.3	330.8	338.1	345.1	346.7	345.2	352.8	346.9	349.9	3,427.8
8	Araçatuba	348.8	346.6	350.1	342.5	346.6	331.9	341.1	0.0	344.8	337.7	331.8	333.8	348.5	340.5	349.7	347.0	348.3	3,082.2
9	Piracicaba	333.6	326.2	338.1	335.7	329.2	342.3	331.3	344.8	0.0	334.9	341.2	346.7	344.8	345.9	352.9	345.5	349.3	2,761.3
10	Bauru	343.0	339.7	345.3	337.2	339.2	335.4	330.8	337.7	334.9	0.0	329.3	341.1	344.6	341.0	351.8	344.1	347.1	2,399.0
11	Marília	346.0	344.0	347.9	341.3	343.3	335.3	338.1	331.8	341.2	329.3	0.0	334.7	345.3	336.3	348.8	343.7	345.8	2,054.5
12	Presidente Prudente	350.1	348.6	352.9	346.4	347.9	341.4	345.1	333.8	346.7	341.1	334.7	0.0	347.1	332.7	345.7	345.0	345.2	1,715.8
13	Curitiba	345.1	345.2	347.6	348.9	342.6	349.2	346.7	348.5	344.8	344.6	345.3	347.1	0.0	343.5	348.1	330.0	340.3	1,361.8
14	Londrina	349.0	347.8	352.2	347.3	346.4	344.4	345.2	340.5	345.9	341.0	336.3	332.7	343.5	0.0	343.4	339.5	339.8	1,022.7
15	Cascavel	355.1	354.6	356.1	354.8	352.8	353.4	352.8	349.7	352.9	351.8	348.8	345.7	348.1	343.4	0.0	345.3	339.5	684.8
16	Ponta Grossa	346.9	346.7	349.4	349.1	344.7	348.5	346.9	347.0	345.5	344.1	343.7	345.0	330.0	339.5	345.3	0.0	333.8	333.8
17	Guarapuava	351.9	351.6	352.4	352.9	348.7	351.5	349.9	348.3	349.3	347.1	345.8	345.2	340.3	339.8	339.5	333.8	0.0	46,677.8

Table 4.7. Matrix of Average Actual Transport Costs (D_{rs}) – 2002 (considering a 100% reduction in both taxation and toll duties)

	TRANSPORT COSTS + TAX (0%) + TOLL (0%) - R$/T - 2002												R$/TK =		0.1431			
	Urban Center	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	**São Paulo**	0	15	14	48	16	68	42	78	22	49	63	87	58	80	128	67	100
2	**Campinas**	15	0	21	34	14	56	27	66	12	38	54	77	59	72	124	67	98
3	**São José dos Campos**	14	21	0	50	27	74	48	87	33	59	73	109	71	102	139	82	104
4	**Ribeirão Preto**	48	34	50	0	42	28	14	47	27	30	43	65	79	70	125	80	108
5	**Sorocaba**	16	14	27	42	0	60	33	66	15	36	51	73	48	65	108	57	78
6	**São José do Rio Preto**	68	56	74	28	60	0	27	19	46	26	26	43	81	55	113	76	97
7	**Araraquara/São Carlos**	42	27	48	14	33	27	0	42	18	18	33	58	67	59	107	68	86
8	**Araçatuba**	78	66	87	47	66	19	42	0	57	32	19	23	77	40	85	68	76
9	**Piracicaba**	22	12	33	27	15	46	18	57	0	25	42	66	57	62	108	61	82
10	**Bauru**	49	38	59	30	36	26	18	32	25	0	15	42	56	42	99	54	68
11	**Marília**	63	54	73	43	51	26	33	19	42	15	0	25	59	28	78	52	62
12	**Presidente Prudente**	87	77	109	65	73	43	58	23	66	42	25	0	69	21	61	58	59
13	**Curitiba**	58	59	71	79	48	81	67	77	57	56	59	69	0	51	74	16	39
14	**Londrina**	80	72	102	70	65	55	59	40	62	42	28	21	51	0	51	37	38
15	**Cascavel**	128	124	139	125	108	113	107	85	108	99	78	61	74	51	0	59	37
16	**Ponta Grossa**	67	67	82	80	57	76	68	68	61	54	52	58	16	37	59	0	23
17	**Guarapuava**	100	98	104	108	78	97	86	76	82	68	62	59	39	38	37	23	0

Table 4.8. Matrix of 'Unitary Iceberg Transport Costs' ($T_{(u)rs}$) – 2002 (considering a 100% reduction in both taxation and toll duties)

	ACTUAL UNITARY 'ICEBERG' TRANSPORT COSTS									TON OF IMAGINARY PRODUCT =				300.00					
	Urban Center	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**Σ**
1	**São Paulo**	1.0000	1.0486	1.0477	1.1588	1.0520	1.2261	1.1402	1.2609	1.0749	1.1636	1.2084	1.2904	1.1946	1.2652	1.4283	1.2246	1.3338	19.1181
2	**Campinas**	1.0486	1.0000	1.0692	1.1130	1.0453	1.1874	1.0901	1.2203	1.0386	1.1254	1.1784	1.2575	1.1960	1.2408	1.4130	1.2218	1.3267	17.7237
3	**São José dos Campos**	1.0477	1.0692	1.0000	1.1669	1.0916	1.2466	1.1607	1.2900	1.1092	1.1974	1.2442	1.3625	1.2375	1.3415	1.4626	1.2742	1.3482	17.5331
4	**Ribeirão Preto**	1.1588	1.1130	1.1669	1.0000	1.1412	1.0920	1.0453	1.1574	1.0892	1.1016	1.1426	1.2160	1.2633	1.2318	1.4178	1.2676	1.3606	15.5263
5	**Sorocaba**	1.0520	1.0453	1.0916	1.1412	1.0000	1.1984	1.1111	1.2194	1.0506	1.1197	1.1684	1.2432	1.1588	1.2165	1.3586	1.1884	1.2590	14.2921
6	**São José do Rio Preto**	1.2261	1.1874	1.2466	1.0920	1.1984	1.0000	1.0887	1.0644	1.1545	1.0873	1.0863	1.1440	1.2699	1.1841	1.3753	1.2547	1.3248	13.0341
7	**Araraquara/São Carlos**	1.1402	1.0901	1.1607	1.0453	1.1111	1.0887	1.0000	1.1402	1.0610	1.0587	1.1092	1.1941	1.2218	1.1955	1.3577	1.2251	1.2852	11.8486
8	**Araçatuba**	1.2609	1.2203	1.2900	1.1574	1.2194	1.0644	1.1402	1.0000	1.1903	1.1059	1.0639	1.0758	1.2561	1.1335	1.2819	1.2275	1.2523	10.5872
9	**Piracicaba**	1.0749	1.0386	1.1092	1.0892	1.0506	1.1545	1.0610	1.1903	1.0000	1.0839	1.1412	1.2213	1.1893	1.2079	1.3615	1.2017	1.2723	9.6793
10	**Bauru**	1.1636	1.1254	1.1974	1.1016	1.1197	1.0873	1.0587	1.1059	1.0839	1.0000	1.0510	1.1402	1.1874	1.1397	1.3315	1.1798	1.2280	8.2577
11	**Marília**	1.2084	1.1784	1.2442	1.1426	1.1684	1.0863	1.1092	1.0639	1.1412	1.0510	1.0000	1.0825	1.1974	1.0940	1.2609	1.1736	1.2056	7.0139
12	**Presidente Prudente**	1.2904	1.2575	1.3625	1.2160	1.2432	1.1440	1.1941	1.0758	1.2213	1.1402	1.0825	1.0000	1.2289	1.0692	1.2046	1.1932	1.1965	5.8923
13	**Curitiba**	1.1946	1.1960	1.2375	1.2633	1.1588	1.2699	1.2218	1.2561	1.1893	1.1874	1.1974	1.2289	1.0000	1.1707	1.2466	1.0544	1.1312	4.6028
14	**Londrina**	1.2652	1.2408	1.3415	1.2318	1.2165	1.1841	1.1955	1.1335	1.2079	1.1397	1.0940	1.0692	1.1707	1.0000	1.1698	1.1230	1.1264	3.4192
15	**Cascavel**	1.4283	1.4130	1.4626	1.4178	1.3586	1.3753	1.3577	1.2819	1.3615	1.3315	1.2609	1.2046	1.2466	1.1698	1.0000	1.1979	1.1230	2.3210
16	**Ponta Grossa**	1.2246	1.2218	1.2742	1.2676	1.1884	1.2547	1.2251	1.2275	1.2017	1.1798	1.1736	1.1932	1.0544	1.1230	1.1979	1.0000	1.0763	1.0763
17	**Guarapuava**	1.3338	1.3267	1.3482	1.3606	1.2590	1.3248	1.2852	1.2523	1.2723	1.2280	1.2056	1.1965	1.1312	1.1264	1.1230	1.0763	1.0000	161.9257

Table 4.9. Matrix of 'Total Iceberg Transport Costs' ($T_{(t)rs}$) – 2002 (considering a 100% reduction in both taxation and toll duties)

	ACTUAL TOTAL 'ICEBERG' TRANSPORT COSTS									TON OF IMAGINARY PRODUCT =				300.00				
	Urban Center	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**Σ**
1	**São Paulo**	0.0	314.6	314.3	347.6	315.6	367.8	342.1	378.3	322.5	349.1	362.5	387.1	358.4	379.6	428.5	367.4	400.2	5,735.4
2	**Campinas**	314.6	0.0	320.7	333.9	313.6	356.2	327.0	366.1	311.6	337.6	353.5	377.3	358.8	372.3	423.9	366.5	398.0	5,317.1
3	**São José dos Campos**	314.3	320.7	0.0	350.1	327.5	374.0	348.2	387.0	332.8	359.2	373.3	408.7	371.3	402.4	438.8	382.3	404.4	5,259.9
4	**Ribeirão Preto**	347.6	333.9	350.1	0.0	342.4	327.6	313.6	347.2	326.8	330.5	342.8	364.8	379.0	369.5	425.3	380.3	408.2	4,657.9
5	**Sorocaba**	315.6	313.6	327.5	342.4	0.0	359.5	333.3	365.8	315.2	335.9	350.5	373.0	347.6	365.0	407.6	356.5	377.7	4,287.6
6	**São José do Rio Preto**	367.8	356.2	374.0	327.6	359.5	0.0	326.6	319.3	346.4	326.2	325.9	343.2	381.0	355.2	412.6	376.4	397.4	3,910.2
7	**Araraquara/São Carlos**	342.1	327.0	348.2	313.6	333.3	326.6	0.0	342.1	318.3	317.6	332.8	358.2	366.5	358.7	407.3	367.5	385.6	3,554.6
8	**Araçatuba**	378.3	366.1	387.0	347.2	365.8	319.3	342.1	0.0	357.1	331.8	319.2	322.7	376.8	340.1	384.6	368.2	375.7	3,176.2
9	**Piracicaba**	322.5	311.6	332.8	326.8	315.2	346.4	318.3	357.1	0.0	325.2	342.4	366.4	356.8	362.4	408.5	360.5	381.7	2,903.8
10	**Bauru**	349.1	337.6	359.2	330.5	335.9	326.2	317.6	331.8	325.2	0.0	315.3	342.1	356.2	341.9	399.4	353.9	368.4	2,477.3
11	**Marília**	362.5	353.5	373.3	342.8	350.5	325.9	332.8	319.2	342.4	315.3	0.0	324.8	359.2	328.2	378.3	352.1	361.7	2,104.2
12	**Presidente Prudente**	387.1	377.3	408.7	364.8	373.0	343.2	358.2	322.7	366.4	342.1	324.8	0.0	368.7	320.7	361.4	357.9	358.9	1,767.7
13	**Curitiba**	358.4	358.8	371.3	379.0	347.6	381.0	366.5	376.8	356.8	356.2	359.2	368.7	0.0	351.2	374.0	316.3	339.3	1,380.9
14	**Londrina**	379.6	372.3	402.4	369.5	365.0	355.2	358.7	340.1	362.4	341.9	328.2	320.7	351.2	0.0	350.9	336.9	337.9	1,025.8
15	**Cascavel**	428.5	423.9	438.8	425.3	407.6	412.6	407.3	384.6	408.5	399.4	378.3	361.4	374.0	350.9	0.0	359.4	336.9	696.3
16	**Ponta Grossa**	367.4	366.5	382.3	380.3	356.5	376.4	367.5	368.2	360.5	353.9	352.1	357.9	316.3	336.9	359.4	0.0	322.9	322.9
17	**Guarapuava**	400.2	398.0	404.4	408.2	377.7	397.4	385.6	375.7	381.7	368.4	361.7	358.9	339.3	337.9	336.9	322.9	0.0	48,577.7

Table 4.10. Matrix of Unitary T_{rs} – 2002 (considering a 100% reduction in both taxation and toll duties)

	THEORETICAL UNITARY 'ICEBERG' TRANSPORT COSTS													T =	1.04534				
	Urban Center	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**Σ**
1	**São Paulo**	1.0000	1.1295	1.1286	1.1880	1.1327	1.2064	1.1816	1.2140	1.1502	1.1895	1.2021	1.2197	1.1985	1.2148	1.2407	1.2061	1.2272	19.0295
2	**Campinas**	1.1295	1.0000	1.1463	1.1706	1.1262	1.1966	1.1593	1.2050	1.1189	1.1759	1.1940	1.2133	1.1989	1.2097	1.2387	1.2054	1.2260	17.7848
3	**São José dos Campos**	1.1286	1.1463	1.0000	1.1905	1.1601	1.2110	1.1886	1.2196	1.1689	1.1993	1.2105	1.2316	1.2090	1.2284	1.2449	1.2166	1.2294	16.9084
4	**Ribeirão Preto**	1.1880	1.1706	1.1905	1.0000	1.1819	1.1603	1.1262	1.1875	1.1588	1.1653	1.1824	1.2040	1.2145	1.2077	1.2393	1.2153	1.2313	15.4746
5	**Sorocaba**	1.1327	1.1262	1.1601	1.1819	1.0000	1.1995	1.1698	1.2048	1.1313	1.1735	1.1910	1.2103	1.1880	1.2041	1.2310	1.1968	1.2136	14.3138
6	**São José do Rio Preto**	1.2064	1.1966	1.2110	1.1603	1.1995	1.0000	1.1585	1.1429	1.1866	1.1577	1.1572	1.1829	1.2158	1.1956	1.2335	1.2127	1.2257	13.0691
7	**Araraquara/São Carlos**	1.1816	1.1593	1.1886	1.1262	1.1698	1.1585	1.0000	1.1816	1.1403	1.1384	1.1689	1.1984	1.2054	1.1988	1.2309	1.2062	1.2187	11.8875
8	**Araçatuba**	1.2140	1.2050	1.2196	1.1875	1.2048	1.1429	1.1816	1.0000	1.1974	1.1673	1.1425	1.1508	1.2130	1.1791	1.2181	1.2067	1.2122	10.6871
9	**Piracicaba**	1.1502	1.1189	1.1689	1.1588	1.1313	1.1866	1.1403	1.1974	1.0000	1.1558	1.1819	1.2053	1.1971	1.2020	1.2315	1.2004	1.2163	9.5902
10	**Bauru**	1.1895	1.1759	1.1993	1.1653	1.1735	1.1577	1.1384	1.1673	1.1558	1.0000	1.1318	1.1816	1.1966	1.1814	1.2268	1.1944	1.2068	8.3193
11	**Marília**	1.2021	1.1940	1.2105	1.1824	1.1910	1.1572	1.1689	1.1425	1.1819	1.1318	1.0000	1.1549	1.1993	1.1614	1.2140	1.1926	1.2014	7.1235
12	**Presidente Prudente**	1.2197	1.2133	1.2316	1.2040	1.2103	1.1829	1.1984	1.1508	1.2053	1.1816	1.1549	1.0000	1.2071	1.1463	1.2011	1.1981	1.1990	5.9517
13	**Curitiba**	1.1985	1.1989	1.2090	1.2145	1.1880	1.2158	1.2054	1.2130	1.1971	1.1966	1.1993	1.2071	1.0000	1.1917	1.2110	1.1348	1.1782	4.7156
14	**Londrina**	1.2148	1.2097	1.2284	1.2077	1.2041	1.1956	1.1988	1.1791	1.2020	1.1814	1.1614	1.1463	1.1917	1.0000	1.1914	1.1749	1.1763	3.5426
15	**Cascavel**	1.2407	1.2387	1.2449	1.2393	1.2310	1.2335	1.2309	1.2181	1.2315	1.2268	1.2140	1.2011	1.2110	1.1914	1.0000	1.1994	1.1749	2.3743
16	**Ponta Grossa**	1.2061	1.2054	1.2166	1.2153	1.1968	1.2127	1.2062	1.2067	1.2004	1.1944	1.1926	1.1981	1.1348	1.1749	1.1994	1.0000	1.1511	1.1511
17	**Guarapuava**	1.2272	1.2260	1.2294	1.2313	1.2136	1.2257	1.2187	1.2122	1.2163	1.2068	1.2014	1.1990	1.1782	1.1763	1.1749	1.1511	1.0000	161.9232

Table 4.11. Matrix of Total T_{rs} – 2002 (considering a 100% reduction in both taxation and toll duties)

	THEORETICAL TOTAL 'ICEBERG' TRANSPORT COSTS													T =	1.04534				
	Urban Center	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**Σ**
1	**São Paulo**	0.0	338.9	338.6	356.4	339.8	361.9	354.5	364.2	345.1	356.9	360.6	365.9	359.6	364.5	372.2	361.8	368.2	5,708.8
2	**Campinas**	338.9	0.0	343.9	351.2	337.9	359.0	347.8	361.5	335.7	352.8	358.2	364.0	359.7	362.9	371.6	361.6	367.8	5,335.4
3	**São José dos Campos**	338.6	343.9	0.0	357.2	348.0	363.3	356.6	365.9	350.7	359.8	363.1	369.5	362.7	368.5	373.5	365.0	368.8	5,072.5
4	**Ribeirão Preto**	356.4	351.2	357.2	0.0	354.6	348.1	337.9	356.3	347.6	349.6	354.7	361.2	364.3	362.3	371.8	364.6	369.4	4,642.4
5	**Sorocaba**	339.8	337.9	348.0	354.6	0.0	359.9	350.9	361.4	339.4	352.1	357.3	363.1	356.4	361.2	369.3	359.0	364.1	4,294.1
6	**São José do Rio Preto**	361.9	359.0	363.3	348.1	359.9	0.0	347.6	342.9	356.0	347.3	347.2	354.9	364.7	358.7	370.1	363.8	367.7	3,920.7
7	**Araraquara/São Carlos**	354.5	347.8	356.6	337.9	350.9	347.6	0.0	354.5	342.1	341.5	350.7	359.5	361.6	359.6	369.3	361.9	365.6	3,566.2
8	**Araçatuba**	364.2	361.5	365.9	356.3	361.4	342.9	354.5	0.0	359.2	350.2	342.7	345.2	363.9	353.7	365.4	362.0	363.7	3,206.1
9	**Piracicaba**	345.1	335.7	350.7	347.6	339.4	356.0	342.1	359.2	0.0	346.7	354.6	361.6	359.1	360.6	369.4	360.1	364.9	2,877.1
10	**Bauru**	356.9	352.8	359.8	349.6	352.1	347.3	341.5	350.2	346.7	0.0	339.5	354.5	359.0	354.4	368.0	358.3	362.1	2,495.8
11	**Marília**	360.6	358.2	363.1	354.7	357.3	347.2	350.7	342.7	354.6	339.5	0.0	346.5	359.8	348.4	364.2	357.8	360.4	2,137.1
12	**Presidente Prudente**	365.9	364.0	369.5	361.2	363.1	354.9	359.5	345.2	361.6	354.5	346.5	0.0	362.1	343.9	360.3	359.4	359.7	1,785.5
13	**Curitiba**	359.6	359.7	362.7	364.3	356.4	364.7	361.6	363.9	359.1	359.0	359.8	362.1	0.0	357.5	363.3	340.4	353.4	1,414.7
14	**Londrina**	364.5	362.9	368.5	362.3	361.2	358.7	359.6	353.7	360.6	354.4	348.4	343.9	357.5	0.0	357.4	352.5	352.9	1,062.8
15	**Cascavel**	372.2	371.6	373.5	371.8	369.3	370.1	369.3	365.4	369.4	368.0	364.2	360.3	363.3	357.4	0.0	359.8	352.5	712.3
16	**Ponta Grossa**	361.8	361.6	365.0	364.6	359.0	363.8	361.9	362.0	360.1	358.3	357.8	359.4	340.4	352.5	359.8	0.0	345.3	345.3
17	**Guarapuava**	368.2	367.8	368.8	369.4	364.1	367.7	365.6	363.7	364.9	362.1	360.4	359.7	353.4	352.9	352.5	345.3	0.0	48,577.0

Table 4.12. Matrix of Average Actual Transport Costs (D_{rs}) – 2002 (considering a 50% reduction in both taxation and toll duties)

	TRANSPORT COSTS + TAX (50%) + TOLL (50%) - R$/T - 2002												R$/TK =	0.1645			
	Urban Center	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	**São Paulo**	0	17	16	55	18	78	48	90	26	56	72	100	67	91	148	77	115
2	**Campinas**	17	0	24	39	16	65	31	76	13	43	62	89	68	83	142	76	113
3	**São José dos Campos**	16	24	0	58	32	85	55	100	38	68	84	125	82	118	160	95	120
4	**Ribeirão Preto**	55	39	58	0	49	32	16	54	31	35	49	74	91	80	144	92	124
5	**Sorocaba**	18	16	32	49	0	68	38	76	17	41	58	84	55	75	124	65	89
6	**São José do Rio Preto**	78	65	85	32	68	0	31	22	53	30	30	50	93	63	129	88	112
7	**Araraquara/São Carlos**	48	31	55	16	38	31	0	48	21	20	38	67	76	67	123	78	98
8	**Araçatuba**	90	76	100	54	76	22	48	0	66	37	22	26	88	46	97	78	87
9	**Piracicaba**	26	13	38	31	17	53	21	66	0	29	49	76	65	72	125	70	94
10	**Bauru**	56	43	68	35	41	30	20	37	29	0	18	48	65	48	114	62	79
11	**Marília**	72	62	84	49	58	30	38	22	49	18	0	28	68	32	90	60	71
12	**Presidente Prudente**	100	89	125	74	84	50	67	26	76	48	28	0	79	24	71	67	68
13	**Curitiba**	67	68	82	91	55	93	76	88	65	65	68	79	0	59	85	19	45
14	**Londrina**	91	83	118	80	75	63	67	46	72	48	32	24	59	0	59	42	44
15	**Cascavel**	148	142	160	144	124	129	123	97	125	114	90	71	85	59	0	68	42
16	**Ponta Grossa**	77	76	95	92	65	88	78	78	70	62	60	67	19	42	68	0	26
17	**Guarapuava**	115	113	120	124	89	112	98	87	94	79	71	68	45	44	42	26	0

Table 4.13. Matrix of 'Unitary Iceberg Transport Costs' ($T_{(u)rs}$) – 2002 (considering a 50% reduction in both taxation and toll duties)

ACTUAL UNITARY 'ICEBERG' TRANSPORT COSTS **TON OF IMAGINARY PRODUCT = 300.00**

	Urban Center	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Σ
1	São Paulo	1.0000	1.0559	1.0548	1.1825	1.0598	1.2598	1.1612	1.2998	1.0861	1.1880	1.2396	1.3338	1.2237	1.3048	1.4923	1.2582	1.3837	19.5839
2	Campinas	1.0559	1.0000	1.0795	1.1299	1.0521	1.2154	1.1036	1.2533	1.0444	1.1442	1.2050	1.2960	1.2253	1.2768	1.4747	1.2549	1.3755	18.1306
3	São José dos Campos	1.0548	1.0795	1.0000	1.1919	1.1052	1.2834	1.1847	1.3333	1.1255	1.2269	1.2807	1.4166	1.2730	1.3925	1.5317	1.3152	1.4002	18.0609
4	Ribeirão Preto	1.1825	1.1299	1.1919	1.0000	1.1623	1.1058	1.0521	1.1809	1.1025	1.1168	1.1639	1.2483	1.3026	1.2664	1.4802	1.3075	1.4144	15.9037
5	Sorocaba	1.0598	1.0521	1.1052	1.1623	1.0000	1.2280	1.1277	1.2522	1.0581	1.1376	1.1935	1.2796	1.1825	1.2489	1.4122	1.2165	1.2977	14.6345
6	São José do Rio Preto	1.2598	1.2154	1.2834	1.1058	1.2280	1.0000	1.1020	1.0740	1.1776	1.1003	1.0992	1.1655	1.3103	1.2116	1.4314	1.2927	1.3733	13.3380
7	Araraquara/São Carlos	1.1612	1.1036	1.1847	1.0521	1.1277	1.1020	1.0000	1.1612	1.0702	1.0674	1.1255	1.2231	1.2549	1.2248	1.4111	1.2587	1.3278	12.1247
8	Araçatuba	1.2998	1.2533	1.3333	1.1809	1.2522	1.0740	1.1612	1.0000	1.2187	1.1217	1.0735	1.0872	1.2944	1.1535	1.3240	1.2615	1.2900	10.8243
9	Piracicaba	1.0861	1.0444	1.1255	1.1025	1.0581	1.1776	1.0702	1.2187	1.0000	1.0965	1.1623	1.2544	1.2176	1.2390	1.4155	1.2319	1.3130	9.9301
10	Bauru	1.1880	1.1442	1.2269	1.1168	1.1376	1.1003	1.0674	1.1217	1.0965	1.0000	1.0587	1.1612	1.2154	1.1606	1.3810	1.2067	1.2620	8.4455
11	Marília	1.2396	1.2050	1.2807	1.1639	1.1935	1.0992	1.1255	1.0735	1.1623	1.0587	1.0000	1.0948	1.2269	1.1080	1.2998	1.1995	1.2363	7.1654
12	Presidente Prudente	1.3338	1.2960	1.4166	1.2483	1.2796	1.1655	1.2231	1.0872	1.2544	1.1612	1.0948	1.0000	1.2631	1.0795	1.2352	1.2220	1.2258	6.0256
13	Curitiba	1.2237	1.2253	1.2730	1.3026	1.1825	1.3103	1.2549	1.2944	1.2176	1.2154	1.2269	1.2631	1.0000	1.1962	1.2834	1.0625	1.1507	4.6929
14	Londrina	1.3048	1.2768	1.3925	1.2664	1.2489	1.2116	1.2248	1.1535	1.2390	1.1606	1.1080	1.0795	1.1962	1.0000	1.1951	1.1414	1.1453	3.4818
15	Cascavel	1.4923	1.4747	1.5317	1.4802	1.4122	1.4314	1.4111	1.3240	1.4155	1.3810	1.2998	1.2352	1.2834	1.1951	1.0000	1.2275	1.1414	2.3689
16	Ponta Grossa	1.2582	1.2549	1.3152	1.3075	1.2165	1.2927	1.2587	1.2615	1.2319	1.2067	1.1995	1.2220	1.0625	1.1414	1.2275	1.0000	1.0877	1.0877
17	Guarapuava	1.3837	1.3755	1.4002	1.4144	1.2977	1.3733	1.3278	1.2900	1.3130	1.2620	1.2363	1.2258	1.1507	1.1453	1.1414	1.0877	1.0000	165.7986

Table 4.14. Matrix of 'Total Iceberg Transport Costs' ($T_{(t)rs}$) – 2002 (considering a 50% reduction in both taxation and toll duties)

ACTUAL TOTAL 'ICEBERG' TRANSPORT COSTS **TON OF IMAGINARY PRODUCT = 300.00**

	Urban Center	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Σ
1	São Paulo	0.0	316.8	316.4	354.8	317.9	377.9	348.3	390.0	325.8	356.4	371.9	400.2	367.1	391.4	447.7	377.5	415.1	5,875.2
2	Campinas	316.8	0.0	323.8	339.0	315.6	364.6	331.1	376.0	313.3	343.3	361.5	388.8	367.6	383.0	442.4	376.5	412.6	5,439.2
3	São José dos Campos	316.4	323.8	0.0	357.6	331.6	385.0	355.4	400.0	337.7	368.1	384.2	425.0	381.9	417.7	459.5	394.6	420.0	5,418.3
4	Ribeirão Preto	354.8	339.0	357.6	0.0	348.7	331.7	315.6	354.3	330.8	335.0	349.2	374.5	390.8	379.9	444.1	392.3	424.3	4,771.1
5	Sorocaba	317.9	315.6	331.6	348.7	0.0	368.4	338.3	375.6	317.4	341.3	358.1	383.9	354.8	374.7	423.7	365.0	389.3	4,390.4
6	São José do Rio Preto	377.9	364.6	385.0	331.7	368.4	0.0	330.6	322.2	353.3	330.1	329.8	349.7	393.1	363.5	429.4	387.8	412.0	4,001.4
7	Araraquara/São Carlos	348.3	331.1	355.4	315.6	338.3	330.6	0.0	348.3	321.0	320.2	337.7	366.9	376.5	367.4	423.3	377.6	398.3	3,637.4
8	Araçatuba	390.0	376.0	400.0	354.3	375.6	322.2	348.3	0.0	365.6	336.5	322.0	326.1	388.3	346.0	397.2	378.4	387.0	3,247.3
9	Piracicaba	325.8	313.3	337.7	330.8	317.4	353.3	321.0	365.6	0.0	328.9	348.7	376.3	365.3	371.7	424.7	369.6	393.9	2,979.0
10	Bauru	356.4	343.3	368.1	335.0	341.3	330.1	320.2	336.5	328.9	0.0	317.6	348.3	364.6	348.2	414.3	362.0	378.6	2,533.7
11	Marília	371.9	361.5	384.2	349.2	358.1	329.8	337.7	322.0	348.7	317.6	0.0	328.5	368.1	332.4	390.0	359.9	370.9	2,149.6
12	Presidente Prudente	400.2	388.8	425.0	374.5	383.9	349.7	366.9	326.1	376.3	348.3	328.5	0.0	378.9	323.8	370.5	366.6	367.8	1,807.7
13	Curitiba	367.1	367.6	381.9	390.8	354.8	393.1	376.5	388.3	365.3	364.6	368.1	378.9	0.0	358.9	385.0	318.7	345.2	1,407.9
14	Londrina	391.4	383.0	417.7	379.9	374.7	363.5	367.4	346.0	371.7	348.2	332.4	323.8	358.9	0.0	358.5	342.4	343.6	1,044.6
15	Cascavel	447.7	442.4	459.5	444.1	423.7	429.4	423.3	397.2	424.7	414.3	390.0	370.5	385.0	358.5	0.0	368.2	342.4	710.7
16	Ponta Grossa	377.5	376.5	394.6	392.3	365.0	387.8	377.6	378.4	369.6	362.0	359.9	366.6	318.7	342.4	368.2	0.0	326.3	326.3
17	Guarapuava	415.1	412.6	420.0	424.3	389.3	412.0	398.3	387.0	393.9	378.6	370.9	367.8	345.2	343.6	342.4	326.3	0.0	49,739.6

Table 4.15. Matrix of Unitary T_{rs} – 2002 (considering a 50% reduction in both taxation and toll duties)

	THEORETICAL UNITARY 'ICEBERG' TRANSPORT COSTS													T =	1.04987				
	Urban Center	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**Σ**
1	**São Paulo**	1.0000	1.1503	1.1493	1.2161	1.1538	1.2369	1.2089	1.2454	1.1736	1.2179	1.2321	1.2519	1.2280	1.2464	1.2756	1.2365	1.2603	19.4830
2	**Campinas**	1.1503	1.0000	1.1692	1.1966	1.1466	1.2258	1.1838	1.2354	1.1383	1.2025	1.2229	1.2447	1.2284	1.2407	1.2733	1.2357	1.2590	18.2029
3	**São José dos Campos**	1.1493	1.1692	1.0000	1.2190	1.1847	1.2421	1.2168	1.2518	1.1946	1.2289	1.2415	1.2653	1.2398	1.2617	1.2803	1.2484	1.2629	17.3379
4	**Ribeirão Preto**	1.2161	1.1966	1.2190	1.0000	1.2093	1.1850	1.1466	1.2156	1.1833	1.1906	1.2099	1.2342	1.2460	1.2384	1.2740	1.2469	1.2650	15.8447
5	**Sorocaba**	1.1538	1.1466	1.1847	1.2093	1.0000	1.2292	1.1956	1.2351	1.1524	1.1999	1.2195	1.2412	1.2161	1.2343	1.2647	1.2261	1.2450	14.6591
6	**São José do Rio Preto**	1.2369	1.2258	1.2421	1.1850	1.2292	1.0000	1.1830	1.1653	1.2145	1.1821	1.1814	1.2105	1.2475	1.2248	1.2675	1.2440	1.2586	13.3791
7	**Araraquara/São Carlos**	1.2089	1.1838	1.2168	1.1466	1.1956	1.1830	1.0000	1.2089	1.1624	1.1603	1.1946	1.2279	1.2357	1.2283	1.2645	1.2366	1.2508	12.1702
8	**Araçatuba**	1.2454	1.2354	1.2518	1.2156	1.2351	1.1653	1.2089	1.0000	1.2267	1.1929	1.1649	1.1743	1.2443	1.2061	1.2501	1.2373	1.2434	10.9400
9	**Piracicaba**	1.1736	1.1383	1.1946	1.1833	1.1524	1.2145	1.1624	1.2267	1.0000	1.1799	1.2093	1.2356	1.2264	1.2319	1.2652	1.2301	1.2480	9.8265
10	**Bauru**	1.2179	1.2025	1.2289	1.1906	1.1999	1.1821	1.1603	1.1929	1.1799	1.0000	1.1528	1.2089	1.2258	1.2087	1.2599	1.2234	1.2374	8.5169
11	**Marília**	1.2321	1.2229	1.2415	1.2099	1.2195	1.1814	1.1946	1.1649	1.2093	1.1528	1.0000	1.1789	1.2289	1.1862	1.2454	1.2213	1.2312	7.2920
12	**Presidente Prudente**	1.2519	1.2447	1.2653	1.2342	1.2412	1.2105	1.2279	1.1743	1.2356	1.2089	1.1789	1.0000	1.2376	1.1692	1.2310	1.2276	1.2286	6.0940
13	**Curitiba**	1.2280	1.2284	1.2398	1.2460	1.2161	1.2475	1.2357	1.2443	1.2264	1.2258	1.2289	1.2376	1.0000	1.2203	1.2421	1.1562	1.2051	4.8237
14	**Londrina**	1.2464	1.2407	1.2617	1.2384	1.2343	1.2248	1.2283	1.2061	1.2319	1.2087	1.1862	1.1692	1.2203	1.0000	1.2200	1.2014	1.2030	3.6244
15	**Cascavel**	1.2756	1.2733	1.2803	1.2740	1.2647	1.2675	1.2645	1.2501	1.2652	1.2599	1.2454	1.2310	1.2421	1.2200	1.0000	1.2290	1.2014	2.4304
16	**Ponta Grossa**	1.2365	1.2357	1.2484	1.2469	1.2261	1.2440	1.2366	1.2373	1.2301	1.2234	1.2213	1.2276	1.1562	1.2014	1.2290	1.0000	1.1746	1.1746
17	**Guarapuava**	1.2603	1.2590	1.2629	1.2650	1.2450	1.2586	1.2508	1.2434	1.2480	1.2374	1.2312	1.2286	1.2051	1.2030	1.2014	1.1746	1.0000	165.7994

Table 4.16. Matrix of Total T_{rs} – 2002 (considering a 50% reduction in both taxation and toll duties)

	THEORETICAL TOTAL 'ICEBERG' TRANSPORT COSTS													T =	1.04987				
	Urban Center	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**Σ**
1	**São Paulo**	0.0	345.1	344.8	364.8	346.1	371.1	362.7	373.6	352.1	365.4	369.6	375.6	368.4	373.9	382.7	371.0	378.1	5,844.9
2	**Campinas**	345.1	0.0	350.8	359.0	344.0	367.7	355.2	370.6	341.5	360.8	366.9	373.4	368.5	372.2	382.0	370.7	377.7	5,460.9
3	**São José dos Campos**	344.8	350.8	0.0	365.7	355.4	372.6	365.0	375.5	358.4	368.7	372.4	379.6	371.9	378.5	384.1	374.5	378.9	5,201.4
4	**Ribeirão Preto**	364.8	359.0	365.7	0.0	362.8	355.5	344.0	364.7	355.0	357.2	363.0	370.3	373.8	371.5	382.2	374.1	379.5	4,753.4
5	**Sorocaba**	346.1	344.0	355.4	362.8	0.0	368.7	358.7	370.5	345.7	360.0	365.9	372.4	364.8	370.3	379.4	367.8	373.5	4,397.7
6	**São José do Rio Preto**	371.1	367.7	372.6	355.5	368.7	0.0	354.9	349.6	364.4	354.6	354.4	363.1	374.2	367.4	380.2	373.2	377.6	4,013.7
7	**Araraquara/São Carlos**	362.7	355.2	365.0	344.0	358.7	354.9	0.0	362.7	348.7	348.1	358.4	368.4	370.7	368.5	379.4	371.0	375.2	3,651.0
8	**Araçatuba**	373.6	370.6	375.5	364.7	370.5	349.6	362.7	0.0	368.0	357.9	349.5	352.3	373.3	361.8	375.0	371.2	373.0	3,282.0
9	**Piracicaba**	352.1	341.5	358.4	355.0	345.7	364.4	348.7	368.0	0.0	354.0	362.8	370.7	367.9	369.6	379.6	369.0	374.4	2,947.9
10	**Bauru**	365.4	360.8	368.7	357.2	360.0	354.6	348.1	357.9	354.0	0.0	345.9	362.7	367.7	362.6	378.0	367.0	371.2	2,555.1
11	**Marília**	369.6	366.9	372.4	363.0	365.9	354.4	358.4	349.5	362.8	345.9	0.0	353.7	368.7	355.9	373.6	366.4	369.4	2,187.6
12	**Presidente Prudente**	375.6	373.4	379.6	370.3	372.4	363.1	368.4	352.3	370.7	362.7	353.7	0.0	371.3	350.8	369.3	368.3	368.6	1,828.2
13	**Curitiba**	368.4	368.5	371.9	373.8	364.8	374.2	370.7	373.3	367.9	367.7	368.7	371.3	0.0	366.1	372.6	346.9	361.5	1,447.1
14	**Londrina**	373.9	372.2	378.5	371.5	370.3	367.4	368.5	361.8	369.6	362.6	355.9	350.8	366.1	0.0	366.0	360.4	360.9	1,087.3
15	**Cascavel**	382.7	382.0	384.1	382.2	379.4	380.2	379.4	375.0	379.6	378.0	373.6	369.3	372.6	366.0	0.0	368.7	360.4	729.1
16	**Ponta Grossa**	371.0	370.7	374.5	374.1	367.8	373.2	371.0	371.2	369.0	367.0	366.4	368.3	346.9	360.4	368.7	0.0	352.4	352.4
17	**Guarapuava**	378.1	377.7	378.9	379.5	373.5	377.6	375.2	373.0	374.4	371.2	369.4	368.6	361.5	360.9	360.4	352.4	0.0	49,739.8

Table 4.17. Matrix of Average Actual Transport Costs (D_{rs}) – 2002 (considering no reduction in both taxation and toll duties)

	TRANSPORT COSTS + TAX (100%) + TOLL (100%) - R$/T - 2002												R$/TK =	0.1858				
	Urban Center	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
1	**São Paulo**	0	19	19	62	20	88	55	102	29	64	81	113	76	103	167	88	130
2	**Campinas**	19	0	27	44	18	73	35	86	15	49	69	100	76	94	161	86	127
3	**São José dos Campos**	19	27	0	65	36	96	63	113	43	77	95	141	93	133	180	107	136
4	**Ribeirão Preto**	62	44	65	0	55	36	18	61	35	40	56	84	103	90	163	104	140
5	**Sorocaba**	20	18	36	55	0	77	43	85	20	47	66	95	62	84	140	73	101
6	**São José do Rio Preto**	88	73	96	36	77	0	35	25	60	34	34	56	105	72	146	99	127
7	**Araraquara/São Carlos**	55	35	63	18	43	35	0	55	24	23	43	76	86	76	139	88	111
8	**Araçatuba**	102	86	113	61	85	25	55	0	74	41	25	30	100	52	110	89	98
9	**Piracicaba**	29	15	43	35	20	60	24	74	0	33	55	86	74	81	141	79	106
10	**Bauru**	64	49	77	40	47	34	23	41	33	0	20	55	73	54	129	70	89
11	**Marília**	81	69	95	56	66	34	43	25	55	20	0	32	77	37	102	68	80
12	**Presidente Prudente**	113	100	141	84	95	56	76	30	86	55	32	0	89	27	80	75	77
13	**Curitiba**	76	76	93	103	62	105	86	100	74	73	77	89	0	67	96	21	51
14	**Londrina**	103	94	133	90	84	72	76	52	81	54	37	27	67	0	66	48	49
15	**Cascavel**	167	161	180	163	140	146	139	110	141	129	102	80	96	66	0	77	48
16	**Ponta Grossa**	88	86	107	104	73	99	88	89	79	70	68	75	21	48	77	0	30
17	**Guarapuava**	130	127	136	140	101	127	111	98	106	89	80	77	51	49	48	30	0

Table 4.18. Matrix of 'Unitary Iceberg Transport Costs' ($T_{(u)rs}$) – 2002 (considering no reduction in both taxation and toll duties)

	ACTUAL UNITARY 'ICEBERG' TRANSPORT COSTS									TON OF IMAGINARY PRODUCT =					300.00				
	Urban Center	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**Σ**
1	**São Paulo**	1.0000	1.0632	1.0619	1.2063	1.0675	1.2936	1.1821	1.3388	1.0972	1.2125	1.2707	1.3772	1.2527	1.3444	1.5562	1.2917	1.4336	20.0497
2	**Campinas**	1.0632	1.0000	1.0898	1.1468	1.0588	1.2434	1.1171	1.2862	1.0502	1.1629	1.2317	1.3345	1.2546	1.3128	1.5364	1.2880	1.4243	18.5375
3	**São José dos Campos**	1.0619	1.0898	1.0000	1.2168	1.1189	1.3202	1.2087	1.3766	1.1418	1.2564	1.3171	1.4708	1.3085	1.4435	1.6008	1.3562	1.4522	18.5886
4	**Ribeirão Preto**	1.2063	1.1468	1.2168	1.0000	1.1833	1.1195	1.0588	1.2044	1.1158	1.1319	1.1852	1.2806	1.3419	1.3010	1.5426	1.3475	1.4683	16.2811
5	**Sorocaba**	1.0675	1.0588	1.1189	1.1833	1.0000	1.2577	1.1443	1.2849	1.0657	1.1555	1.2187	1.3159	1.2063	1.2812	1.4658	1.2447	1.3363	14.9769
6	**São José do Rio Preto**	1.2936	1.2434	1.3202	1.1195	1.2577	1.0000	1.1152	1.0836	1.2007	1.1134	1.1121	1.1871	1.3506	1.2391	1.4875	1.3308	1.4218	13.6418
7	**Araraquara/São Carlos**	1.1821	1.1171	1.2087	1.0588	1.1443	1.1152	1.0000	1.1821	1.0793	1.0762	1.1418	1.2521	1.2880	1.2540	1.4646	1.2924	1.3704	12.4009
8	**Araçatuba**	1.3388	1.2862	1.3766	1.2044	1.2849	1.0836	1.1821	1.0000	1.2471	1.1375	1.0830	1.0985	1.3326	1.1734	1.3661	1.2955	1.3277	11.0614
9	**Piracicaba**	1.0972	1.0502	1.1418	1.1158	1.0657	1.2007	1.0793	1.2471	1.0000	1.1090	1.1833	1.2874	1.2459	1.2701	1.4695	1.2620	1.3537	10.1810
10	**Bauru**	1.2125	1.1629	1.2564	1.1319	1.1555	1.1134	1.0762	1.1375	1.1090	1.0000	1.0663	1.1821	1.2434	1.1815	1.4305	1.2335	1.2961	8.6334
11	**Marília**	1.2707	1.2317	1.3171	1.1852	1.2187	1.1121	1.1418	1.0830	1.1833	1.0663	1.0000	1.1072	1.2564	1.1220	1.3388	1.2255	1.2670	7.3169
12	**Presidente Prudente**	1.3772	1.3345	1.4708	1.2806	1.3159	1.1871	1.2521	1.0985	1.2874	1.1821	1.1072	1.0000	1.2973	1.0898	1.2657	1.2509	1.2552	6.1589
13	**Curitiba**	1.2527	1.2546	1.3085	1.3419	1.2063	1.3506	1.2880	1.3326	1.2459	1.2434	1.2564	1.2973	1.0000	1.2218	1.3202	1.0706	1.1703	4.7829
14	**Londrina**	1.3444	1.3128	1.4435	1.3010	1.2812	1.2391	1.2540	1.1734	1.2701	1.1815	1.1220	1.0898	1.2218	1.0000	1.2205	1.1598	1.1641	3.5445
15	**Cascavel**	1.5562	1.5364	1.6008	1.5426	1.4658	1.4875	1.4646	1.3661	1.4695	1.4305	1.3388	1.2657	1.3202	1.2205	1.0000	1.2571	1.1598	2.4169
16	**Ponta Grossa**	1.2917	1.2880	1.3562	1.3475	1.2447	1.3308	1.2924	1.2955	1.2620	1.2335	1.2255	1.2509	1.0706	1.1598	1.2571	1.0000	1.0991	1.0991
17	**Guarapuava**	1.4336	1.4243	1.4522	1.4683	1.3363	1.4218	1.3704	1.3277	1.3537	1.2961	1.2670	1.2552	1.1703	1.1641	1.1598	1.0991	1.0000	169.6715

Table 4.19. Matrix of 'Total Iceberg Transport Costs' ($T_{(t)rs}$) – 2002 (considering no reduction in both taxation and toll duties)

ACTUAL TOTAL 'ICEBERG' TRANSPORT COSTS — TON OF IMAGINARY PRODUCT = 300.00

	Urban Center	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Σ
1	São Paulo	0.0	319.0	318.6	361.9	320.3	388.1	354.6	401.6	329.2	363.7	381.2	413.2	375.8	403.3	466.9	387.5	430.1	6,014.9
2	Campinas	319.0	0.0	326.9	344.0	317.7	373.0	335.1	385.9	315.1	348.9	369.5	400.3	376.4	393.8	460.9	386.4	427.3	5,561.2
3	São José dos Campos	318.6	326.9	0.0	365.0	335.7	396.1	362.6	413.0	342.6	376.9	395.1	441.2	392.5	433.1	480.3	406.8	435.7	5,576.6
4	Ribeirão Preto	361.9	344.0	365.0	0.0	355.0	335.9	317.7	361.3	334.7	339.6	355.6	384.2	402.6	390.3	462.8	404.2	440.5	4,884.3
5	Sorocaba	320.3	317.7	335.7	355.0	0.0	377.3	343.3	385.5	319.7	346.6	365.6	394.8	361.9	384.4	439.7	373.4	400.9	4,493.1
6	São José do Rio Preto	388.1	373.0	396.1	335.9	377.3	0.0	334.6	325.1	360.2	334.0	333.6	356.1	405.2	371.7	446.2	399.2	426.5	4,092.5
7	Araraquara/São Carlos	354.6	335.1	362.6	317.7	343.3	334.6	0.0	354.6	323.8	322.9	342.6	375.6	386.4	376.2	439.4	387.7	411.1	3,720.3
8	Araçatuba	401.6	385.9	413.0	361.3	385.5	325.1	354.6	0.0	374.1	341.3	324.9	329.5	399.8	352.0	409.8	388.6	398.3	3,318.4
9	Piracicaba	329.2	315.1	342.6	334.7	319.7	360.2	323.8	374.1	0.0	332.7	355.0	386.2	373.8	381.0	440.9	378.6	406.1	3,054.3
10	Bauru	363.7	348.9	376.9	339.6	346.6	334.0	322.9	341.3	332.7	0.0	319.9	354.6	373.0	354.4	429.1	370.1	388.8	2,590.0
11	Marília	381.2	369.5	395.1	355.6	365.6	333.6	342.6	324.9	355.0	319.9	0.0	332.1	376.9	336.6	401.6	367.6	380.1	2,195.1
12	Presidente Prudente	413.2	400.3	441.2	384.2	394.8	356.1	375.6	329.5	386.2	354.6	332.1	0.0	389.2	326.9	379.7	375.3	376.6	1,847.7
13	Curitiba	375.8	376.4	392.5	402.6	361.9	405.2	386.4	399.8	373.8	373.0	376.9	389.2	0.0	366.5	396.1	321.2	351.1	1,434.9
14	Londrina	403.3	393.8	433.1	390.3	384.4	371.7	376.2	352.0	381.0	354.4	336.6	326.9	366.5	0.0	366.2	347.9	349.2	1,063.3
15	Cascavel	466.9	460.9	480.3	462.8	439.7	446.2	439.4	409.8	440.9	429.1	401.6	379.7	396.1	366.2	0.0	377.1	347.9	725.1
16	Ponta Grossa	387.5	386.4	406.8	404.2	373.4	399.2	387.7	388.6	378.6	370.1	367.6	375.3	321.2	347.9	377.1	0.0	329.7	329.7
17	Guarapuava	430.1	427.3	435.7	440.5	400.9	426.5	411.1	398.3	406.1	388.8	380.1	376.6	351.1	349.2	347.9	329.7	0.0	50,901.4

Table 4.20. Matrix of Unitary T_{rs} – 2002 (considering no reduction in both taxation and toll duties)

THEORETICAL UNITARY 'ICEBERG' TRANSPORT COSTS — T = 1.05419

	Urban Center	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Σ
1	São Paulo	1.0000	1.1711	1.1700	1.2442	1.1750	1.2673	1.2362	1.2768	1.1970	1.2462	1.2620	1.2840	1.2575	1.2779	1.3104	1.2669	1.2934	19.9359
2	Campinas	1.1711	1.0000	1.1921	1.2225	1.1670	1.2550	1.2084	1.2656	1.1577	1.2291	1.2518	1.2760	1.2579	1.2715	1.3079	1.2661	1.2919	18.6206
3	São José dos Campos	1.1700	1.1921	1.0000	1.2475	1.2093	1.2731	1.2450	1.2839	1.2204	1.2584	1.2724	1.2990	1.2706	1.2949	1.3157	1.2802	1.2963	17.7667
4	Ribeirão Preto	1.2442	1.2225	1.2475	1.0000	1.2367	1.2097	1.1670	1.2437	1.2077	1.2158	1.2373	1.2643	1.2774	1.2690	1.3087	1.2785	1.2986	16.2144
5	Sorocaba	1.1750	1.1670	1.2093	1.2367	1.0000	1.2587	1.2215	1.2653	1.1734	1.2262	1.2480	1.2722	1.2442	1.2645	1.2983	1.2553	1.2763	15.0039
6	São José do Rio Preto	1.2673	1.2550	1.2731	1.2097	1.2587	1.0000	1.2074	1.1878	1.2425	1.2064	1.2057	1.2379	1.2791	1.2538	1.3014	1.2752	1.2916	13.6888
7	Araraquara/São Carlos	1.2362	1.2084	1.2450	1.1670	1.2215	1.2074	1.0000	1.2362	1.1846	1.1822	1.2204	1.2573	1.2661	1.2578	1.2981	1.2670	1.2828	12.4524
8	Araçatuba	1.2768	1.2656	1.2839	1.2437	1.2653	1.1878	1.2362	1.0000	1.2560	1.2184	1.1873	1.1977	1.2756	1.2331	1.2820	1.2677	1.2746	11.1925
9	Piracicaba	1.1970	1.1577	1.2204	1.2077	1.1734	1.2425	1.1846	1.2560	1.0000	1.2040	1.2367	1.2659	1.2557	1.2618	1.2988	1.2598	1.2797	10.0623
10	Bauru	1.2462	1.2291	1.2584	1.2158	1.2262	1.2064	1.1822	1.2184	1.2040	1.0000	1.1739	1.2362	1.2550	1.2360	1.2929	1.2523	1.2679	8.7143
11	Marília	1.2620	1.2518	1.2724	1.2373	1.2480	1.2057	1.2204	1.1873	1.2367	1.1739	1.0000	1.2029	1.2584	1.2109	1.2768	1.2500	1.2611	7.4601
12	Presidente Prudente	1.2840	1.2760	1.2990	1.2643	1.2722	1.2379	1.2573	1.1977	1.2659	1.2362	1.2029	1.0000	1.2682	1.1921	1.2607	1.2570	1.2581	6.2361
13	Curitiba	1.2575	1.2579	1.2706	1.2774	1.2442	1.2791	1.2661	1.2756	1.2557	1.2550	1.2584	1.2682	1.0000	1.2489	1.2731	1.1777	1.2320	4.9316
14	Londrina	1.2779	1.2715	1.2949	1.2690	1.2645	1.2538	1.2578	1.2331	1.2618	1.2360	1.2109	1.1921	1.2489	1.0000	1.2486	1.2279	1.2296	3.7061
15	Cascavel	1.3104	1.3079	1.3157	1.3087	1.2983	1.3014	1.2981	1.2820	1.2988	1.2929	1.2768	1.2607	1.2731	1.2486	1.0000	1.2586	1.2279	2.4865
16	Ponta Grossa	1.2669	1.2661	1.2802	1.2785	1.2553	1.2752	1.2670	1.2677	1.2598	1.2523	1.2500	1.2570	1.1777	1.2279	1.2586	1.0000	1.1981	1.1981
17	Guarapuava	1.2934	1.2919	1.2963	1.2986	1.2763	1.2916	1.2828	1.2746	1.2797	1.2679	1.2611	1.2581	1.2320	1.2296	1.2279	1.1981	1.0000	169.6703

Table 4.21. Matrix of Total T_{rs} – 2002 (considering no reduction in both taxation and toll duties)

	THEORETICAL TOTAL 'ICEBERG' TRANSPORT COSTS													T =	1.05419				
	Urban Center	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**Σ**
1	**São Paulo**	0.0	351.3	351.0	373.3	352.5	380.2	370.9	383.1	359.1	373.8	378.6	385.2	377.2	383.4	393.1	380.1	388.0	5,980.8
2	**Campinas**	351.3	0.0	357.6	366.8	350.1	376.5	362.5	379.7	347.3	368.7	375.5	382.8	377.4	381.5	392.4	379.8	387.6	5,586.2
3	**São José dos Campos**	351.0	357.6	0.0	374.2	362.8	381.9	373.5	385.2	366.1	377.5	381.7	389.7	381.2	388.5	394.7	384.1	388.9	5,330.0
4	**Ribeirão Preto**	373.3	366.8	374.2	0.0	371.0	362.9	350.1	373.1	362.3	364.7	371.2	379.3	383.2	380.7	392.6	383.6	389.6	4,864.3
5	**Sorocaba**	352.5	350.1	362.8	371.0	0.0	377.6	366.4	379.6	352.0	367.8	374.4	381.7	373.3	379.3	389.5	376.6	382.9	4,501.2
6	**São José do Rio Preto**	380.2	376.5	381.9	362.9	377.6	0.0	362.2	356.3	372.7	361.9	361.7	371.4	383.7	376.1	390.4	382.6	387.5	4,106.6
7	**Araraquara/São Carlos**	370.9	362.5	373.5	350.1	366.4	362.2	0.0	370.9	355.4	354.7	366.1	377.2	379.8	377.3	389.4	380.1	384.8	3,735.7
8	**Araçatuba**	383.1	379.7	385.2	373.1	379.6	356.3	370.9	0.0	376.8	365.5	356.2	359.3	382.7	369.9	384.6	380.3	382.4	3,357.8
9	**Piracicaba**	359.1	347.3	366.1	362.3	352.0	372.7	355.4	376.8	0.0	361.2	371.0	379.8	376.7	378.5	389.6	377.9	383.9	3,018.7
10	**Bauru**	373.8	368.7	377.5	364.7	367.8	361.9	354.7	365.5	361.2	0.0	352.2	370.9	376.5	370.8	387.9	375.7	380.4	2,614.3
11	**Marília**	378.6	375.5	381.7	371.2	374.4	361.7	366.1	356.2	371.0	352.2	0.0	360.9	377.5	363.3	383.1	375.0	378.3	2,238.0
12	**Presidente Prudente**	385.2	382.8	389.7	379.3	381.7	371.4	377.2	359.3	379.8	370.9	360.9	0.0	380.4	357.6	378.2	377.1	377.4	1,870.8
13	**Curitiba**	377.2	377.4	381.2	383.2	373.3	383.7	379.8	382.7	376.7	376.5	377.5	380.4	0.0	374.7	381.9	353.3	369.6	1,479.5
14	**Londrina**	383.4	381.5	388.5	380.7	379.3	376.1	377.3	369.9	378.5	370.8	363.3	357.6	374.7	0.0	374.6	368.4	368.9	1,111.8
15	**Cascavel**	393.1	392.4	394.7	392.6	389.5	390.4	389.4	384.6	389.6	387.9	383.1	378.2	381.9	374.6	0.0	377.6	368.4	745.9
16	**Ponta Grossa**	380.1	379.8	384.1	383.6	376.6	382.6	380.1	380.3	377.9	375.7	375.0	377.1	353.3	368.4	377.6	0.0	359.4	359.4
17	**Guarapuava**	388.0	387.6	388.9	389.6	382.9	387.5	384.8	382.4	383.9	380.4	378.3	377.4	369.6	368.9	368.4	359.4	0.0	50,901.1

Table 4.22. Urban and Rural Population Shares

	Prime City		**Population 1996**				**Population 2002**			
	Urban Centers / IPEA (2001)	**State**	**Urban**	**Share**	**Rural**	**Share**	**Urban**	**Share**	**Rural**	**Share**
1	**São Paulo** Baixada Santista	**SP**	17,010,049	43.86%	556,528	12.81%	19,172,194	43.41%	779,310	18.07%
2	**Campinas** Mogi-Guaçu/Mogi-Mirim	**SP**	2,916,494	7.52%	257,724	5.93%	3,224,867	7.30%	216,280	5.01%
3	**São José dos Campos** Guaratinguetá/Aparecida	**SP**	1,642,201	4.23%	150,513	3.47%	1,944,363	4.40%	145,451	3.37%
4	**Ribeirão Preto** Franca	**SP**	1,824,289	4.70%	133,147	3.07%	2,073,016	4.69%	116,838	2.71%
5	**Sorocaba** Jundiaí, Bragança Paulista	**SP**	2,529,482	6.52%	499,344	11.50%	3,040,335	6.88%	578,490	13.41%
6	**São José do Rio Preto** Catanduva	**SP**	1,165,289	3.00%	172,291	3.97%	1,310,902	2.97%	161,035	3.73%
7	**Araraquara/São Carlos**	**SP**	602,538	1.55%	62,858	1.45%	695,475	1.57%	55,421	1.28%
8	**Araçatuba**	**SP**	548,551	1.41%	60,029	1.38%	596,427	1.35%	55,734	1.29%
9	**Piracicaba** Limeira	**SP**	1,017,313	2.62%	104,225	2.40%	1,199,104	2.72%	80,121	1.86%
10	**Bauru** Jaú, Botucatu	**SP**	1,101,875	2.84%	113,501	2.61%	1,257,489	2.85%	106,831	2.48%
11	**Marília**	**SP**	768,515	1.98%	111,878	2.58%	859,966	1.95%	105,419	2.44%
12	**Presidente Prudente**	**SP**	641,022	1.65%	129,454	2.98%	698,277	1.58%	120,958	2.80%
13	**Curitiba** Paranaguá	**PR**	2,455,713	6.33%	278,787	6.42%	2,953,865	6.69%	309,990	7.19%
14	**Londrina** Maringá	**PR**	2,309,313	5.95%	583,820	13.44%	2,579,827	5.84%	486,895	11.29%
15	**Cascavel** Foz do Iguaçú	**PR**	1,073,887	2.77%	360,888	8.31%	1,209,220	2.74%	299,337	6.94%
16	**Ponta Grossa**	**PR**	629,897	1.62%	312,160	7.19%	732,490	1.66%	298,112	6.91%
17	**Guarapuava**	**PR**	543,180	1.40%	456,159	10.50%	616,344	1.40%	397,232	9.21%
	TOTAL		38,779,608	100.00%	4,343,306	100.00%	44,164,161	100.00%	4,313,454	100.00%

Table 4.23. Manufactures and Agriculture GDP Shares

	Prime City Unban Centers / IPEA (2001)	State	GDP 1996 Agric.	GDP 1996 Share	GDP 1996 Manufac.	GDP 1996 Share	GDP 2002 Agric.	GDP 2002 Share	GDP 2002 Manufac.	GDP 2002 Share
1	**São Paulo** (Baixada Santista)	**SP**	117,349	0.49%	165,725,116	54.39%	212,800	0.98%	80,861,724	45.21%
2	**Campinas** (Mogi-Guaçu/Mogi-Mirim)	**SP**	888,812	3.75%	26,748,815	8.78%	1,751,774	8.04%	14,134,548	7.90%
3	**São José dos Campos** (Guaratinguetá/Aparecida)	**SP**	480,946	2.03%	19,362,489	6.36%	250,403	1.15%	15,064,254	8.42%
4	**Ribeirão Preto** (Franca)	**SP**	2,010,660	8.47%	9,699,644	3.18%	2,328,523	10.69%	5,032,053	2.81%
5	**Sorocaba** (Jundiaí, Bragança Paulista)	**SP**	1,235,595	5.21%	18,962,430	6.22%	1,543,778	7.09%	11,086,712	6.20%
6	**São José do Rio Preto** (Catanduva)	**SP**	1,591,636	6.71%	4,631,276	1.52%	1,881,473	8.64%	2,847,877	1.59%
7	**Araraquara/São Carlos**	**SP**	797,799	3.36%	4,992,513	1.64%	1,203,366	5.53%	2,877,543	1.61%
8	**Araçatuba**	**SP**	588,396	2.48%	2,349,833	0.77%	735,596	3.38%	2,829,612	1.58%
9	**Piracicaba** (Limeira)	**SP**	510,097	2.15%	8,745,368	2.87%	874,667	4.02%	4,538,298	2.54%
10	**Bauru** (Jaú, Botucatu)	**SP**	1,159,949	4.89%	5,348,200	1.76%	1,283,281	5.89%	2,897,287	1.62%
11	**Marília**	**SP**	1,138,206	4.80%	3,308,920	1.09%	1,188,460	5.46%	1,709,299	0.96%
12	**Presidente Prudente**	**SP**	651,559	2.75%	3,207,462	1.05%	668,410	3.07%	1,562,010	0.87%
13	**Curitiba** (Paranaguá)	**PR**	897,259	3.78%	14,830,116	4.87%	639,164	2.93%	2,471,933	1.38%
14	**Londrina** (Maringá)	**PR**	3,910,699	16.48%	6,157,358	2.02%	3,812,254	17.50%	22,790,874	12.74%
15	**Cascavel** (Foz do Iguaçú)	**PR**	3,534,873	14.90%	5,446,536	1.79%	1,598,765	7.34%	4,683,950	2.62%
16	**Ponta Grossa**	**PR**	1,856,817	7.83%	3,126,314	1.03%	596,755	2.74%	979,623	0.55%
17	**Guarapuava**	**PR**	2,356,422	9.93%	2,036,196	0.67%	1,210,702	5.56%	2,501,629	1.40%
	TOTAL		23,727,074	100.00%	304,678,586	100.00%	21,780,171	100.00%	178,869,227	100.00%

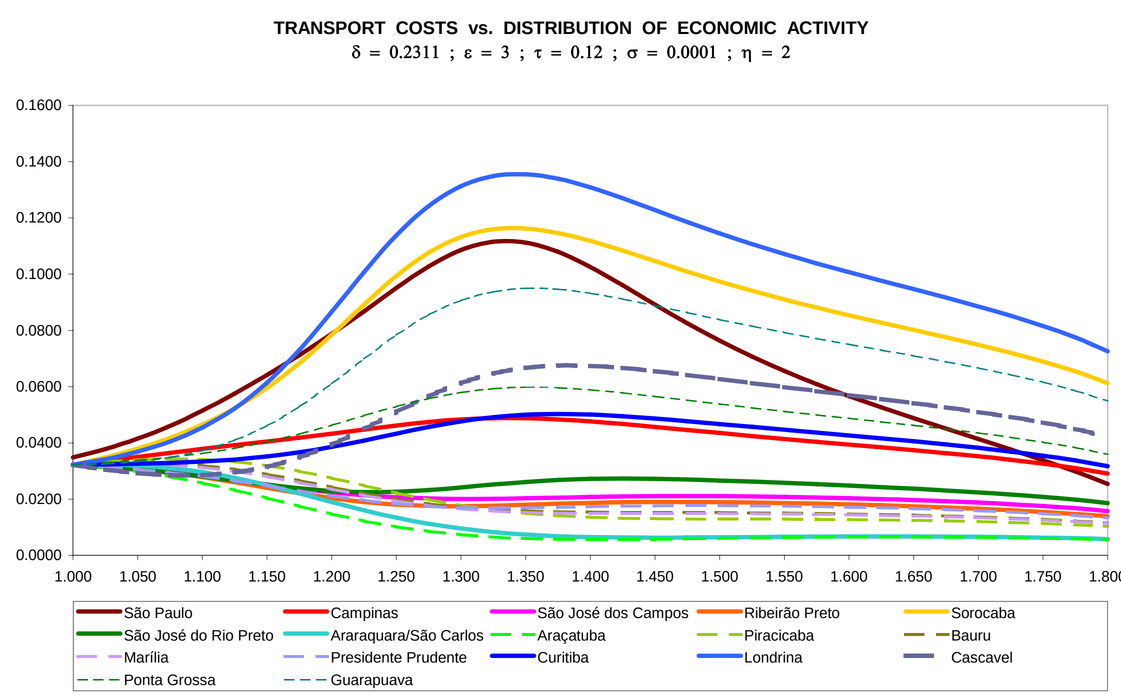
5. Results

This section to presents the results of structural change systematic variations to which parameters were subject to in this research. Note that in the graphs each number and color corresponds to one urban center considered. The graphs also inform under their title the values of the other parameters, which were held constant when the one featuring parameter was made to vary during the simulations.

5.1. Transport Costs *T*

Figure 5.1. represents the results in simulation round (i): structural change systematic variation in parameter $T \rightarrow$ 1.00 to 1.80 at increments of 0.025 using equation (4.2.1) to compute T_{rs} having as proxy for D_{rs} the physical road distances between urban centers and shares of mobile and immobile workforce of 1996.

Figure 5.1. Results – Simulation Round (i)



First it is important to notice that the level where actual transport costs for Brazil matters lies between points 1.03745 and 1.05418 in the horizontal axis, that is, in the 'very low' transport costs definition of the core model of geographical economics. Recall that at that level agglomeration of economic activity is the more likely outcome due to the efficient trade of manufactures between regions. That is consistent with our results first because at point 1.00 on the horizontal axis (which corresponds to 'zero' transport costs) even spreading of economic activity among all urban centers is the more likely outcome and because as we move from point 1.00 to the right agglomeration becomes stronger. Moving further to the right it is possible to distinguish the 'intermediate' level of transport costs as defined in the core model of geographical economics with congestion, where either agglomeration or spreading of economic activity are both likely to occur, more precisely between points 1.10 and 1.15 on the horizontal axis. This is also consistent with our results for it is observable in the graph the strengthening of agglomeration tendencies as we move to the right from point 1.10 to 1.15. In the interval between points 1.15 and 1.35 lies the range where agglomeration is the likely outcome, according to the definition of the core model of geographical economics with congestion. As a mater of fact, at point 1.35 agglomeration reaches its peak. Finally, beyond point 1.35 moving to the right on the horizontal axis lies the level termed as 'high' transport costs in the core model of geographical economics with congestion. From that point on agglomeration of economic activity starts to lose its strength and spreading starts to be more likely. Though the results of the simulation is in accordance with the core model of geographical economics with congestion, the observation matters concerning that in practical terms, that is for transport costs between 1.00 and 1.10, agglomeration mounts at ever increasing rates as transport costs continue to mount. Also important to notice that the level of transport costs at which there would be a change form agglomerating to spreading tendencies occurs at beyond point 1.35. In practical terms (that is, is in actual transport costs terms), that would mean an exorbitant cost. If point 1.35 is ever to be reached in practice, the whole economy would probably have collapsed long before transport costs having achieved that level.

Figure 5.2. on next page portrays the results in simulation round (ii): structural change systematic variation in parameter $T \rightarrow 0.00$ to 10.00 at increments of 0.10 using equation (4.2.5) to compute T_{rs} having as proxy for D_{rs} the physical road distances between urban centers and shares of mobile and immobile workforce of 1996. The results are similar to those of simulation round (i) and again in accordance with the core model of geographical economics with congestion. Notice however that in simulation round (ii) the picture of what actual transport costs mean is much clearer. Point 1.00 on the horizontal axis stands for actual transport costs levels in 1996. Any point to the left of point 1.00 means a proportional decrease in transport costs (e.g. point 0.80 is tantamount to a decrease of 80% in the transport costs levels of 1996) and any point to the right of point 1.00 means a proportional increase in transport costs (e.g. point 1.50 is tantamount to an increase of 150% in the transport costs levels of 1996). Notice also that in simulation round (ii) the picture of what is happening to each urban center is also much clearer. We can see that the highest agglomeration would happen at point 4.00. It is also beyond point 4.00 that spreading tendencies would start to become stronger than agglomeration. Yet again, point 4.00

(which represents an increase of 400% in the 1996 transport costs level) is way too high to happen in practice. Mark finally that in simulation round (ii) 'leapfrogging' between urban centers is much more the rule than in simulation round (i), especially for lower transport costs levels. It seems that simulation round (ii), when equation (4.2.5) is used in place of equation (4.2.1), the results are more in accordance with the real situation in which a more balanced set of urban centers (regarding manufactures and agriculture workforce shares) is analyzed.

Figure 5.2. Results – Simulation Round (ii)

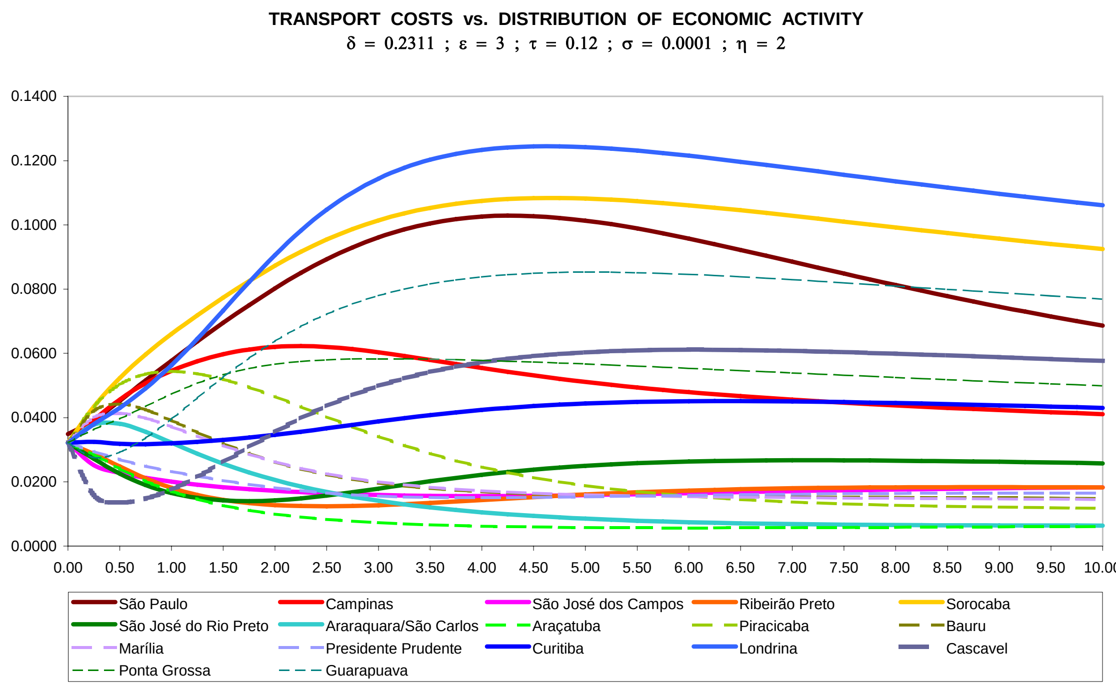


Figure 5.3. on next page shows the results in simulation round (iii): structural change systematic variation in parameter T → 1.00 to 1.80 at increments of 0.025 using equation (4.2.1) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 1996 (considering full taxation) and the shares of mobile and immobile workforce of 1996. The results are analogous to those found in simulation round (i), with the exception that when using actual transport costs instead of physical distances as the proxy for D_{rs} the 'bump' in the graph, starts to take place from point 1.60 onwards. That is to say, beyond point 1.60 moving to the left on the horizontal axis lies the level termed as 'high' transport costs in the core model of geographical economics with congestion. From that point on agglomeration of economic activity starts to lose its strength and spreading starts to be more likely. Yet again, at that exorbitant level of transport costs the whole economy would probably have collapsed already.

Figure 5.3. Results – Simulation Round (iii)

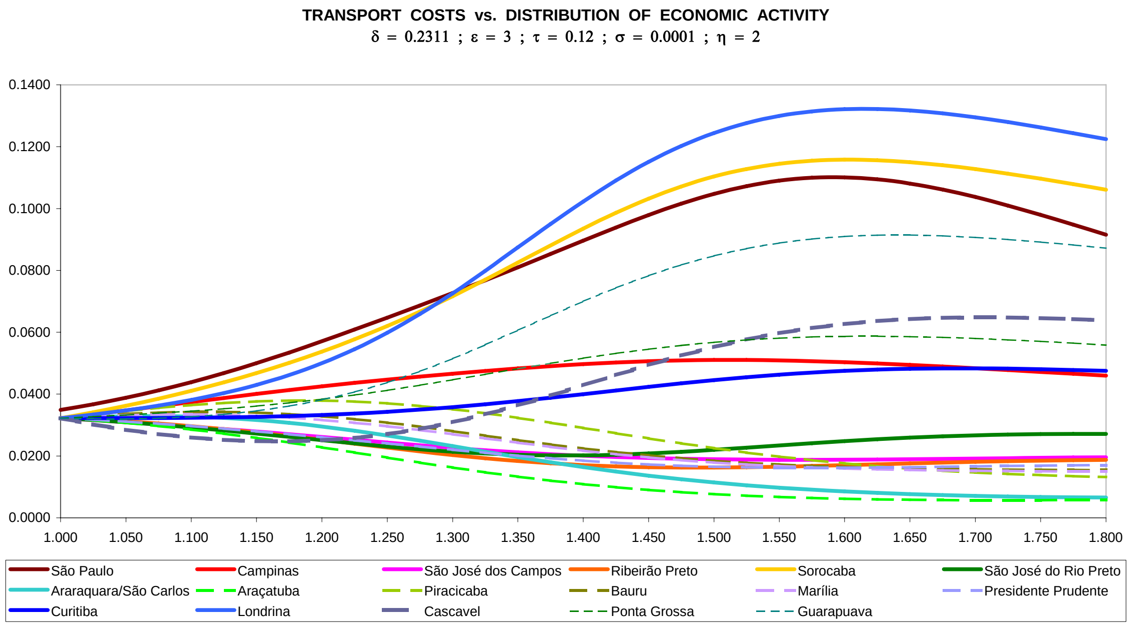
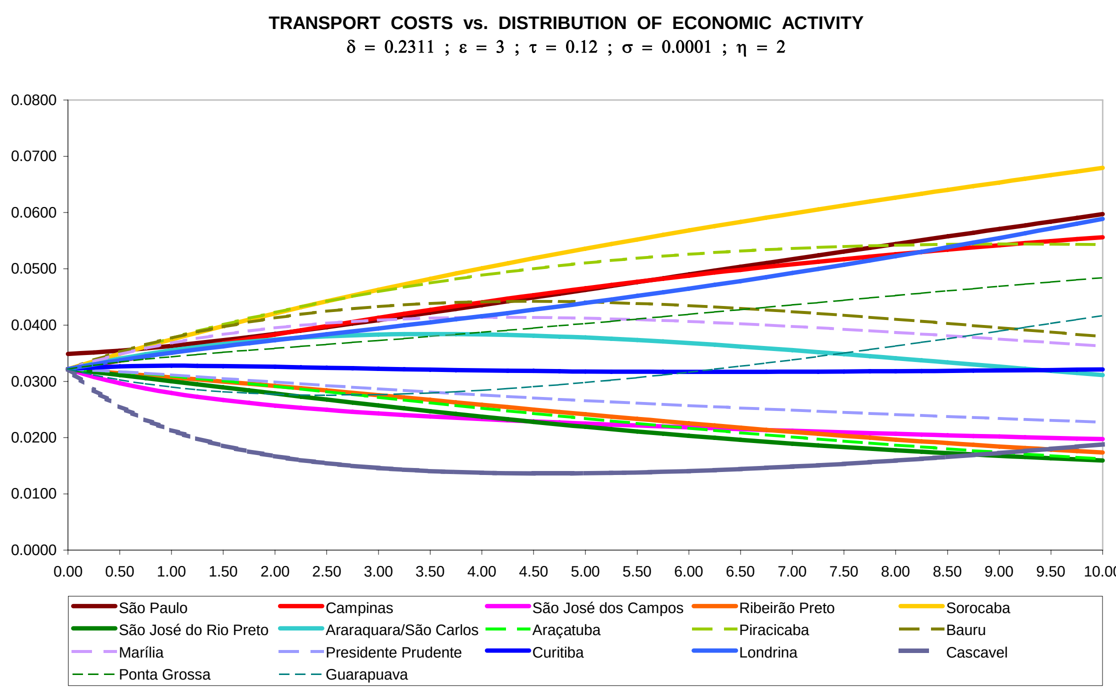


Figure 5.4. displays the results in simulation round (iv): Structural change systematic variation in parameter $T \rightarrow 0.00$ to 10.00 at increments of 0.10 using equation (4.2.5) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 1996 (considering full taxation) and the shares of mobile and immobile workforce of 1996.

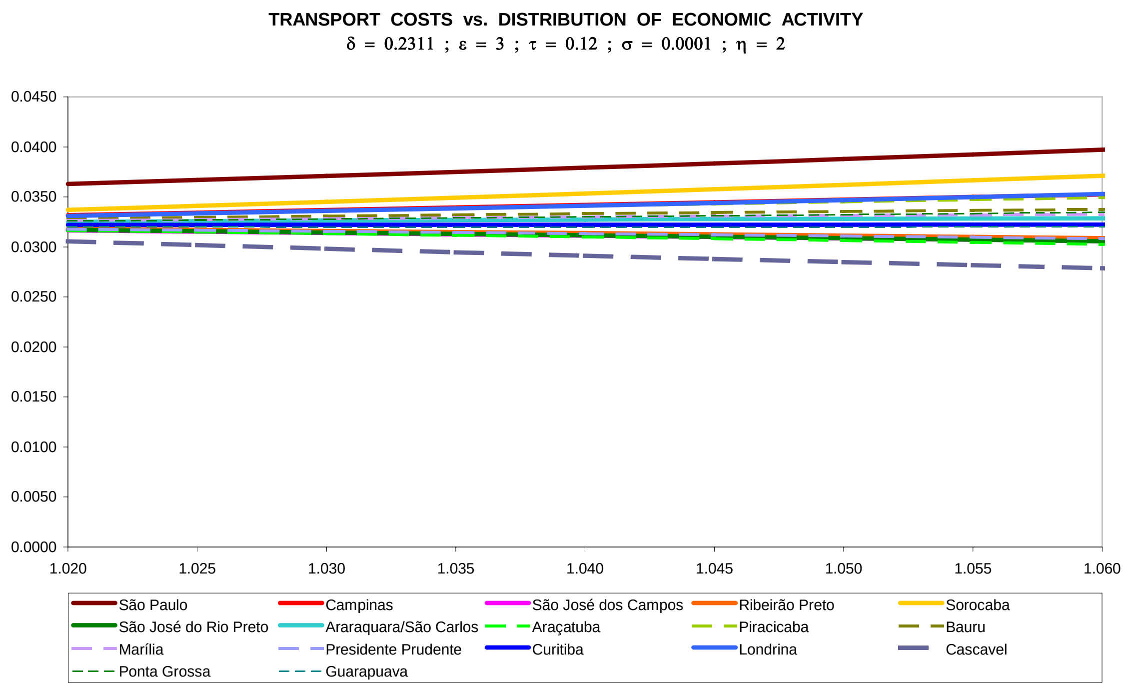
Figure 5.4. Results – Simulation Round (iv)



The results are similar to those of simulation round (ii) and again in accordance with the core model of geographical economics with congestion. Note that now, using actual transport costs, the point at which spreading tendencies would start to become stronger than agglomeration cannot even be displayed in the graph, lying beyond an increase of 10 times actual 1996 transport costs levels (point 1.00). It becomes more apparent that, in comparison with simulation round (iii), 'leapfrogging' between urban centers is much more the rule in simulation round (iv).

Figure 5.5. displays the results in simulation round (v): structural change systematic variation in parameter $T \rightarrow$ 1.02 to 1.06 at increments of 0.005 using equation (4.2.1) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 1996 (considering full taxation) and the shares of mobile and immobile workforce of 1996.

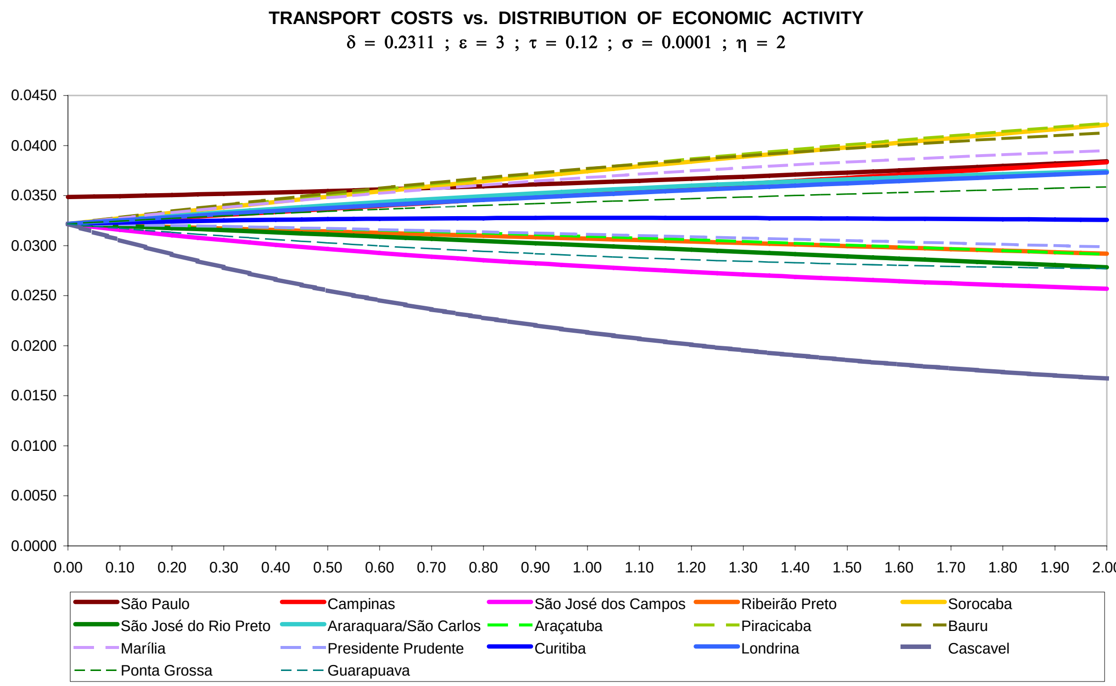
Figure 5.5. Results – Simulation Round (v)



The intention of simulation round (v) was to 'zoom in' simulation round (iii) to the levels of transport costs that actually matter for the Brazilian recent reality, or 1.03745 (for year 1996 considering full taxation), 1.04534 (for year 2002 considering a 100% reduction in both taxation and toll duties), 1.04986 (for year 2002 considering a 50% reduction in both taxation and toll duties), and 1.05418 (for year 2002 considering no reduction in neither taxation or toll duties). By doing so it becomes evident from the graph that the higher transport costs are agglomeration will increase at increasing rates, whereas any decrease in transport costs would mean a more even distribution of human activity between urban centers. It is also clear form the previous simulations that, according to the core model of geographical economics with congestion, the level at which this tendency might be reversed would be prohibitive in practice.

Figure 5.6. displays the results in simulation round (vi): structural change systematic variation in parameter $T \rightarrow$ 0.00 to 2.00 at increments of 0.050 using equation (4.2.5) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 1996 (considering full taxation) and the shares of mobile and immobile workforce of 1996.

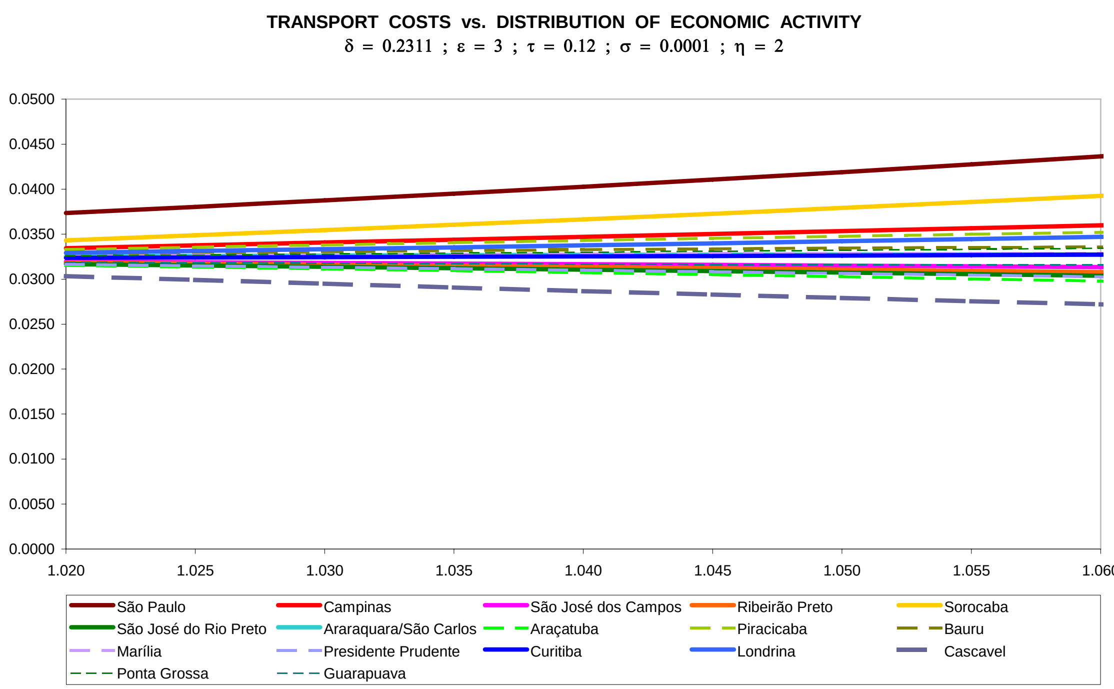
Figure 5.6. Results – Simulation Round (vi)



The objective of simulation round (vi) was to 'zoom in' simulation round (iv) to the levels of transport costs that actually matter for the Brazilian recent reality, or 1.0000 for year 1996 considering full taxation (road transport costs quoted on average at 0.1081 R$/TK), 1.3233 for year 2002 considering a 100% reduction in both taxation and toll duties (road transport costs quoted on average at 0.1431 R$/TK), 1.5210 for year 2002 considering a 50% reduction in both taxation and toll duties (road transport costs quoted on average at 0.1645 R$/TK), and 1.7187 for year 2002 considering no reduction in neither taxation or toll duties (road transport costs quoted on average at 0.1858 R$/TK). That is to say, when comparing to 1996 levels (point 1.00) transport costs 32.33% higher in 2002 considering a 100% reduction in both taxation and toll duties, 52.10% higher in 2002 considering a 50% reduction in both taxation and toll duties, and 71.87% higher in 2002 considering no reduction in neither taxation or toll duties. Not only the analysis of the results is much simpler using equation (4.2.5), but also the results are more in accordance with the Brazilian reality for the dynamic 'leapfrogging' amongst urban centers – which in simulation round (v) simply did not happen – and due to the higher disparity in the distribution of human activity the higher transport costs move. Nevertheless, similarly to the conclusion with simulation round (v), any increase in transport costs would mean further agglomeration at increasing rates, whereas any decrease in transport costs would mean a more even distribution of human activity between the urban centers.

Figure 5.7. portrays the results in simulation round (vii): structural change systematic variation in parameter $T \rightarrow 1.02$ to 1.06 at increments of 0.005 using equation (4.2.1) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 2002 (considering no reduction in neither taxation or toll duties) and the shares of mobile and immobile workforce of 2002.

Figure 5.7. Results – Simulation Round (vii)

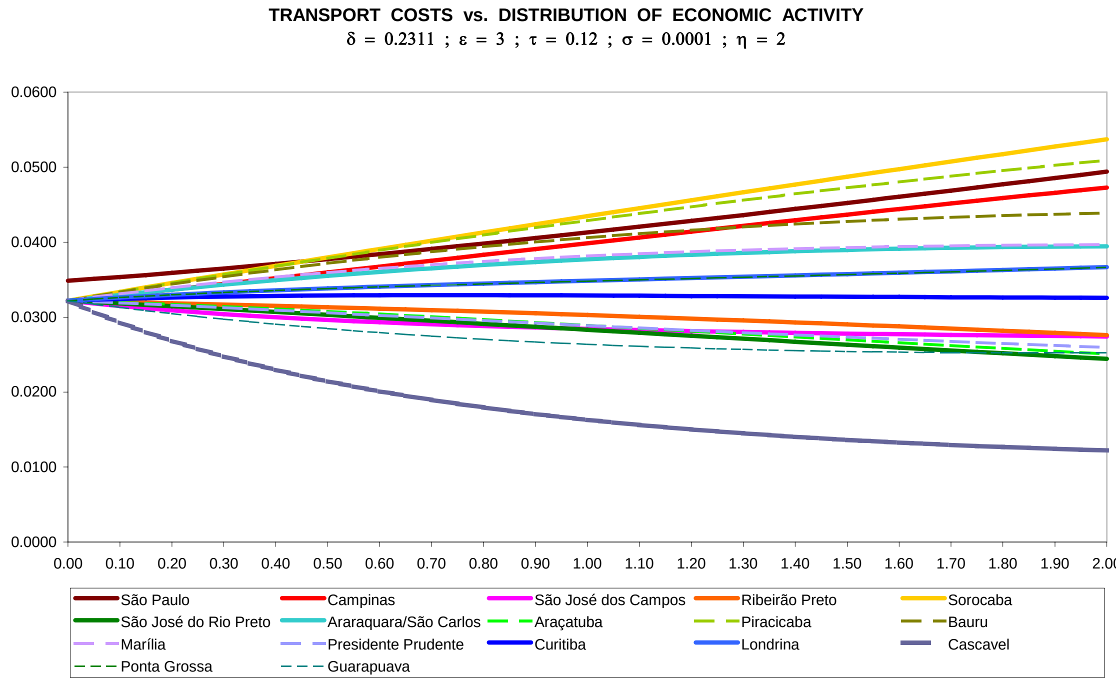


As it was expected, the results are virtually identical to those of simulation round (v). The conclusions are therefore the same, this time strengthening the assertion that that any increase in transport costs would mean further agglomeration at increasing rates, whereas any decrease in transport costs would mean a more even distribution of human activity between the urban centers.

Figure 5.8. on next page presents the results in simulation round (viii): structural change systematic variation in parameter $T \rightarrow 0.00$ to 2.00 at increments of 0.050 using equation (4.2.5) to compute T_{rs} having as proxy for D_{rs} the actual values of

transport costs for 2002 (considering no reduction in neither taxation or toll duties) and the shares of mobile and immobile workforce of 2002.

Figure 5.8. Results – Simulation Round (viii)



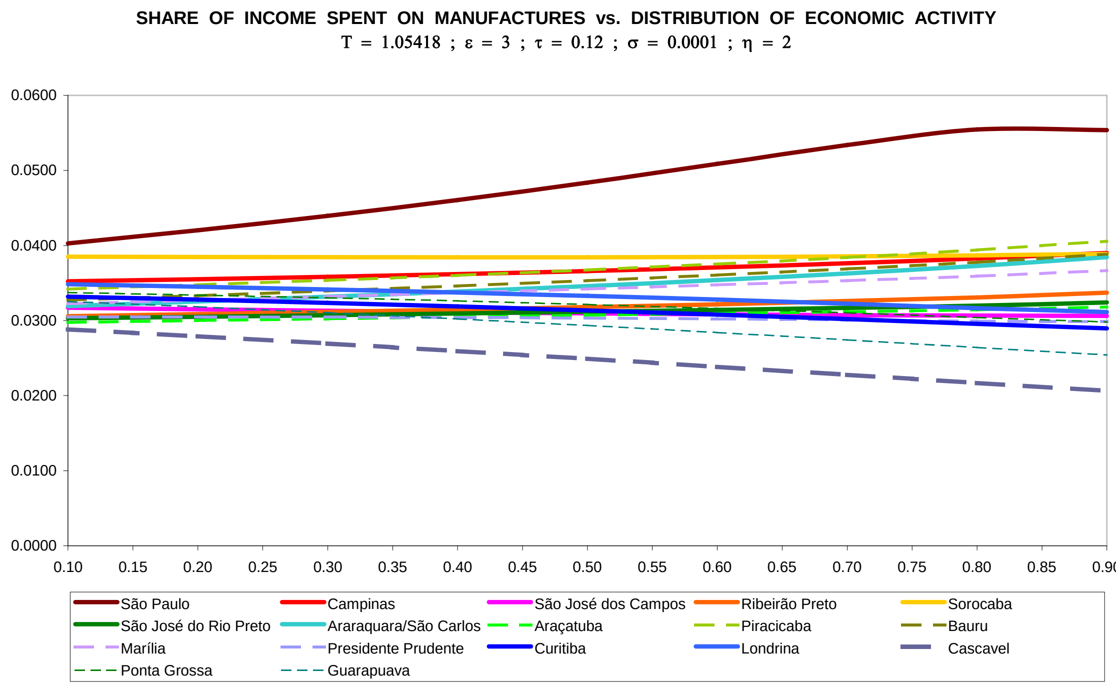
As it was expected, the results are similar to those of simulation round (vi). Take notice, however, how the agglomeration at transport costs higher than the levels of 2002 (considering no reduction in neither taxation or toll duties) is much more pronounced from point 1.00 onwards with 'winners' agglomerating more and 'losers' agglomerating less. São Paulo (brown #1), Campinas (red #2), Sorocaba (yellow #5), and Piracicaba (green #9), which are in reality the most centralizing urban centers tend to agglomerate even more as transport costs increase. There is again the indication that when utilizing equation (4.2.5) as the T_{rs} generator, results will be more in accordance with the Brazilian reality of late.

We conclude therefore this sub-section first with the judgment reaffirmed in every round of simulations from (i) to (viii) that for the recent case of Brazil any increase in the level of transport costs would entail agglomeration of human activity to accelerate at increasing rates, whereas any decrease would favor the spreading of human activity at decreasing rates. Second, we would like to point that by using formula (4.2.5) instead of formula (4.2.1), as put forth in this paper, not only theoretical geographical economics transport costs bear more resemblance to actual transport costs but the very results of simulations do so as well.

5.2. Share of Income δ

Figure 5.9. represents the results in simulation round (ix): structural change systematic variation in parameter $\delta \rightarrow$ 0.1 to 0.9 at increments of 0.1, using equation (4.2.1) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 2002 (considering no reduction in neither taxation or toll duties) and the shares of mobile and immobile workforce of 2002. In this round of simulations parameter T has been held constant at 1.05418 (the actual level of transport costs in 2002 considering no reduction in neither taxation or toll duties).

Figure 5.9. Results – Simulation Round (ix)

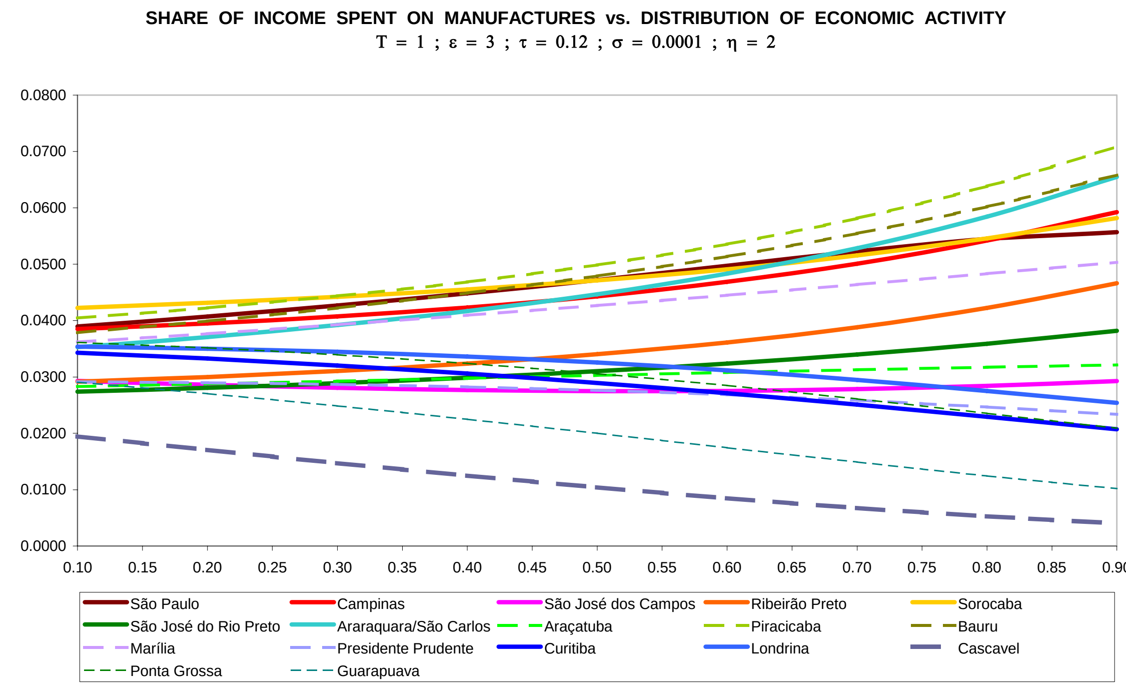


The results are once more in accordance with the core model of geographical economics with congestion, or: as the share of income spent on manufactures gets larger for the economy as a whole, the more agglomeration is the expected resulting equilibrium. São Paulo (brown #1), which currently concentrates the highest share of the national industry, increases its attractiveness in comparison to other urban centers as δ grows higher.

Figure 5.10. portrays the results in simulation round (x): structural change systematic variation in parameter $\delta \rightarrow$ 0.1 to 0.9 at increments of 0.1, using equation (4.2.5) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 2002 (considering no reduction in neither taxation or toll duties) and the shares of mobile and immobile workforce of 2002. In this round of simulations parameter T has been

held constant at 1.00 (the actual level of transport costs in 2002 considering no reduction in neither taxation or toll duties).

Figure 5.10. Results – Simulation Round (x)

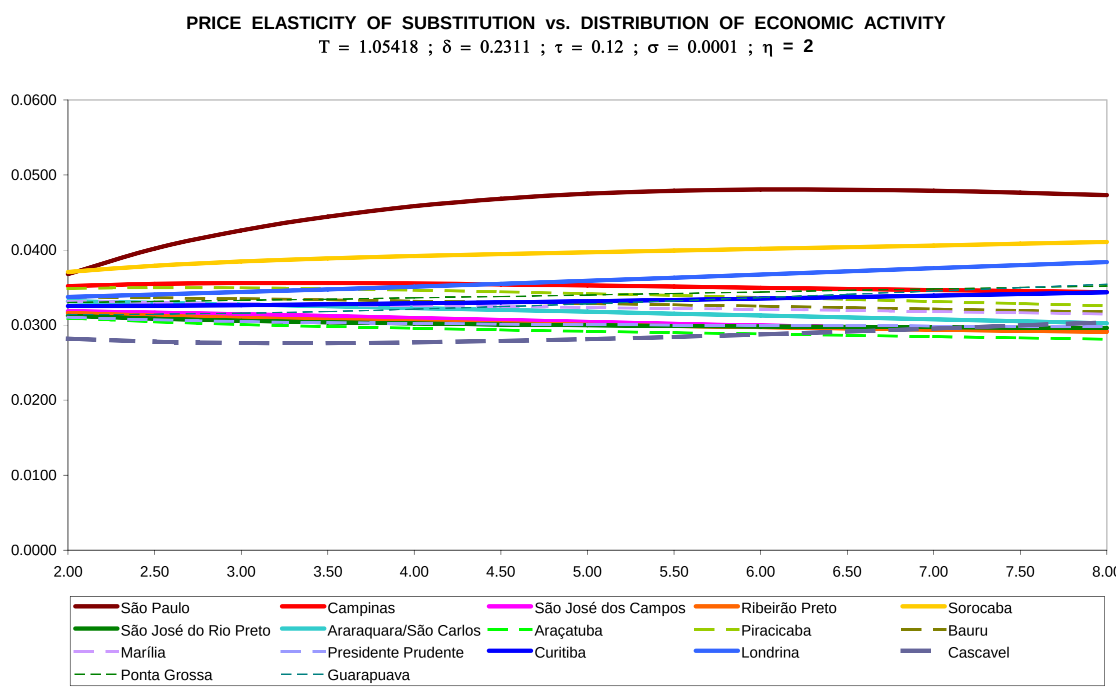


Similar to simulation round (ix), the results are in accordance with the core model of geographical economics with congestion. But using equation (4.2.5) 'leapfrogging' between urban centers takes place more constantly in all the span of variation of δ. São Paulo (brown #1), although standing all along as one of the agglomeration poles, has to share its front position with other urban centers as δ escalates. Piracicaba (green #9), Bauru (green #10), Araraquara/São Carlos (blue #7), and Campinas (red #2) overtake São Paulo (red #1) depending on the level of δ. These results bear greater resemblance to the reality of the recent process of '*interiorization*' of the industry once located almost exclusively at metropolitan São Paulo. Taking the broader interpretation of parameter δ, the more advanced the economy becomes the more the city of São Paulo reassures its primacy as the center of high technological industries with other urban centers mainly in the hinterland of the state of São Paulo profiting from a more balanced distribution in the lower tiers of economic activity. Regarding the low level of the actual share of income spent in manufactures in Brazil (23.11%), there seems to be ample margin for increase in δ, which adds to the credibility of the event.

5.3. Elasticity of Substitution ε

Figure 5.11. represents the results in simulation round (ix): structural change systematic variation in parameter $\varepsilon \rightarrow$ 2 to 8 at increments of 0.5, using equation (4.2.1) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 2002 (considering no reduction in neither taxation or toll duties) and the shares of mobile and immobile workforce of 2002. In this round of simulations parameter T has been held constant at 1.05418 (the actual level of transport costs in 2002 considering no reduction in neither taxation or toll duties).

Figure 5.11. Results – Simulation Round (xi)

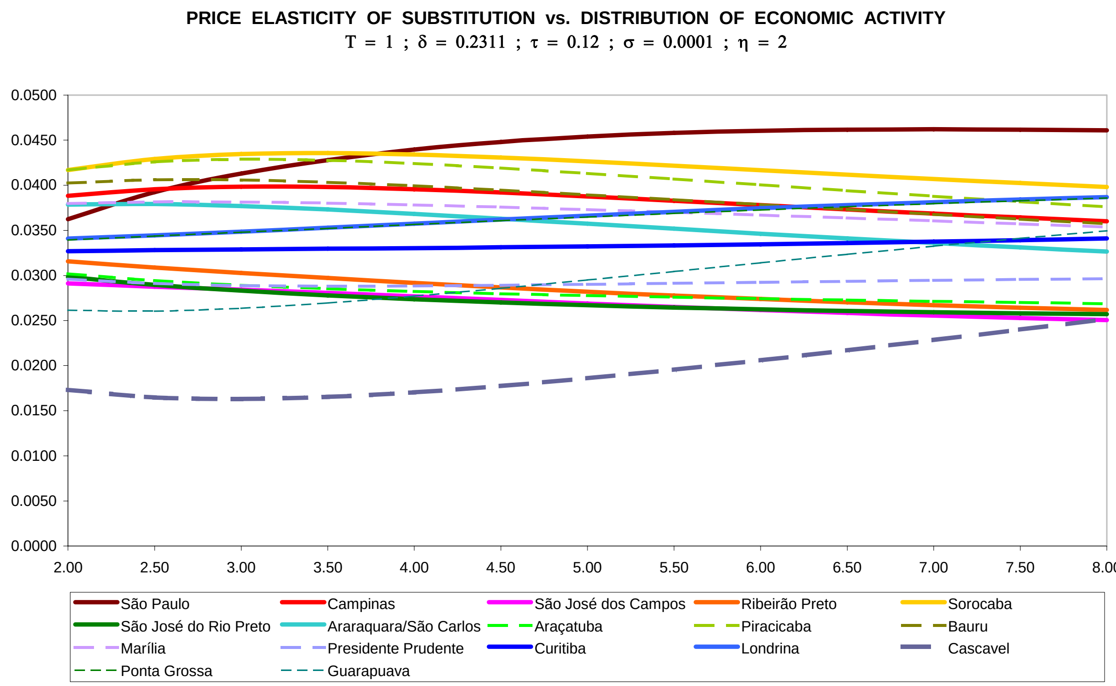


Variations in parameter ε using equation (4.2.1) to obtain values of T_{rs} show that the higher the degree of competitiveness between the varieties consumed, the higher the agglomeration of manufacturing activity, which is in agreement with the core model of geographical economics with congestion. São Paulo enlarges its detachment form other urban centers as the degree of competition expands. Near point 8.00 in the horizontal axis, Sorocaba (yellow #5), Londrina (blue #14), and Ponta Grossa (green #16) seem to challenge São Paulo's (brown #1) agglomerating position.

Figure 5.12. on the next page depicts the results in simulation round (xii): structural change systematic variation in parameter $\varepsilon \rightarrow$ 2 to 8 at increments of 0.5, using equation (4.2.5) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 2002 (considering no reduction in neither taxation or toll duties) and the

shares of mobile and immobile workforce of 2002. In this round of simulations parameter T has been held constant at 1.00 (the actual level of transport costs in 2002 considering no reduction in neither taxation or toll duties).

Figure 5.12. Results – Simulation Round (xii)

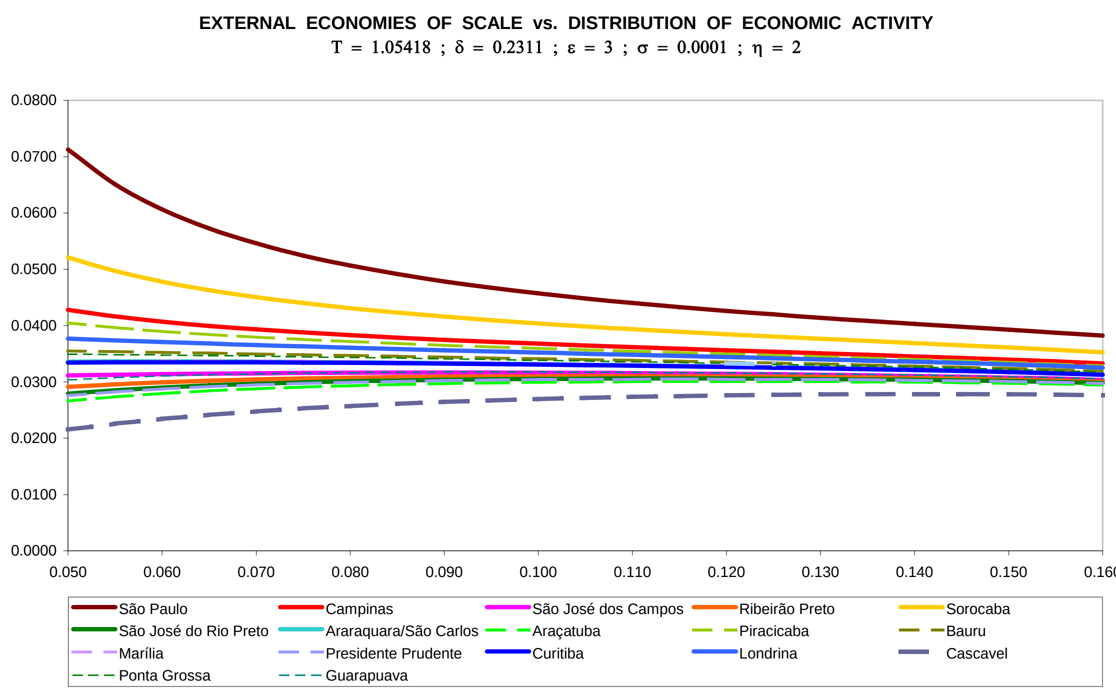


As it has become visible in every simulation performed so far in this paper, whenever equation (4.2.5) is used to evaluate T_{rs} leapfrogging happens more constantly throughout the span of parameter variation analyzed as does the similarity to recent Brazilian reality. It has been no different with simulation round (xii) when compared to simulation round (xi). The basic remarks concerning the dilation of ε are similar to those made in simulation round (xi), except that for lower values of ε (until approximately at point 3.50 in the horizontal axis) at which São Paulo (brown #1) actually loses its primacy in manufacturing activity to Sorocaba (yellow #5), Piracicaba (green #9), Bauru (green #10), and Campinas (red #2), confirming the movement of economic activity form the metropolis to medium-size cities especially in the hinterland of the state of São Paulo. To the right of point 3.50, or the more competitive the economy (with more firms producing varieties that are substitutes amongst each other), the more probable that São Paulo will slowly gain on the other urban centers. Yet, conversely to what happened in simulation round (xi), the distance between São Paulo (brown #1) and the least agglomerating urban center (Cascavel, gray #15) grows thinner and the overall distribution of economic activity amongst urban centers becomes more uniform.

5.4. Congestion τ

Figure 5.13. portrays the results in simulation round (xiii): structural change systematic variation in parameter $\tau \rightarrow$ 0.05 to 0.16 at increments of 0.005, using equation (4.2.1) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 2002 (considering no reduction in neither taxation or toll duties) and the shares of mobile and immobile workforce of 2002. In this round of simulations parameter T has been held constant at 1.05418 (the actual level of transport costs in 2002 considering no reduction in neither taxation or toll duties).

Figure 5.13. Results – Simulation Round (xiii)

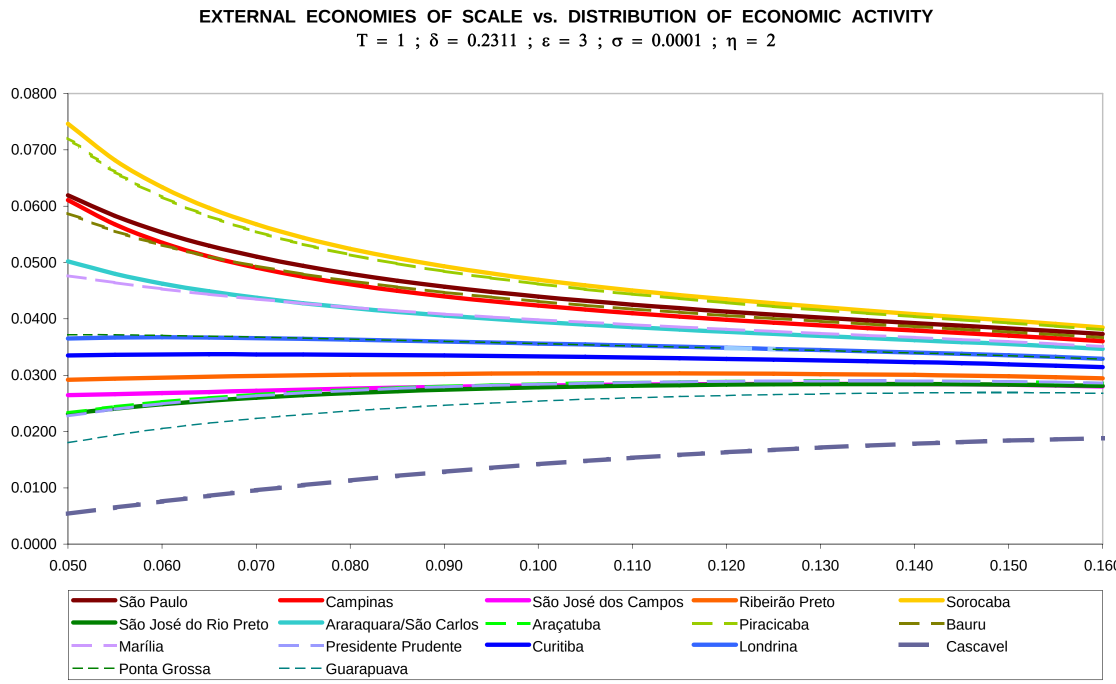


We can deduce from the graph that as congestion heightens the spread of human activity proceeds from larger urban centers to smaller urban ones, particularly from the metropolitan area of São Paulo (brown, #1), from Sorocaba (yellow, #5), and Campinas (red #3). Interesting to witness how strong a spreading force in the core model of geographical economics can congestion be. Slight changes in the values attributed to τ might turn the picture from strong agglomeration into full spreading.

Figure 5.14. on the next page display the results in simulation round (xiv): Structural change systematic variation in parameter $\tau \rightarrow$ 0.05 to 0.16 at increments of 0.005, using equation (4.2.5) to compute T_{rs} having as proxy for D_{rs} the actual values of transport costs for 2002 (considering no reduction in neither taxation or toll duties) and the shares of mobile and immobile workforce of 2002. In this round of

simulations parameter T has been held constant at 1.00 (the actual level of transport costs in 2002 considering no reduction in neither taxation or toll duties).

Figure 5.14. Results – Simulation Round (xiv)



Again, as it has been happening invariably when applying formula (4.2.5) to generate T_{rs} in our simulation rounds, in simulation round (xiv) the effects of congestion in the core model, while still noteworthy, grant nonetheless a little more dynamism to the model. São Paulo (brown #1) does not agglomerate the most as a consequence of congestion. Sorocaba (yellow, #5) and Piracicaba (green #9) stand above São Paulo (brown #1) throughout the graph. Campinas (red #2), and Bauru (green #10) follow very closely to São Paulo (brown #1) as congestion mounts. This is more in accordance with the recent Brazilian trend of displacement of human activity from metropolitan São Paulo to other urban centers within the state of São Paulo and neighboring states, which are represented in the graph of figure 5.14. by Curitiba (blue #13) and Londrina (blue #14), both in the state of Paraná. Note again that at any instance we have arbitrarily chosen the level 0.12 for congestion when performing structural change systematic variations with the other parameters. There is however no scientific base behind this choice. Based on the graphs of Figures 5.13. and 5.14. this paper simply assumed that at the 0.12 level congestion would be strong enough to promote some de-concentration from the city of São Paulo while not too strong to force complete spreading from São Paulo to other municipalities. In the end it turned out to be that we seem to have been successful in our intuitive choice.

6. Conclusions and Recommendations

6.1. Research Questions

6.1.1. The Range of Transport Costs

Is it possible, using the core model of geographical economics with congestion, to determine a range of transport costs that contributes to the spreading (or to the agglomeration) of economic activity, especially towards medium-size cities in the hinterland of the Brazilian states of São Paulo and Paraná?

The answer is yes. As far as the data available for this research allows, this research concludes through the structural changes performed with parameters first that the increase in transport costs from years 1996 to 2002 have promoted the concentration of economic activity in the larger urban centers considered. Second that any increase in the level transport costs as they stood in both 1996 and 2002 would contribute to more concentration of population and economic activity especially in metropolitan São Paulo at an increasing rate; whereas any decrease in the level of transport costs as they stood in both 1996 and 2002 would contribute to the spreading of human activity. More importantly, by zooming in the range of 'iceberg' transport costs that actually correspond to the actual levels of transport costs in Brazil, we were able to determine exactly where actual transport costs in Brazil lies. In doing so we conclude, based on the results obtained with the core model of geographical economics with congestion, that it would take an exorbitant increase in actual transport costs in Brazil for spreading of economic activity to be the likely outcome. Nevertheless, if such a prohibitive increase in transport costs ever happened, the whole economy of the country would probably collapse. Such situation would be in practice to the aftermath of a world nuclear war, when there is simply no economic means of transportation – and therefore no trade – among urban centers, which will have to produce by themselves everything their inhabitants consume.

6.1.2. The Effects of the Privatization of Federal Roads

Is it possible, using the core model of geographical economics with congestion, to draw any conclusions on what have been the effects in terms of spreading (or agglomeration) of economic activity, if any, brought about by taxation and toll duties on transport, especially to medium-size cities in the hinterland of the Brazilian states of São Paulo and Paraná?

Yes again. For the same reasons stated before, the increase in transport costs from 1996 to 2002 have been caused especially by increases in diesel prices and by the tolls charged in federal roads in the states of Paraná and São Paulo. This increase has accelerated the concentration of economic activity in a few urban centers, counter acting the movement to medium-size municipalities observed in later years prior to 1996. Judging by the rates of increase in agglomeration that increases in transport cost would bring, as portrayed in the graphs of subsection 5.1. – be through decreases in taxation or in toll duties – any foreseeable decrease in transport costs would be advisable if spreading of economic activity towards other urban centers is the expected outcome.

6.1.3. Public Policy Issues

Can the core model of geographical economics with congestion, the way it has been applied to this concrete case, through the analysis of structural changes be of some guidance in the shaping of policy options available to decision-makers in Brazil?

Urban policies in Brazil have so far been limited to shortsighted solutions of the problems related to urban agglomerations such as congestion. This research brings to the fore the fact that cities are invariably organized in urban systems, or systems of cities. By no means can the effects national policies such as the privatization federal roads systems might have on the overall urbanization process of macro-regions, states, and micro-regions within the country, be neglected: especially in a large country such as Brazil. The way the privatization of the federal roads system has taken place in Brazil, many as one municipality became as if cut off the area of influence of its urban system due to the imposition of heavy toll fares in even small distances between small municipalities, which increases the 'economic' distance between municipalities. The de-concentration of population and industrial activity form the metropolitan area of São Paulo would not only allow the city to address more efficaciously the issue of congestion within its jurisdiction, but also be beneficial to smaller and medium-size municipalities belonging to other urban systems. Leeway in the maneuver of possible decreases in road transport costs would be feasible if only a little more fiscal discipline, sound financial management, better public administration practices, and foresighted planning were set in practice. Maybe it is time also for urban decision makers to adopt a more far-reaching view of the causes of the problems affecting their cities thus integrating the analysis and the solutions of such problems to the wider area of the urban systems to which their cities belong.

6.2. Final Remarks

Firstly, we would like to point that the conclusions of this paper are not conclusive due to the fact that much more research is still needed in trying to 'calibrate' the core model of geographical economics as to become applicable in practice. This research hopes humbly to have contributed but a little towards that direction.

It is implied in the literature[45] pertaining the matter that the core model of geographical economics seems to befit those situations in which differences in concentration of economic activity between countries or continents are of prime concern, or when labor mobility between countries is constrained; whereas the literature also suggests that the Helpman–Hanson model appears to harmonize with those circumstances in which economic dissimilarities between cities within countries are the variables of interest. The variant of the core model of geographical economics allowing for congestion has demonstrated nonetheless in this research the ability to deal with urban systems and smaller regions within a country. It would be advisable, however, further research be carried out to perform a comparison between the Helpman–Hanson model and on more effective measurements of congestion that can be utilized as proxies in the core model of geographical economics with congestion.

It is also important to stress that this paper justifies the suitability of replacing the agriculture sector for the housing sector in Helpman–Hanson for reasons complementary to that observed by Brakman, Garretsen, and Van Marrewijk (2001) – in verbatim: "*A further advantage is that it deals with the fact that in practice the size of agriculture is simply too small to act as a substantial spreading force*", concluding latter that "*(…) the housing sector in the Helpman model provides a more powerful spreading force*". Although the core model with congestion has the impacts of using a immobile economic sector attenuated by the size this sector has in many economies, the replacement of the food sector of the core model with the non-traded sector spontaneously gives reasonable impression of suitability for regional reality since there are far greater barriers to the mobility of farming activity from one country to another than within countries, as previously discussed. Besides that, the specific case of Brazil draws attention to the fact that the agriculture sector can have quite a weight on the aggregate GDP and on the trade balance of the country as long as agro-industrial production is computed together with farmland production. Finally, this paper assumes to have presented enough evidence of the mobility of farming activity within Brazil (please, refer to the introductory section).

Finally, the remark appended by Brakman, Garretsen, and Van Marrewijk (2001), when referring to Helpman (1998), that "*(…) it more closely resembles phenomena studied by regional scientists, who stress the importance of the availability of usable land and of local factors such as climate, good schools, etc. (…) Consumers buy differentiated products and pay for housing. The higher the labor supply in a region, the higher is the number of locally supplied varieties of differentiated products. This raises the living standard of the region. However in more densely populated regions housing is more expensive, thus lowering the standard of living. These two forces determine the final equilibrium in which the standard of living is equal for the regions*

[45] Please refer to Brakman, Garretsen, and Van Marrewijk (2001).

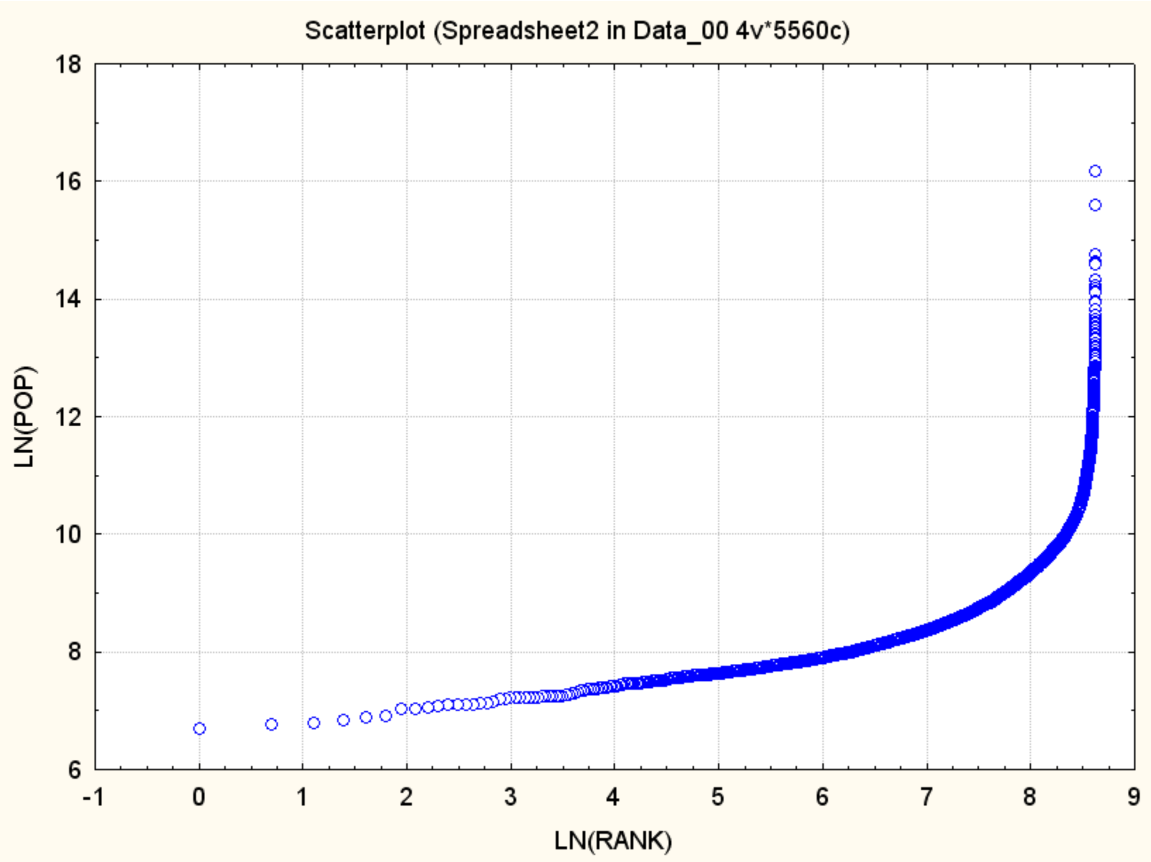
(…)" actually recognizes those more relative, hard to measure outcomes of congestion. Maybe housing prices could offer a fine proxy to congestion. Not that housing prices can act as a measure of congestion, but that higher housing prices are a direct, tractable consequence of congestion. No matter how many new modes of transportation are offered by metropolitan administrations to its citizens, how many new expressways are built in urban areas, how many new subway stations are inaugurated: all those costly investments in mass transit and other amenities intended to counteract congestion are nonetheless limited to the urban sphere of the cities where they belong and in the end serve to attract even more people and the ensuing crowdedness. Land and housing prices in locations close to urban transport facilities often soar even before the utilities are built because demand for such places grows astronomically. It may sound strange to some that people actually pay more to live in overpopulated areas worldwide. Yet, remember that mankind is a social species that finds in the society with other people a multitude of much-valued advantages and benefits, some hard to quantify in monetary terms such as the opportunities offered by cities for urbane existence and enlightenment. Since the primordial of human history, the grouping of human activity has brought good and bad consequences. The notable example of ancient Rome – the cradle of western civilization, where a well designed system of roads maintained and extended the domination of the prime city through fast linkages to the far boundaries of the empire – brings to the memory the supremacy of civic society but also the corruption of an ideal, warning those interested in assessing congestion to keep in mind that '*omni omnis lupo*', or 'man is the wolf of man'. Far from dismissing every type of crowdedness as undesirable, it is just quite hard to evaluate where lies the dividing line separating crowdedness from over-crowdedness. Conversely to investments in mass transit within cities, one way out of congested areas could be the improvement of connections between cities kept at affordable transport costs to promote the spreading of human activity to other cities. Prime cities need not worry to lose their primacy in doing so, history has shown, particularly in Brazil where the closeness of state capitals to the Atlantic ocean have granted these metropolises the position of gateways to international trade, that in reality de-concentration of economic activity made possible by a reduction in economic transport costs towards the hinterland would alleviate much of the congestion and urban problems now faced by those cities whilst strengthening and enlarging the area of influence of the prime cities themselves via the consolidation of minor urban agglomerations and their systems of influence in the inland.

We would like to end this paper reminding the geographical economics[46] notion of the fractal continuity of the distribution urban systems fits as a glove to the Brazilian reality. It takes but a look at Figures 1.3. to 1.6. in the introductory section of this

[46] Refer to Brakman, Garretsen, and Van Marrewijk (2001) for an in depth account of the evidence and findings about the fractal dimension observed in the distribution of economic activity across space.

paper to convince oneself of the amazing organization of Brazilian municipalities in urban systems with a conspicuous fractal hierarchy of urban centers. If not convinced, figure 6.1. below offers an scatter plot carried out with 2002 data on the population of all 5.560 Brazilian municipalities ranked in reverse order in which the rank-size correlation acquires a more than exponential dimension. We are witnessing a non-planned, natural phenomenon pertaining to the distribution of human activity over space where both spreading and agglomeration of human activity have a complementary role to play on the fractal stage. Being a natural phenomenon, the odds are for the continuation of the rank-size distribution (or Zipf's Law, after George K. Zipf, 1949). The fractal dimension of the event tell us that the odds are not only for the maintenance, but also in favor of the strengthening of the hegemony of the primate city over urban systems as smaller municipalities grow. Sprawling, after all, may not be such a bad idea, as long as carried out in an orderly way with residential compounds moving horizontally together with the decentralization of civil administrations, businesses, industries, or put short: with the whole city moving off horizontally in a sustainable way. Coordinated planning approaches aimed at the decentralization of urban areas have been tried quite successfully in cities and regions in the Netherlands, in Europe, and in a few notable instances in the USA too, like the city of Portland. Everything depending however on the level transport costs are kept.

Figure 6.1. Zipf's Law in Brazil



7. Bibliography / References

Brakman, S., Garretsen, H., Gigengack, R., Marrewijk C. van, Wagenvoort, R., 1996, 'Negative feedbacks in the economy and industrial location', in *Journal of Regional Science*, no. 36, pp. 183-215.

Brakman, S., Garretsen, H., Marrewijk, C. van, Schramm, M., 2000, 'Empirical Research in Geographical Economics', University of Groningen, Groningen, the Netherlands.

Brakman, S., Garretsen, H., Marrewijk, C. van, 2001, 'An Introduction to Geographical Economics', Cambridge University Press, Cambridge, the UK.

Brakman, S., Garretsen, H., Schramm, M., 2002, 'New Economic Geography in Germany: Testing the Helpman–Hanson Model', in *HWWA Discussion Paper*, No. 172, Hamburg Institute of International Economics, Hamburg, Germany.

Castro, A. C., and Fonseca, M. da G. D., 1995, 'A Dinâmica Agroindustrial do Centro-Oeste', in *Série IPEA*, no. 148, pp. 84-85, IPEA, Brasília, Brazil.

Faria, V. E., 1976, 'O Sistema Urbano Brasileiro – Um Resumo das Características e Tendências Recentes', in *Estudos CEBRAP*, no. 18, out/set, pp. 91-115, São Paulo, Brazil.

Faria, V. E., 1992, 'A Conjuntura Social Brasileira: Dilemas e Perspectivas', in *Novos Estudos CEBRAP*, no. 33, CEBRAP, São Paulo, Brazil.

Forslid, R., 1999, 'Agglomeration with human and physical capital: an analytically solvable case', in *CEPR Discussion Paper*, no. 2102, London, the UK.

Garretsen, H., Schramm, M., Brakman, S., 2003, 'The Spatial Distribution of Wages: Estimating the Helpman-Hanson Model for Germany', in *Tjalling C. Koopmans Research Institute Discussion Paper Series*, nr: 03-08, Tjalling C. Koopmans Research Institute, Utrecht School of Economics, Utrecht, the Netherlands.

Hanson, G. H., 1997, 'Increasing Returns, Trade, and the Regional Structure of Wages', in *The Economic Journal*, vol. 107, no. 440, pp. 113-133, Royal Economic Society, Blackwell, Oxford, the UK.

Hanson, G. H., 1998, 'Market Potential, Increasing Returns, and Geographic Concentration', in *NBER Working Paper*, no. 6249, Cambridge MA, the USA.

Hanson, G. H., 2000, 'Scale Economies and the Geographic Concentration of Industry', in *NBER Working Paper*, no. 8013, Cambridge MA, the USA.

Helpman, E., 1998, ‘The size of regions’, in *D. Pines, E. Sadka and I. Zilcha (eds.): Topics in Public Economics*, Cambridge University Press, Cambridge MA, the USA.

IBGE – Instituto Brasileiro de Geografia e Estatística, 2004, (Bivar, W., et al, 2004), ‘Contas Regionais do Brasil’, in *Contas Nacionais*, no. 13, IBGE, Rio de Janeiro, Brazil.

IBGE – Instituto Brasileiro de Geografia e Estatística, 2004, (Bivar, W., et al, 2004), ‘Pesquisa de Orçamentos Familiares 2002-2003: Primeiros Resultados / Brasil e grandes regiões’, Coordenação de Índices de Preços, IBGE, Rio de Janeiro, Brazil.

IPEA – Instituto de Pesquisa Econômica Aplicada, 1997, (Galindo Filho, O. T., 1997), ‘Transformações Recentes da Fronteira Agrícola e Implicações para a Dinâmica Espacial do Brasil’, IPEA/Fundação Joaquim Nabuco, E. Massangana, Recife, Brazil.

IPEA – Instituto de Pesquisa Econômica Aplicada, 2001, (da Motta D. M., Ajara C., et al, 2001), ‘Configuração Atual e Tendências da Rede Urbana’, in *Série Caracterização e Tendências da Rede Urbana do Brasil*, vol. 1, vol. 2, vol. 5, vol. 6, IPEA/IBGE/NESUR/ IE/UNICAMP, Ed. BNDES, Brasília, Brazil.

Katz, F., and Lima, P., 1992, ‘Inovações Tecnológicas e Desenvolvimento na Periferia: Estudos de Caso no Nordeste Brasileiro’, in *XX Encontro Nacional de Economia*, Anais, Campos do Jordão, Brazil.

Krugman, P., 1991, ‘Increasing Returns and Economic Geography’, in *Journal of Political Economy*, no. 99, no. 3, The University of Chicago, Chicago, the USA.

Lima, P., 1993, ‘Economias do Nordeste: Tendências Recentes das Áreas Dinâmicas’, in *ANPEC XX Encontro Nacional*, Anais, Anpec, Mimeo, Recife, Brazil.

Marrewijk, C. van, 2005 ‘Geographical Economics and the Role of Pollution on Location’, in *Tinbergen Institute Discussion Paper*, no. TI2005-018/2, Erasmus Universiteit, Rotterdam, the Netherlands.

Meller, P., 2001, ‘Trade and Development in Latin America’, Universidad de Chile, Facultad de Ciencias Físicas y Matemáticas, Departamento de Ingenieria Industrial, Santiago, Chile.

Negri, B., 1996, ‘Concentração e Desconcentração Industrial em São Paulo (1880-1990)’, Ed. BNDES, Unicamp, Campinas, Brazil.

Ottaviano, G.I.P., 2001, ‘Monopolistic Competition, Trade, and Endogenous Spatial Fluctuations’, in *Regional Science and Urban Economics*, vol. 31, pp. 51-77.

Pflüger, M., 2001, ‘A Simple, Analytically Solvable Chamberlinian Agglomeration Model’, in *IZA Discussion Paper,* no. 359, Bonn, Germany.

Silva, J. G., et al, 1996, ‘A Nova Dinâmica da Agricultura Brasileira’, Mimeo, Unicamp/IE, Campinas, Brazil.

Tolosa, H., 1973, ‘A Macroeconomia da Urbanização Brasileira’, in *Pesquisa e Planejamento Econômico*, no. 2, pp. 585-644, São Paulo, Brazil.

Zipf, G., K., 1949, ‘Human Behavior and the Principle of Least Effort’, Addison-Wesley, New York, the USA.