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THE TRANSPORT-REGIONAL EQUITY ISSUE REVISITED

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ABSTRACT

The objective of this article is to analyze the relationship between transport and regional equity in Minas Gerais (Brazil). Furthermore, the existence of a trade-off between economic performance and regional equity is investigated as well. To do so, we develop a spatial computable general equilibrium model to implement comparative static analysis, explicitly incorporating iceberg transportation costs. Four activities are modeled, namely, production, consumption, transportation and exports. Two production factors are assumed: labor and other factors. In the model, there are twelve domestic regions and three external regions. We develop four counterfactual experiments based on decreases in transportation costs due to a "distance shortening". The main findings indicate that if the transport infrastructure improvement is just among poor regions, the promotion of the regional equity is insignificant. If the transport infrastructure improvement links are just among rich regions, there is an increase of the regional income inequalities. If the improvement happens to the roads linking poor regions and rich ones, there is promotion of regional equity. The same happens to improvement of all road links of the state. By the same token, there seems to exist actually a trade-off between economic performance and regional equity in Minas Gerais.

KEY WORDS: spatial computable general equilibrium model; regional equity; economic performance; transportation costs.

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1. INTRODUCTION

Over the years, there has been an intense debate in the literature about the relationship between the role of the transport infrastructure provision and regional equity. With respect to the nature of this relationship, the research community has generated both empirical evidences, suggesting either a positive or negative relationship (Kim *et al*. 2002; Dall'erba and Hewings, 2003, Vickermann *et al*. 1996). These inconsistent results are partially due to methodological differences. Hence, it is absolutely reasonable to admit that two different theories/models should generate controversial results about the nature of the relationship between transport and regional equity. For instance, it is understandable that an economic geographical model may yield evidence that may contest those arising from a neoclassical model, adopted to examine this research issue.

Similarly, distinct methods of investigation of this relationship have been used, such as multi-regional input-output and econometric models, transportation network models or spatial CGE models. Once again, based upon strictly methodological grounds, it is understandable that, even adopting the same theoretical model, the evidences extracted from an econometric model may be quite different from those generated from a spatial CGE model. Even keeping the same theoretical model and method of investigation, it is also possible that different specifications of the method adopted are able to produce different outcomes.[1] Then a spatial CGE model that includes the transportation in its specification as a sector may generate conclusions on the nature of this relationship that are different from a spatial CGE model that incorporates, in turn, the transportation as an iceberg cost. Interpretation of the relationship between transport and regional equity is unlikely to be independent of the model adopted.

Therefore, this has not surprised us that there have been controversial results about the nature of the relationship. Indeed, the most of controversial evidences stem from this kind of methodological discrepancy. We can consider that these discrepancies have a spurious source, inasmuch as they do not allow us to focus on essentials of the issue.

Our objective in this article is to reveal that, methodological differences aside, the evidence about the nature of the relationship between transport infrastructure provision

[1] See also McGregor *et al*. on effect of different closures rules in CGE modeling.

and regional equity are controversial due to a fundamental characteristic associated with this issue. In other words, even with the same theory/model, method and its specification, we continue obtaining different results about this relationship. This outcome arises because this relationship crucially depends upon *where* the transport infrastructure is located.[2] In addition to methodological considerations, there seems to exist authentic spatial reasons to yield controversial results. Indeed, transport infrastructure is strongly region-dependent. The *spatial structure* of the transport infrastructure provision matters in this question, playing a fundamental role in determining its effects on the economic system.

Besides examining the relationship between transport and the regional equity, our objective is to shed some light on another controversial point, namely the trade-off between economic performance (growth and efficiency) and regional equity, which is directly linked to transport infrastructure provision. Regional equity and economic performance are two sides of the same coin. The transportation sector determines the general conditions of systemic efficiency of a region or a country, conditioning its economic development. Since transportation has the economic function of transferring final goods and intermediate inputs across regions, its performance affects the degree of competitiveness of the other sectors in the economy. However, economic performance does not accrue randomly across space. Under certain circumstances, there are regions that benefit themselves more than others. To put it another way, the effects of the transport infrastructure contribute to economic performance that induces, in turn, development impacts such that there will probably be to identify winning regions as well as losing ones from any given investment.

In order to explore these two points in this article, and given the complexity and the amount of feedbacks involved in this kind of investigation, we feel the need for more explicit modeling of the behavior functions (production and demand functions) and spatial structure of the phenomenon under study. Accordingly, we develop a spatial computable general equilibrium model, based on the parsimonious approach, proposed by Bröcker (1998), Bröcker and Schneider (2002) and Schneider (1998). The main

[2] This outcome has a parallel in the identification of analytically important elements in an input-output model. Location, as well as the size of the elements together with the overall complexity of the structure determines importance.

advantages of this approach rely on its analytical power and its capacity for examining policy shocks across regions in the midst of all complexity and feedback effects involved. In this perspective, the model, the method of investigation and its specification are chosen and will be kept constant.

The paper is divided into four sections, aside from this introduction. A brief introduction to the region is provided in section two. The next section presents the basic ideas of the theoretical structure of the spatial CGE adopted. The fourth section is reserved for describing the experiments and exhibiting the simulation results, as well as interpreting them. The last section recovers the main conclusions drawn from the investigation.

2. REGION OF ANALYSIS

Table 1: Area, Population and Production in Minas Gerais (1996)

Region	*Area*	*Population*	*Production*
Noroeste	10.7	1.9	1.6
Norte	21.7	8.7	4.4
Jequitinhonha	8.6	4.1	1.1
Vale do Mucuri	3.4	2.4	1.0
Triângulo/Alto Paranaíba	15.5	10.2	11.7
Central	5.4	2.2	1.6
RMBH	6.7	29.9	44.6
Vale do Rio Doce	7.2	9.0	9.1
Oeste	4.1	4.6	3.8
Sul/Sudoeste	8.5	12.5	10.9
Campo das Vertentes	2.1	2.9	1.9
Zona da Mata	6.1	11.6	8.3

Source: IBGE.

Minas Gerais is an interesting case to be examined within the 27 Brazilian states with respect to regional disparities and economic performance among its twelve domestic regions (see Table 1). This is so because Minas Gerais state is Brazil's third most richest state and the country's second most populous state. It is noteworthy that the regions Triângulo Mineiro/Alto Paranaíba, RMBH and Sul/Sudoeste possess just 31 percent of

Minas Gerais' territory, but they host 53 percent of Minas Gerais's population and 67 percent of the state's production. The regions Noroeste, Norte de Minas, Vale do Jequitinhonha and Vale do Mucuri possess almost half of the state's territory, but they shelter just 17 percent of Minas Gerais' population and about 18 percent of the state's production. So Minas Gerais can be split into rich and poor regions, consisting of two homogeneous parts. The rich part, named henceforth "South", is composed of Triângulo Mineiro/Alto Paranaíba, Central, RMBH, Vale do Rio Doce, Oeste, Sul/Sudoeste, Campo das Vertentes and Zona da Mata. The other part, named hereafter "North", is composed of the following regions: Noroeste, Norte, Vale do Jequitinhonha and Vale do Mucuri.

Let's try shed further light on this issue, using the Human Development Index at municipal level (HDI-M), constructed by PNUD, IPEA, Fundação João Pinheiro and IBGE, we can observe that the HDI-M of Minas Gerais amounts for 0.719, positioning it as Top 12 within Brazil (see Table 1). In despite of this good economic performance, there are strong regional inequalities inside its territory. Taking into account the dispersion of the HDI-M within the State, measured by the standard deviation, Minas Gerais is Brazil's second most disperse state, denoting clearly the degree of inequalities among its regions. Furthermore, among the Top 15 most disperse states, Minas Gerais exhibits the highest HDI level.

As for the transportation system, the modal distribution of the freight transportation exhibits an accentuated importance of the highway mode in Minas Gerais state: in 1992, the road freight transportation was responsible by 52.8 percent of all amount of commodities transferred within the state. By the way of comparison, the average participation of this mode in developed countries amounts to about 30 percent. Due to this completely unbalanced transportation matrix, one used to say that there is a "highway hypertrophy" in it. Consequently, the modal composition of Minas Gerais reflects a non-multimodal environment. In Minas Gerais, there is a road network of approximately 265,000 kilometers, although the majority of it consists of non-paved roads (92.3 percent of the total network). In view of this, in this paper our focus is on the road infrastructure improvement in Minas Gerais.

3. THE THEORETICAL MODEL

Most of spatial CGE models present a sophisticated theoretical structure that requires much interregional data and information to implement them. On the one hand, it is often necessary to obtain a full social accounting matrix (SAM), with interregional trade flows, regional prices of all production factors, as well as their quantities. On the other hand, few countries have statistical agencies that generate this type of data. Consequently, it is necessary to construct such a demanding database by means of regionalization techniques and gravitational methods.

Another strategy for elaborating spatial CGE was proposed by Bröcker (1998), Schneider (1998) and Bröcker and Schneider (2002). It consists of recognizing that we live in a "poor data world". Following this line of reasoning, it would be useful to simplify the theoretical structure to match the actual data generated by the statistical agencies. According to Bröcker and Schneider (2002), the set of information that is normally available consists of an input-output table, employment data by sector and region, information on regional wages and interregional transportation freights. Therefore, this strategy for elaborating spatial CGE models is based on the parsimony in the mathematical specification of the theoretical model, making simplifying assumptions.

We begin by exposing the basic ideas of the specification of the spatial CGE model for Minas Gerais (MINAS-SPACE).[3] There are three assumptions that reduce the data requirements to apply this type of model, namely: a) the pooling concept; b) the iceberg transportation cost assumption; c) the Armington specification.

According to the pooling concept, all commodities produced by sector i in various regions are aggregated in a pool of the commodity i in region s; from this pool, deliveries are made to intermediate and final consumers. Hence, the pool goods, as well as the output of the sectors, are discriminated by region. Furthermore, there is no direct link between the production side and the consumption side, that is, the firms and the consumers do not meet directly in the market. With the help of this concept, it is not obligatory to have the data about the trade flows among regions anymore.

The iceberg transportation cost assumption considers that a portion of the commodity transported dissipates itself during the transportation process. So, in the

[3] The complete list of equations and variables of the model is available in appendix A.

destination of the route, there would be a smaller amount of commodity transported than in its origin, because part of the commodity would have been used in the form of transportation costs. It is noteworthy that the iceberg assumption avoids the need of constructing a sector offering transportation services.

The Armington specification is adopted to differentiate the commodities according to origin regions. This specification rejects the assumption that the goods are perfectly substitutes. The Armington specification recognizes that there is an imperfect degree of substitutability among the commodities. In this manner, it is possible to admit that the price system exerts a role in the determination of the trade flows. Besides, the Armington specification allows a better matching of the interregional trade data, because it allows the presence of "cross-hauling", that is, the situation that a good is imported and exported at the same time.

We assume an open economy with I sectors, R regions and L external regions. There are four activities in this economy: production, transportation, final demand and export. Each region hosts I representative firms, a representative household and I transportation agents. From the production side, a firm i in region r produces the output I by means of a nested CES (NCES) linear-homogeneous production technology, using intermediate inputs taken from the pool in region s, and using primary inputs $k=1,\ldots, K$.

From the transportation side, a transport agent i in region s is responsible to transform outputs of sector i in all regions, including the own region s, and the imported goods of all external regions into pool good of type i available in region s by means of NCES linear-homogeneous production technology. This functional form allows for commodity diversity, because commodities from different regions are not considered identical. Accordingly, the final demanders do not purchase just from the region with the lowest *cif* price (Bröcker, 1998, p. 371). Hence, we adopt the Armington specification to deal with the interregional substitution, treating the commodities from different origins as imperfect substitutes. According to Bröcker (1998, p. 372), the transportation activity can be separated into two parts: "*One is transporting the outputs from all regions of origin to the region of destination; the other is merging the amounts left, after all commodities arrived in the region of destination, into the pool*".

Regarding the consumption activity, the regional representative household earns its income by selling its production factors to firms. Afterwards, it completely spends this income in pool goods of the region where it lives. Regional households enjoy welfare from the consumption of pool goods; such a behavior is described according to a linear-homogeneous utility function. Representative households do not save, spending their entire income on the consumption of pool goods. Following the duality theory, their preferences are specified by an NCES expenditure function. Note that the quantity of production factors owned by the representative household in each region is exogenously given.

Concerning the foreign sector, the MINAS-SPACE model is developed for an open economy where just the economic agents' behavior in Minas Gerais is founded. It is not our intention to model the economic agent's behavior in external regions. Following this approach, trade is explained by means of a system of export demand and import supply functions. Besides, due to the spatial nature of the model, it is necessary to have a regional distribution of the export and import flows according to the heterogeneity of commodity across distinct external regions by the Armington specification. The export activity is carried out by means of a NCES linear-homogeneous technology. Every external region l consists of I export agents, whose behavior is similar to the domestic transport agents.

For the sake of simplicity, there is no public sector and the final demand is not subdivided into components such as public spending, investments or inventories. By the same token, value-added is not disaggregated into components such as indirect taxes, subsidies, contributions to social insurance, etc.

A perfect competition environment is assumed where firms, transport agents and export agents minimize costs. In view of the linear-homogeneous technology, this assumption implies that, in equilibrium, prices equal unit costs. Hence, there is no possibility to accrue pure profits in the economy.

Minas Gerais is subdivided into twelve regions shown in Table 1. The model implemented here is an open system since there are three external regions, São Paulo State (SP), Rio de Janeiro State (RJ) and the Rest of Brazil (RB). The model is divided

into five sectors: agriculture and living stock (AGR), mining (MIN), industry (IND), construction (CON) and services (SER).

To implement effectively the MINAS-SPACE model, seven types of information are needed to prepare the database:·a) an input-output table for Minas Gerais State; b)·regional employment data by sector; c)·regional wages; d) substitution structure for NCES functions; e) transport rates; f) domestic interregional distances; g) distances among the domestic regions of Minas Gerais and the external regions.[4]

The input-output data for Minas Gerais comes from a non-survey study elaborated by FIPE (Economic Research Institute) and BDMG (Development Bank of Minas Gerais). This input-output table is available for the year 1996, the year chosen as the reference year for the entire benchmark dataset. The model is calibrated for two primary factors, labor (*L*) and other factors (*N*). The regional wages and the employment data are extracted from IBGE Census, National Survey of Sample of Households (PNAD) and Administrative List of Social Information (RAIS). The elasticities used in the model come from several sources of the literature (Guilhoto, 1995; Zini Jr., 1988; Bröcker and Schneider, 2002). The transport rates are estimated econometrically by OLS, adopting the procedure described in Castro *et al*. (1999). The idea of this procedure is to construct an econometric model where freight by sector is a function of the distance of routes. The distances are the shortest routes between the coordinates of two regions, which are computed as the latitude and longitude of the main city of these regions. The two distances matrices (one of them for interregional distances and the other one for distances between external regional and domestic one) come from Cesar (1999).

The main advantage of the MINAS-SPACE model rests on the parsimony principle, avoiding extensive calibration of parameters. As a result, the model is tractable in terms of data demand, computation burden and implementation costs. The disadvantages of the model concentrate on the lack of dynamics. There are no equations describing the capital motion or investment pattern. Consequently, the model is not able to take into account transportation project financing. Besides, there is no public sector, so transportation investments are modeled like final demand shocks. In addition, the welfare measure adopted in the model, as further defined, is imperfect, since it does not capture

[4] For complete information about the dataset, see Almeida (2003).

some relevant effects, such as environment cost, macroeconomic impact of transportation financing and so forth.

4. SIMULATIONS

4.1. Counterfactual Experiments

The MINAS-SPACE model is designed to implement comparative static analysis through a series of simulations. Such simulations are based on the counterfactual experiments that seek to grasp the fundamental aspects of the phenomenon under investigation. This section describes the counterfactual experiments to be carried out further. The reduction in the transportation cost stems from the improvement of the road network that shorten the travel time between regions, increasing network connectivity. In the model, travel times can be regarded as similar to interregional distances within the Minas Gerais State. Thus, a road improvement that yields a reduction in the travel time between two regions within the State can be regarded as producing the same effect in the interregional distances. By so doing, the interregional distance parameter in the model needs to be reduced. In line with this idea, four experiments are performed. The design of these counterfactual experiments is presented below.

The experiment, named "All", consists of shortening of all domestic interregional distances by 10 percent (determined arbitrarily) that leads to a further reduction in the transportation costs. In this experiment, all domestic[5] origin region-destination region pairs have their distances reduced by 10 percent, irrespective whether the origin region or the destination one is considered as rich or poor.

The first auxiliary simulation refers to a "shortening of the distances" by 10 percent just among the four poor regions in the North, to wit, Noroeste, Norte, Vale do Jequitinhonha and Vale do Mucuri. That is, such an experiment simulates an improvement of the road network just in the poor part of the Minas Gerais. This experiment is named "North".

The other auxiliary experiment refers to a "shortening of the distances" by 10 percent just among the eight rich regions of Minas Gerais, namely, Triângulo Mineiro/Alto Paranaíba, Central, RMBH, Vale do Rio Doce, Oeste, Sul, Campo das

[5] Domestic regions mean regions within the Minas Gerais State.

Vertentes e Zona da Mata. In other words, this auxiliary experiment simulates the improvement of road network in the South of Minas Gerais. Let it be called "South".

Finally, the last auxiliary experiment simulates the "shortening of the distances" by 10 percent just among rich region-poor region pairs (for instance, Central-Noroeste, Sul-Norte, etc), excluding completely rich region-rich region pairs or poor region-poor region pairs. Let us call it "North-South".

After simulating the experiments, it is very important to interpret properly the results obtained. In this sense, a spatial CGE model generates a myriad of results in terms of quantities and relative prices both at the aggregate and the regional level. Hence, it is important to compute a welfare measure in order to know if the society as a whole or a particular region is gaining or losing with the implementation of any policy. Thus, the welfare effects represent summary measure. The welfare gains (or losses) are defined according to equivalent variation concept, that is, the amount of additional income, measured at benchmark prices, which is necessary to reach the level of utility of the counterfactual equilibrium (Bröcker and Schneider, 2002). Further, since one of our objectives is to investigate the regional equity, it is also relevant to adopt an indicator to measure income disparities among regions. To achieve this, the Gini index for regional real income per employee is computed.

3.2. Issues in Interpretation

Before turning to the results of the simulations, we should deal with the driving forces that work inside the model, explaining their functioning.[6] At the aggregate level, a transportation cost reduction provokes a decrease of pool prices, which leads to an augmentation in household' real income, generating welfare gains. The augmention in real incomes is manifested by means of an increase in final demand, leading to the elevation in the output level of firms. To achieve this, firms have to purchase more primary factors, and thereby, the prices of these factors are increased, augmenting, at the end, household income again. All these aggregate results are reflected in welfare gains.

[6] For the sake of clarity, the index *r* hereafter refers to origin regions, while the index *s* refers to destination regions.

With a better accessibility, there is an income effect, representing a more intense demand from other regions for goods produced in region *r*, which have their prices curbed because of the reduction of transportation costs. It is worth pointing out that the final demand elevation is derived from two causes. The first cause is a substitution effect due to the decrease in pool prices. This effect means that, in region *s*, it is more inexpensive to purchase goods from region *r* and, thereby, the later region will export more goods to region *s*. The second one is an income effect due to an augment of real incomes.

As to the spatial impact on welfare and output level, we also have a very interesting causal mechanism. Road network improvements may generate welfare losses for a particular region due to the reorientations of trade flows toward regions that enjoy a better market access after these improvements. In this case, we have interregional trade deviations that cause economic damages in certain regions. For instance, a region that makes little use of a new road may trade with other regions that, in turn, use this new road more intensely. In this case, the former region could find that the demand for its goods to shift to the later regions, because now these regions become more accessible as purchasing regions. The lesson is that the benefits from a reduction in transportation costs do not accrue everywhere; some regions may lose with this process.

Transportation costs are regarded as interregional trade barriers. In a sense, the reduction in transportation costs among regions has a similar effect of a diminution in tariffs among countries. Trade deviations aside, it is possible to have trade creation as well. If there are winning or losing regions, the definition of this region status depends on the possibility of a region having a better access to the markets of other regions. In the presence of a reduction of transportation costs, a winning region enjoys more trade creations than trade deviations, obtaining a positive net impact on its welfare.

3.3. Results

Let us start presenting the most important results of the model on the aggregate level (Table 2). For the main experiment ("All"), the road network improvement generates an increase in the welfare gains by 0.10% of the gross production (or R$ 71.7 millions). This welfare gain is due to two effects. From the production side, the better

access to intermediate inputs and product markets allow firms to raise their output, augmenting, thereby, the wages and other factor prices by 0.10% and, consequently, elevating household income. From the consumption side, the road network improvement reduces the pool prices, increasing real income. These two effects are responsible for an increase in the final demand by 0.09 percent and an increase in the output of pool goods by 0.06 percent.

Table 2: Aggregate Results of the Model

	"All"	*"North"*	*"South"*	*"North-South"*
Quantities				
Total exports	0.00	0.00	0.00	0.00
Total imports	-0.01	0.00	-0.01	0.00
Domestic production	0.00	0.00	0.00	0.00
Pool goods production	0.06	0.00	0.05	0.01
Final demand	0.09	0.00	0.08	0.01
Relative Prices				
Prices of total exports	0.04	0.00	0.04	0.01
Prices of total imports	0.06	0.00	0.05	0.00
Production prices	0.05	0.00	0.04	0.01
Pool prices	-0.01	0.00	-0.01	0.00
Wage	0.10	0.00	0.09	0.01
Other factor price	0.10	0.00	0.09	0.01
Other Results				
Welfare gains	0.10	0.00	0.09	0.01
Gini index	-0.18	-0.01	0.16	-0.33
Price index	-0.06	0.00	-0.05	-0.01

As for the regional results, Table 3 reveals the quantitative details of the simulations for the experiment "All". Indeed, all regions obtain welfare gains, as well as reductions in the price level, provoked by the decline of the transportation costs. For this experiment, the average welfare is 0.20 percent, although there is dispersion around it. In this sense, note that the standard deviation is 0.11; hence the coefficient of variation is a little higher than 50 percent, since the maximal gain is 0.37 percent (Noroeste) and the minimal gain is 0.04 percent (RMBH).

Notwithstanding, the most striking outcome is in the spatial distribution of the welfare effects (see Map 1). In spite of all welfare effects are positive, it is worth pointing out that the poorer regions are benefited more than the richer ones in relative terms. As

for regional income disparities, there is a decrease in the Gini index by 0.18 percent, signaling that the regional income disparities among the regions decline.

This occurs because these regions are farther from the richer regions, sited in the Center-South of Minas Gerais, whose market potential is greater. The rationale of the experiment is to "bring near" these farther regions to the richer regions whose centers of population and activity are larger. In this sense, such a phenomenon has a similar effect a program to enhance economic integration.

To identify more clearly what is going on with this promotion of the regional equity, let us take a closer look at the simulations. The experiment "South", at the aggregate level, provides similar results to the experiment "All". As to the regional results, the welfare gains for the richer regions remain almost the same, but for the poorer regions, they face welfare losses now (see Map 2). The average welfare gain is 0.06 percent, although there is much oscillation around it, as can be observed by means of the high standard deviation (0.13); thus, the coefficient of variation is more than 200 percent. The maximal gain is 0.25 percent (Triângulo/Alto Paranaíba), whereas the minimal gain (or maximal loss) is –0.10 percent (Vale do Mucuri). Consequently, the Gini index is increased by 0.16 percent, increasing the regional income disparities when the road infrastructure improvement concentrates on the richer regions.

The experiment "North", in turn, provokes minimal effect on most variables in terms of both the aggregate level and the regional level (see Tables 2 and 3). In spite of this, the Gini index drops slightly by 0.01 percent.

Table 3: Regional Results of the Model

			Welfare	
	"All"	*"North"*	*"South"*	*"North-South"*
Noroeste	0.37	0.01	-0.09	0.45
Norte	0.29	0.01	-0.09	0.38
Jequitinhonha	0.31	0.01	-0.08	0.39
Vale do Mucuri	0.35	0.01	-0.10	0.43
Triângulo/Alto Paranaíba	0.25	0.00	0.25	0.00
Central	0.11	0.00	0.12	-0.01
RMBH	0.04	0.00	0.04	0.00
Vale do Rio Doce	0.22	0.00	0.22	0.00
Oeste	0.07	0.00	0.07	0.00
Sul/Sudoeste	0.15	0.00	0.15	0.00
Campo das Vertentes	0.11	0.00	0.10	0.00
Zona da Mata	0.15	0.00	0.15	0.00
Average	0.20	0.00	0.06	0.14
Standard Deviation	0.11	0.00	0.13	0.20
Maximum	0.37	0.01	0.25	0.45
Minimum	0.04	0.00	-0.10	-0.01

Source: The authors' own calculations.

The most fascinating results come from the experiment "North-South". It seems the poorer regions capture all benefits at the expense of the richer regions, but the aggregate impacts on quantities (domestic production, pool goods production, final demand, export and imports) and relative prices are very small (see Map 3). This experiment witnesses the largest decline in the Gini index by 0.33 percent, suggesting that the poorer regions catch-up in this simulated environment, in spite of its mediocre economic performance.

The trade-off between economic performance and regional equity strongly accrues from these findings. On one hand, the experiment "North-South" substantially improves the regional equity, but its economic performance is mediocre (see Tables 2 and 3). On the other hand, the experiment "South" stimulates the regional income disparities, as indicated by the Gini index, but it has a good economic performance at the aggregate level.

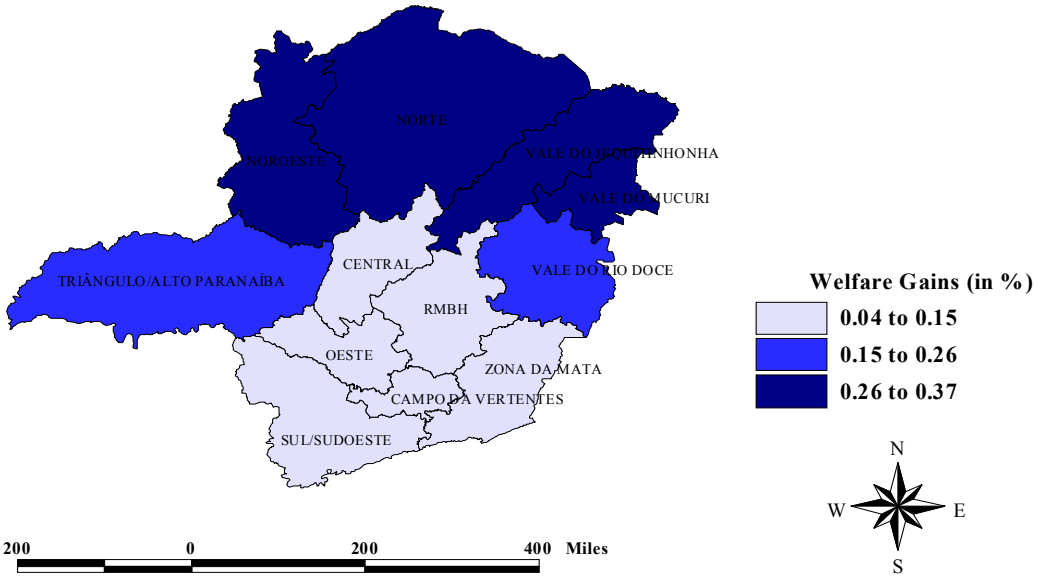
The policy makers are not totally in trouble. Actually, there exists an experiment that is capable of mixing the performance and equity proprieties in relative harmony. This is the case of the experiment "All", which reaches a high level of economic performance, as can be shown by means of aggregate welfare gains (0.20 percent), with a considerable reduction in the regional income inequalities, as measured by the Gini index.

As can be appreciated, these different types of experiments generate different results regarding the regional equity issue. Two of them (experiments "All" and "North-South") generate promotion of the regional income equality, whereas one of them ("South") yields an incitement of the regional income disparities; furthermore, another one ("North") is almost negligible in terms of aggregate impact on the economic system.

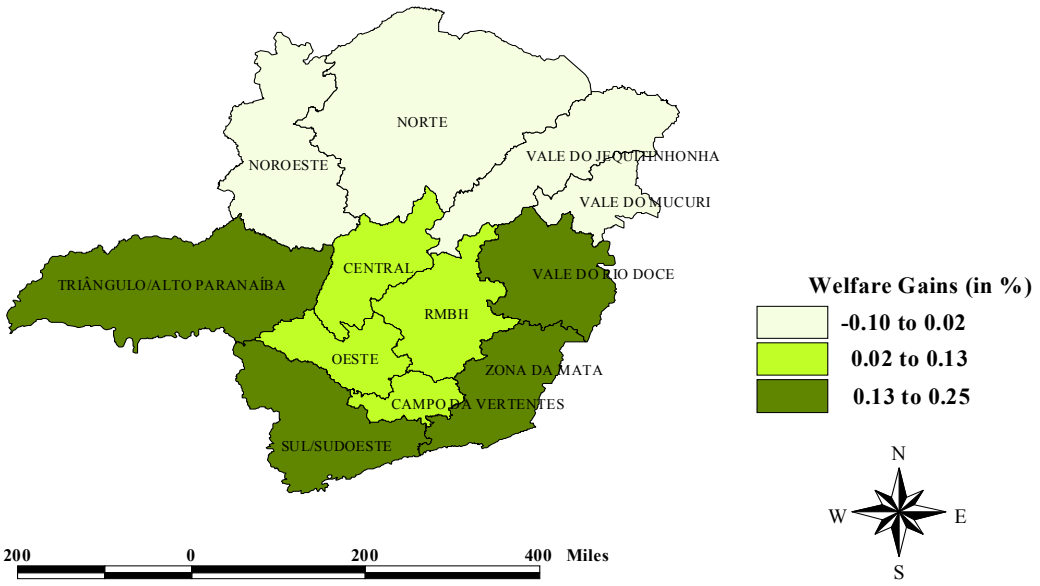
It is relevant to point out that the theoretical model, the method and study site are the same in these experiments. The only element that has been changed is the spatial structure of the transport network improvement. As an aftermath, the researcher may draw misleading conclusions whether he/she does not take into account the spatial structure of the transportation infrastructure. In some cases he/she might consider that the transport-regional equity issue has a positive relationship, whereas in others he/she might judge that this relationship is negative, and, therefore, conclude that there exists a trade-off. Our findings indicate clear evidences that this issue depends substantially upon the spatial structure of the links. Put it differently, questions like "which regions are hosting the transportation investments", "which regions is a transport improvement linking to" or "where does the road comes from and where does it go to" matter a lot in the economic appraisement and the social judgement of transportation projects.

The explanation of these results follows the argumentation lines carried out so far: poor regions benefit themselves of the economic integration to regions with high market potential when the trade barriers fall induced by the reduction of the transportation costs. In this sense, we could shed light on the following important finding: the transportation policies can promote regional equity, since these policies consist in linking poor regions to rich ones so that the former can enjoy the integration benefits.

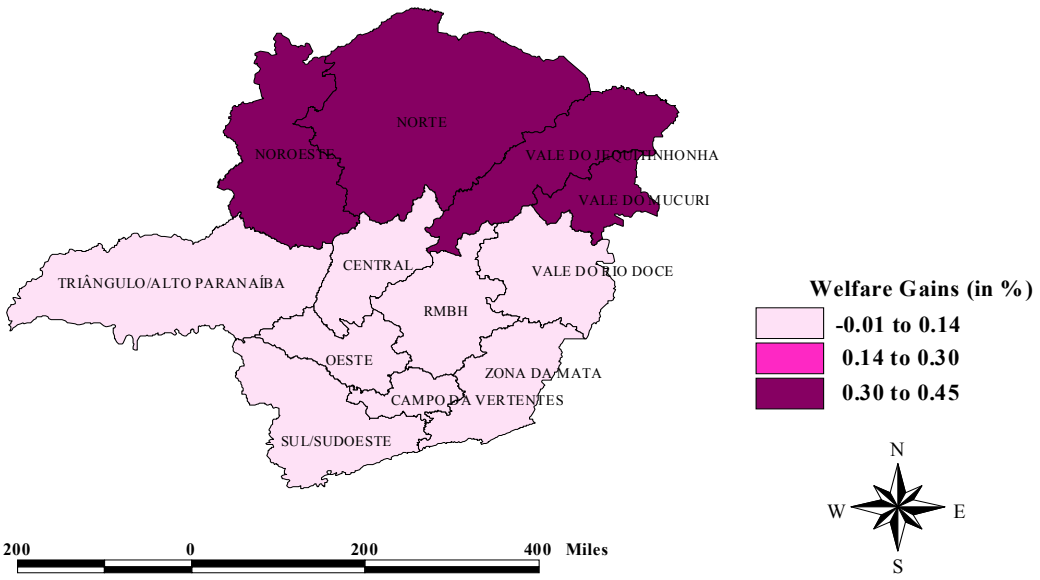
Map 1: Welfare Gains of the Experiment "All"



Map 2: Welfare Gains of the Experiment "South"



Map 3: Welfare Gains of Experiment "North-South"



4. CONCLUSIONS

The issue of the nature of the relationship between transport and regional equity is very elusive. In the literature, there are pro and contra evidences about this relationship. The most of these controversial evidences stem from methodological discrepancies. In this paper, we followed another way of approaching this issue and showing that, actually, the nature of this relationship is authentically complicated. We kept constant the theoretical model, the method of investigation, as well as its specification, and the study site. We only changed the spatial structure of the provision of transport infrastructure. The results obtained can be summarized as follows.

In the case of Minas Gerais, if the transport infrastructure improvement is just among poor regions, the promotion of the regional equity is insignificant. If the transport infrastructure improvement links only rich regions, there is an incitement of regional income inequalities. If the improvement happens to the roads linking poor regions and

rich ones, there is a promotion of regional equity. The same happens to improvement of all road links of the state.

This paper is, therefore, an exercise of checking the sensibility on the results of the transport infrastructure provision. Even controlling the methodological aspects and study site, the effects of transport infrastructure on regional equity in Minas Gerais is extremely sensitive to spatial structure. In other words, the nature of the relationship between road infrastructure improvement and regional equity depends strongly on "where the road comes from and where it goes to".

Along this article, we could investigate another controversial topic, namely, the trade-off between economic performance and regional equity. Our findings reveal that actually there is this kind of trade-off in Minas Gerais. The experiment that is more capable of reducing the regional income inequalities yields mediocre aggregate impact on several variables, such as welfare gain, production, final demand, exports and imports. Accordingly, it is likely to arise doubts to policy makers in the sense of privileging economic performance or regional equity, assuming that the cost of constructing or improving a road is the same both in the rich part and in the poor part. The dilemma is solved whether the promotion of regional equity belongs to the 'utility function' of the society.

In this sense, we can draw an important conclusion from this paper concerning the influence of transportation policies on the regional equity. Transportation policies may serve as an effective mechanism of fighting regional income disparities. In other words, transportation may serve as a regional policy to diminish regional income differences. The simulation of the experiments allows us to refine this finding. We found out that the source of regional equity promotion induced by a road network improvement rests on the link between poorer regions and richer regions.

The explanation of this lies on the fact that the poorer regions in Minas Gerais benefit more with an ampler economic integration to the richer regions that have a larger market potential. In this context, the transportation cost reduction is able to diminish interregional trade barriers. The advantages from this integration are represented in a situation in which there are more opportunities of trade creations than trade diversions.

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APPENDIX A

LIST OF EQUATIONS AND VARIABLES OF THE MINAS-SPACE MODEL

A.1 Variables

Indices

j	J	Number of sectors (output goods)
i	I	Number of sectors (*pool goods*)

r	R	Number of regions (source regions)
s	S	Number of regions (destination regions)
k	K	Number of primary factors
l	L	Number of external regions

***Endogenous Variables*:**

Quantities:

x_s^j	JxS	Output of sector *j* in region s
d_s^j	JxS	Final demand for good *j* in region s
m_l^i	IxL	Imports of good *i* from external region *l*
e_l^i	IxL	Exports of good *i* to external region *l*

Prices:

p_s^j	JxS	Price of one output unit of sector *j* in region *s*
q_s^i	IxS	Price of one unit of *pool good* of sector *i* in region *s*
q_l^{Ei}	IxL	Price of one unit of export good *i* in external region *l*
p_l^{Mi}	IxL	Price of one unit of import good of sector *i* in external region *l*
w_s^k	KxS	Price of one unit of primary factor *k* in region *s*
r	1	Price index

IO Coefficients

a_s^{ij}	IxSxJ	Demand for *pool goods i* to produce one unit output in sector *j* in region *s*
c_s^{kj}	JxSxK	Demand for primary factor *k* to produce one unit output in sector *j* in region *s*
t_{rs}^i	IxSxR	Demand for output goods *i* in region *r* to produce one unit of *pool good i* in region *s*
t_{ls}^{Mi}	IxLxS	Demand for imports from external region *l* to produce one unit of pool goods *i* in region *s*
t_{rl}^{Ei}	IxRxL	Demand for output goods *i* in region *r* to produce one unit export goods *i* in external region *l*

Income and utility

y_s	Sx1	Real income of the representative household in region *s*
u_s	Sx1	Level of utility of the representative household in region *s*

Position parameters

Parameters

α^{ij}	JxI	Position vector of CES function: production – intermediary inputs
γ^{kj}	KxJ	Position vector of CES function: production – primary inputs
δ^{j}	1xJ	Position vector of CES function: households
ϑ_r^i	IxR	Position vector of CES function: transport
ϑ_l^{Mi}	IxL	Position vector of CES function: imports
π_l^i	IxL	Import supply parameter
τ_l^i	IxL	Export demand parameter

Quantities:

f_r^k	RxK	Primary inputs *k* in region *r*

Elasticities

σ_P^j	I	Elasticity de substitution – production
σ_M^i	I	Elasticity de substitution – transport imports vs. domestic goods
σ_T^i	I	Elasticity de substitution – transport
σ_H	1	Elasticity de substitution – households
μ_l^i	IxL	Price elasticity of foreign import supply
ε_l^i	IxL	Price elasticity of foreign export demand

Parameters

λ_l^{Mi}	IxL	Import supply shift parameter
λ_l^{Ei}	IxL	Export demand shift parameter

Miscellaneous

η^i	I	Transport rate
z_{rs}	RxS	Interregional distances between domestic regions
z_{rl}	RxL	Distance from domestic region *r* to external region *l*
er	1	Exchange rate

A.2 Equations

A.2.1 Firms

Unit-cost functions:

$$p_s^j = \left(\sum_{i=1}^{I} q_s^i \Phi_P^{ij} + p_{ws}^j \Phi_{PK}^{kj} \right) \cdot \left(\sum_{i=1}^{I} \alpha^{ij} + \sum_{k=1}^{K} \gamma^{kj} \right)$$

where

$$\Phi_P^{ij} = \frac{\alpha^{ij}}{\sum_{i=1}^{I} \alpha^{ij} + \sum_{k=1}^{K} \gamma^{kj}} \text{ , } \Phi_{PK}^{kj} = \frac{\sum_{k=1}^{K} \gamma^{kj}}{\sum_{i=1}^{I} \alpha^{ij} + \sum_{k=1}^{K} \gamma^{kj}} \text{ , e } p_{ws}^j = \left[\sum_{k=1}^{K} \left(w_s^{k(1-\sigma_P^j)} \frac{\gamma^{kj}}{\sum_{k=1}^{K} \gamma^{kj}} \right) \right]^{\frac{1}{1-\sigma_P^j}}$$

IO coefficients intermediary inputs:

$$a_s^{ij} = \Phi_P^{ij} \left(\sum_{i=1}^{I} \alpha^{ij} + \sum_{k=1}^{K} \gamma^{kj} \right) = \alpha^{ij}$$

IO coefficients primary inputs:

$$c_s^{kj} = \left(\sum_{k=1}^{K} \left(w_s^{k(1-\sigma_P^j)} \frac{\gamma^{kj}}{\sum_{k=1}^{K} \gamma^{kj}} \right) \right)^{\frac{1}{1-\sigma_P^j}-1} w_s^{k-\sigma_P^j} \gamma^{kj}$$

A.2.2. Transport

Unit-cost functions:

$$q_s^i = \left[p^{i(1-\sigma_M^i)} \phi_T^{ir} + \sum_{l=1}^{L} \left(p_l^{Mi} e^{(\eta^i z_{ls})} \right)^{(1-\sigma_M^i)} \phi_M^{il} \right]^{\frac{1}{1-\sigma_M^i}} \left(\sum_{r=1}^{R} \vartheta_r^i + \sum_{l=1}^{L} \vartheta_l^{Mi} \right)$$

where

$$\phi_T^{ir} = \frac{\sum_{r=1}^{R} \vartheta_r^i}{\sum_{r=1}^{R} \vartheta_r^i + \sum_{l=1}^{L} \vartheta_l^{Mi}} \ , \ \phi_M^{il} = \frac{\vartheta_l^{Mi}}{\sum_{r=1}^{R} \vartheta_r^i + \sum_{l=1}^{L} \vartheta_l^{Mi}} \ \text{and} \ p^i = \left(\sum_{r=1}^{R} \left(p_r^i e^{(\eta^i z_{rs})} \right)^{(1-\sigma_T^i)} \frac{\vartheta_r^i}{\sum_{r=1}^{R} \vartheta_r^i} \right)^{\frac{1}{1-\sigma_T^i}}$$

IO coefficients transport:

$$t_{rs}^i = \left[p^{i(1-\sigma_M^i)} \phi_T^{ir} + \sum_{l=1}^{L} \left(p_l^{Mi} e^{(\eta^i z_{ls})} \right)^{(1-\sigma_M^i)} \phi_M^{il} \right]^{\frac{1}{1-\sigma_M^i}-1} \left(\sum_{r=1}^{R} \left(p_r^i e^{(\eta^i z_{rs})} \right)^{(1-\sigma_T^i)} \frac{\vartheta_r^i}{\sum_{r=1}^{R} \vartheta_r^i} \right)^{\frac{-\sigma_M^i + \sigma_T^i}{1-\sigma_T^i}} \vartheta_r^i \left(p_r^i e^{(\eta^i z_{rs})} \right)^{-\sigma_T^i} e^{(\eta^i z_{rs})}$$

IO coefficients imports:

$$t_{ls}^{Mi} = \left(p^{i(1-\sigma_M^i)} \phi_T^{ir} + \sum_{l=1}^{L} (p_l^{Mi} e^{(\eta^i z_{ls})})^{(1-\sigma_M^i)} \phi_M^{il} \right)^{\frac{1}{1-\sigma_M^i}-1} (p_l^{Mi} e^{(\eta^i z_{ls})})^{-\sigma_M^i} e^{(\eta^i z_{ls})} \vartheta_l^{Mi}$$

A.2.3. Households

Incomes:

$$y_s = \sum_{k=1}^{K} f_s^k w_s^k$$

Unit expenditure functions:

$$ch_s = ch_s(q_s, \delta) = \left(\sum_{j=1}^{J} q_s^{j(1-\sigma_H)} \frac{\delta^j}{\sum_{j=1}^{J} \delta^j} \right)^{\frac{1}{1-\sigma_H}} \sum_{j=1}^{J} \delta^j$$

Total expenditures:

$$eh_s = ch_s(q_s, \delta)u_s = \left(\sum_{j=1}^{J} q_s^{j^{(1-\sigma_H)}} \frac{\delta^j}{\sum_{j=1}^{J} \delta^j} \right)^{\frac{1}{1-\sigma_H}} \sum_{j=1}^{J} \delta^j u_s$$

Budget restrictions:

$$y_s = eh_s(q_s, u_s) = ch_s(q_s, \delta)u_s$$

Final demands:

$$d_s^j = y_s \frac{\delta^j}{\left(\sum_{j=1}^{J} q_s^{j^{(1-\sigma_H)}} \delta^j \right) q_s^{j^{\sigma_H}}}$$

A.2.4. Foreign sector

Foreign export demand function:

$$e_l^i = \lambda_l^{Ei} \tau_l^i \left(\frac{q_l^{Ei}}{er} \right)^{-\varepsilon_l^i}$$

Foreign export prices:

$$q_l^{Ei} = \left(\sum_{r=1}^{R} \left(p_r^i e^{(\eta^i z_{rl})} \right)^{(1-\sigma_T^i)} \frac{\vartheta_r^i}{\sum_{r=1}^{R} \vartheta_r^i} \right)^{\frac{1}{1-\sigma_T^i}} \sum_{r=1}^{R} \vartheta_r^i$$

IO coefficients exports:

$$t_{rl}^{Ei} = \left(\sum_{r=1}^{R} \left(p_r^i e^{(\eta^i z_{rl})} \right)^{(1-\sigma_T^i)} \frac{\vartheta_r^i}{\sum_{r=1}^{R} \vartheta_r^i} \right)^{\frac{1}{1-\sigma_T^i}-1} \left(p_r^i e^{(\eta^i z_{rl})} \right)^{-\sigma_T^i} e^{(\eta^i z_{rl})} \vartheta_r^i$$

Regional export demand:

$$e_{rl}^i = t_{rl}^{Ei} e_l^i$$

Foreign import supply functions:

$$m_l^i = \lambda_l^{Mi} \pi_l^i \left(\frac{p_l^{Mi}}{er} \right)^{\mu_l^i}$$

A.2.5. Equilibrium condition

$$x_r^i = \sum_{s=1}^{S} t_{rs}^i (d_s^i + \sum_{j=1}^{J} a_s^{ij} x_s^j) + \sum_{l=1}^{L} t_{rl}^{Ei} e_l^i$$

A.2.6. Market clearing conditions:

Factor markets:

$$\sum_r f_r^k = \sum_i c_r^{ki} x_r^i$$

Import goods:

$$m_l^i = \sum_{s=1}^{S} t_{ls}^{Mi} \left(d_s^i + \sum_{j=1}^{J} a_s^{ij} x_s^j \right)$$